THE RISE OF MOBILE MONEY: IMPLICATIONS ON MONETARY POLICY

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Contents

List of figures....iv
List of tables....x
Acknowledgements.... xiii
Abstract....xiv
List of abbreviations xv
Chapter 1 Introduction 1
1.1 Growth and definition of mobile money....1
1.2 Factors behind the growth of mobile money 3
1.2.1 Limited access to traditional banking services 3
1.2.2 The spread of mobile telephony....4
1.2.3 Enabling regulatory environment 5
1.2.4 Simplicity and affordability....6
1.3 The impact of mobile money....7
1.3.1 Demand for money, velocity of money and money multiplier....7
1.3.2 Growth of bank deposits, credit and the quantity of money....10
1.3.3 Increase in remittances and stabilization of income 11
1.3.4 Price dispersion, inflation and production 13
1.3.5 Reduction of illicit transactions and increase in revenue collection....14
1.3.6 Financial inclusion, poverty reduction and women empowerment 14
1.4 Gaps in the literature and motivation for this work....16
1.4.1 Summary....16
1.4.2 Motivation for this work....17
Chapter 2 A benchmark DSGE model of the impact of mobile money through the primary income channel....21
2.1 Introduction....21
2.1.1 Overview of DSGE modelling....21
2.1.2 Price stickiness and access to bond market friction....23
2.1.3 Payment friction....25
2.1.4 Rural occupational choice in Africa 26
2.2 New Keynesian DSGE model with payment friction in the primary income....29
2.2.1 Households....30
2.2.2 Firms 35

2.2.3 Prices and inflation 37
2.2.4 Monetary policy 40
2.2.5 Productivity process 41
2.2.6 Clearing equations 42
2.3 Calibration of parameters for Model 1 baseline scenario 43
2.4 Simulations and results 46
2.4.1 Simulations 46
2.4.2 Steady state results 47
2.4.3 Impulse response results 51
2.4.4 Other observations 61
2.5 Conclusion 62
Chapter 3 Extending the benchmark model to include altruistic remittances and industry-specific capital 78
3.1 Introduction 78
3.2 First extension: adding the secondary income channel to the benchmark model 81
3.2.1 Characterizing the mixed household 81
3.3 Second extension: adding industry-specific capital to Model 2 90
3.3.1 Characterizing the households with capital 90
3.3.2 Firms 92
3.3.3 List of model equations arising from the introduction of capital 93
3.4 Calibration of additional parameters for Model 2 and Model 3 baseline scenarios 97
3.5 Simulations and results 99
3.5.1 Simulations 99
3.5.2 Steady-state results for Model 2 and Model 3 99
3.5.3 Impulse response results for Model 2 and Model 3 111
3.5.4 Monetary policy issues 124
3.6 Conclusion 132
Chapter 3 Tables 136
List of variables, parameters and programmed equations 136
Result tables 168
Chapter 4 Mobile money and the income velocity of circulation: the case of East African countries 174
4.1 Introduction 174

4.1.1 Objectives and choice of countries to study 174
4.1.2 Financial developments in the countries studied 176
4.2 Financial developments and the literature on financial innovation, mobile money and monetary policy 178
4.2.1 Financial developments 178
4.2.2 Literature on financial innovation, mobile money and monetary policy 184
4.2.3 Summary and limitations of the existing literature 188
4.3 Theoretical framework and empirical methodology 190
4.3.1 Velocity of money circulation 190
4.3.2 Monetization, financial innovation and the income velocity of circulation 191
4.3.3 Empirical methodology 195
4.4 Estimations and results 198
4.4.1 Estimations 198
4.4.2 Results 205
4.5 Conclusion 214
Chapter 4 Result tables 217
Chapter 5 Conclusion 225
References 231
Chapter 1 Appendices 244
Appendix A: Figures 244
Chapter 2 Appendices 251
Appendix B: Figures 251
Appendix C: Selected impulse response results for Chapter 2 252
Chapter 3 Appendices 285
Appendix D: Selected Tables 285
Appendix E: Selected impulse response graphs for Model 2 and 3 286
Chapter 4 Appendices 377
Appendix F: East Africa figures and tables 377
Appendix G: Figures and tables related to estimations 381
Appendix H: Global figures and tables 388

List of figures

Figure 2.1: Schematic presentation of Model 1 43
Figure 3.1: Schematic representation of Model 2 89
Figure 3.2: Schematic presentation of Model 3 96
Figure 4.1: Variables for Tanzania 200
Figure 4.2: Variables for Kenya........ 202
Figure 4.3: Variables for Uganda........ 204
Figure A1: Evolution of global mobile money landscape – number of live services 2001 to 2020........ 244
Figure A2: Registered mobile money accounts by region per 1,000 adults 245
Figure A3: Top 15 countries with adult population receiving remittance through mobile phone in 2017........ 246
Figure A4: Proportion of population in the rural 2019 for the countries with highest population using mobile money in the world........ 246
Figure B1: Digital payment instruments used to purchase goods in Tanzania, all adults 251
Figure C1A: Production at consumer price, response to farming shock 252
Figure C1B: Production at factor cost, response to farming shock 253
Figure C1C: Consumption and welfare, response to farming shock 254
Figure C1D: Labour supplied, response to farming shock 255
Figure C1E: Labour earning, response to farming shock 256
Figure C1F: Relative prices, response to farming shock 257
Figure C1G: Wage price ratios, response to farming shock 258
Figure C1H: Inflation and interest rate, response to farming shock 259
Figure C2A: Production at consumer price, response to non-farming shock 260
Figure C2B: Production at factor cost, response to non-farming shock 261
Figure C2C: Consumption and welfare, response to non-farming shock 262
Figure C2D: Labour supplied, response to non-farming shock 263
Figure C2E: Labour earning, response to non-farming shock 264
Figure C2F: Relative prices, response to non-farming shock 265
Figure C2G: Wage price ratios, response to non-farming shock 266
Figure C2H: : Inflation and interest rate, response to non-farming shock........ 267

Figure C3A: Production at consumer price, response to manufacturing shock....................268
Figure C3B: Production at factor cost, response to manufacturing shock............................269
Figure C3C: Consumption and welfare, response to manufacturing shock..........................270
Figure C3D: Labour supplied, response to manufacturing shock..271
Figure C3E: Labour earning, response to manufacturing shock..272
Figure C3F: Relative prices, response to manufacturing shock 273
Figure C3G: Wage price ratios, response to manufacturing shock 274
Figure C3H: Relative prices, response to manufacturing shock..275
Figure C4A: Production at consumer price, response to policy shock 276
Figure C4B: Production at factor cost, response to policy shock 277
Figure C4C: Consumption and welfare, response to policy shock 278
Figure C4D: Labour supplied, response to policy shock..279
Figure C4E: Labour earning, response to policy shock..280
Figure C4F: Relative prices, response to policy shock...281
Figure C4G: Wage price ratios, response to policy shock..282
Figure C4H: Inflation and interest rate, response to policy shock..283
Figure C5: Model 1 MRS versus IRR response of selected variables to non-farming shock, mobile money scenario 284
Figure C6: Model 1, headline inflation targeting versus core inflation targeting, response to farming shock...285
Figure E1A: Model 2 response of remittances and non-farm goods to farming shock 286
Figure E1B: Model 2 response of quantity and value output to farming shock 287
Figure E1C: Model 2 response of GDP aggregates to farming shock 288
Figure E1D: Model 2 response of household labour quantity to farming shock 289
Figure E1E: Model 2 response of household labour value to farming shock 290
Figure E1F: Model 2 response of labour quantity and value in firms to farming shock 291
Figure E1G: Model 2 response of consumption to farming shock 292
Figure E1H: Model 2 response of welfare to farming shock..293
Figure E1I: Model 2 response of relative prices and wages to farming shock 294
Figure E1J: Model 2 response of inflation and interest rate to farming shock 295
Figure E2A: Model 2 response of remittances and non-farm goods to non-farming shock..296
Figure E2B: Model 2 response of quantity and value output to non-farming shock 297

Figure E2C: Model 2 response of GDP aggregates to non-farming shock 298
Figure E2D: Model 2 response of household labour quantity to non-farming shock 299
Figure E2E: Model 2 response of household labour value to non-farming shock 300
Figure E2F: Model 2 response of labour quantity and value in firms to non-farming shock 301
Figure E2G: Model 2 response of consumption to non-farming shock 302
Figure E2H: Model 2 response of welfare to non-farming shock 303
Figure E2I: Model 2 response of relative prices and wages to non-farming shock 304
Figure E2J: Model 2 response of inflation and interest rate to non-farming shock 305
Figure E3A: Model 2 response of remittances and non-farm goods to manufacturing shock 306
Figure E3B: Model 2 response of quantity and value of output to manufacturing shock 307
Figure E3C: Model 2 response of GDP aggregates to manufacturing shock 308
Figure E3D: Model 2 response of household labour quantity to manufacturing shock 309
Figure E3E: Model 2 response of household labour value to manufacturing shock 310
Figure E3F: Model 2 response of labour quantity and value in firms to manufacturing shock 311
Figure E3G: Model 2 response of consumption to manufacturing shock 312
Figure E3H: Model 2 response of welfare to manufacturing shock 313
Figure E3I: Model 2 response of relative prices and wages to manufacturing shock 314
Figure E3J: Model 2 response of inflation and interest rate to manufacturing shock 315
Figure E4A: Model 2 response of remittances and non-farm goods to policy shock 316
Figure E4B: Model 2 response of quantity and value output to policy shock 317
Figure E4C: Model 2 response of GDP aggregates to policy shock 318
Figure E4D: Model 2 response of household labour quantity to policy shock 319
Figure E4E: Model 2 response of household labour value to policy shock 320
Figure E4F: Model 2 response of labour quantity and value in firms to policy shock 321
Figure E4G: Model 2 response of consumption to policy shock 322
Figure E4H: Model 2 response of welfare to policy shock 323
Figure E4I: Model 2 response of relative prices and wages to policy shock 324
Figure E5A: Model 3 response of remittances and non-farm goods to farming shock 325
Figure E5B: Model 3 response of quantity and value output to farming shock 326
Figure E5C: Model 3 response of GDP aggregates to farming shock 327

Figure E5D: Model 3 response of household labour quantity to farming shock 328
Figure E5E: Model 3 response of household labour value to farming shock........................329
Figure E5F: Model 3 response of labour quantity and value in firms to farming shock 330
Figure E5G: Model 3 response of consumption to farming shock 331
Figure E5H: Model 3 response of welfare to farming shock..332
Figure E5I: Model 3 response of relative prices and wages to farming shock 333
Figure E5J: Model 3 response of inflation and interest rate to farming shock 334
Figure E5K: Optimal policy response of inflation and interest rate to farming shock 335
Figure E5L: Model 3 response of investment and capital to farming shock 336
Figure E6A: Model 3 response of remittances and non-farm goods to non-farming shock..337
Figure E6B: Model 3 response of quantity and value output to non-farming shock 338
Figure E6C: Model 3 response of GDP aggregates to non-farming shock...........................339
Figure E6D: Model 3 response of household labour quantity to non-farming shock...........340
Figure E6E: Model 3 response of household labour value to non-farming shock................341
Figure E6F: Model 3 response of labour quantity and value in firms to non-farming shock 342
Figure E6G: Model 3 response of consumption to non-farming shock................................343
Figure E6H: Model 3 response of welfare to non-farming shock 344
Figure E6I: Model 3 response of relative prices and wages to non-farming shock..............345
Figure E6J: Model 3 response of inflation and interest rate to non-farming shock..............346
Figure E6K: Optimal policy response of inflation and interest rate to non-farming shock...347
Figure E6L: Model 3 response of investment and capital to non-farming shock 348
Figure E7A: Model 3 response of remittances and non-farm goods to manufacturing shock 349
Figure E7B: Model 3 response of quantity and value of output to manufacturing shock 350
Figure E7C: Model 3 response of GDP aggregates to manufacturing shock 351
Figure E7D: Model 3 response of household labour quantity to manufacturing shock 352
Figure E7E: Model 3 response of household labour value to manufacturing shock 353
Figure E7F: Model 3 response of labour quantity and value in firms to manufacturing shock 354
Figure E7G: Model 3 response of consumption to manufacturing shock 355
Figure E7H: Model 3 response of welfare to manufacturing shock 356
Figure E7I: Model 3 response of relative prices and wages to manufacturing shock 357

Figure E7J: Model 3 response of inflation and interest rate to manufacturing shock 358
Figure E7K: Optimal policy response of inflation and interest rate to manufacturing shock359
Figure E7L: Model 3 response of investment and capital to manufacturing shock...............360
Figure E8A: Model 3 response of remittances and non-farm goods to policy shock............361
Figure E8B: Model 3 response of quantity and value output to policy shock.......................362
Figure E8C: Model 3 response of GDP aggregates to policy shock.....................................363
Figure E8D: Model 3 response of household labour quantity to policy shock......................364
Figure E8E: Model 3 response of household labour value to policy shock...........................365
Figure E8F: Model 3 response of labour quantity and value in firms to policy shock..........366
Figure E8G: Model 3 response of consumption to policy shock..367
Figure E8H: Model 3 response of welfare to policy shock 368
Figure E8I: Model 3 response of relative prices and wages to policy shock.........................369
Figure E8J: Model 3 response of investment and capital to policy shock.............................370
Figure E9A: Model 2 response of selected variables to non-farming shock, MRS versus IRR, mobile money scenario 371
Figure E9B: Model 2 response of selected variables to manufacturing shock, MRS versus IRR, mobile money scenario 372
Figure E9C: Model 3 MRS versus IRR response of selected variables to non-farming shock, mobile money scenario 373
Figure E9D: Model 3 MRS versus IRR response of selected variables to manufacturing shock, mobile money scenario 374
Figure E10A: Model 2 headline inflation targeting versus core inflation targeting, response to farming shock, mobile money scenario 375
Figure E10B: Model 3 headline inflation targeting versus core inflation targeting, response to farming shock, mobile money scenario 376
Figure E10C: Response of welfare to policy shock IRR, Model 2 versus Model 3, mobile money scenario...376
Figure F1: Mobile money transactions in Kenya, Uganda and Tanzania..............................377
Figure F2: Mobile money account (% age 15+) 2017, selected SSA countries 378
Figure F3: Credit to GDP ratio, selected East African countries...378
Figure F4: Bank assets to GDP ratio, selected East African countries..................................379
Figure F5: Mobile money market shares, Tanzania and Kenya 2015 379

Figure G1A: Model selection summary for Tanzania 381
Figure G1B: Model selection summary for Kenya...382
Figure G1C: Model selection summary for Uganda...383
Figure G2A: Stability diagnostics QUSUM tests for Tanzania.......................................384
Figure G2B: Stability diagnostics QUSUM tests for Kenya 385
Figure G2C: Stability diagnostics QUSUM tests for Uganda 386
Figure G3: Other indicators used as proxies for financial innovation..............................387
Figure H1: The ratio of money to GDP and per capita GDP in SSA (2015).........................388
Figure H2: World market price of crude oil 389
Figure H3: World market price of wheat...389
Figure H4: World market price of corn 390
Figure H5: Global spread of mobile money 390
Figure H6: East African Community countries 391
Figure H7: Mobile money prevalence index in Africa 392
Figure H8: Africa's mobile money markets, 2016 393

List of tables

Table 2.1: Defining relative prices, wage-price ratios and inflations 39
Table 2.2: Production, all firms 48
Table 2.3: Generation of primary income 49
Table 2.4: Labour supplied from households and in firms 49
Table 2.5: Consumption – quantities and values 50
Table 2.6: Relative prices and wages 51
Table 2.7: Lifetime welfare 51
Table 2.8: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, under interest rate rule 59
Table 2.9: Qualitative comparison of AW's model with the current model for selected variables 62
Table 2A1: List of Model 1 variables 66
Table 2A2: List of Model 1 parameters 67
Table 2A3: List of Model 1 equations programmed in Dynare 4.3.3 68
Table 2A4: Model 1 steady-state equations in recursive order 75
Table 2B1: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, under money supply rule 77
Table 3.1: Change in production, all firms 102
Table 3.2: Generation of primary income 103
Table 3.3a: Change in labour and capital demanded by firms 103
Table 3.3b: Change in labour supply by the households 104
Table 3.4a: Income by household 105
Table 3.4b: Change in income by household 106
Table 3.5: Change in household expenditures 106
Table 3.6a: Household consumption - quantities and values by good type 109
Table 3.6b: Selected aggregation of consumption by good, household and sector 110
Table 3.7: Welfare comparison 110
Table 3.8: Relative prices, wages and return on capital 111
Table 3.9: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, interest rate rule 125

Table 3.10: Selected second moments [a] 129
Table 3.11a: Optimal policy rule parameters 130
Table 3.11b: Comparison of welfare gain between the policy rules 130
Table 3A1: List of Model 2 variables 136
Table 3A2: List of Model 2 and Model 3 parameters 138
Table 3A3: List of Model 2 equations programmed in Dynare 4.3.3 139
Table 3A4: List of Model 2 steady state equations in recursive order 147
Table 3B1: List of Model 3 variables 151
Table 3B2: List of Model 3 equations programmed in Dynare 4.3.3 154
Table 3B3: List of Model 3 steady state equations in recursive order 164
Table 3C1: Production by all firms 168
Table 3C2: Generation of primary income by firm 168
Table 3C3: Labour and capital demanded by firms 169
Table 3C4: Labour supply by the households 170
Table 3C5: Household consumption - quantities and values by good type 171
Table 3C6: Selected aggregation of consumption by good, household and sector 172
Table 3C7: Household expenditures 172
Table 3C8: Household welfare 173
Table 3C9: Relative prices, wages and return on capital 173
Table 3C10: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, money supply rule 173
Table 4.1: Unit root test, Tanzania variables 201
Table 4.2: Unit root test, Kenya variables 203
Table 4.3: Unit root test, Uganda variables 205
Table 4.4a: Estimation results of long-run velocity equations for the period 2000 to 2021 207
Table 4.4b: Estimation results of long-run velocity equations for the mobile money period 208
Table 4A1: Tanzania data descriptive statistics 217
Table 4A2: Kenya data descriptive statistics 217
Table 4A3: Uganda data descriptive statistics 218
Table 4A4: Comparison of descriptive statistics for the income velocity of circulation 218
Table 4A5: Lag structure of the selected equations 219
Table 4B1: Tanzania short run determinants of velocity, full sample equations 219

Table 4B2: Tanzania short-run determinants of velocity, m-money sub-sample equation ... 220
Table 4C1: Kenya short run determinants of velocity, full sample equations ... 221
Table 4C2: Kenya short-run determinants of velocity, m-money sub-sample equations ... 222
Table 4D1: Uganda short-run determinants of velocity, full sample equations ... 223
Table 4D2: Uganda short-run determinants of velocity, m-money sub-sample equations ... 224
Table A1: Tanzania timeline of mobile money related innovations and regulatory shocks .. 247
Table A2: Kenya timeline of mobile money related innovations and regulatory shocks ... 248
Table A3: Uganda timeline of mobile money related innovations and regulatory shocks ... 249
Table D1: The cost of sending money by M-Pesa or Tigo-Pesa in Tanzania ... 285
Table E1: Comparison of mean values of welfare, headline versus core inflation targeting 377
Table F1: Snapshot of financial sector 2020, selected East African countries ... 380
Table H1: Financial development indicators and expected impact on income velocity of circulation ... 394

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Abstract

The remarkable growth of mobile money observed among developing countries in the last two decades, has enabled extension of basic formal financial services to the unbanked population in predominantly cash-based economies. This development has been credited for its contribution to financial inclusion and stabilization of rural incomes through remittances, but little has been done to study its impact through purchase of goods and services. We expand the framework for analysing the impact of mobile money by building three new Keynesian DSGE models with features to investigate how it affects the economy through the primary and secondary income channels. We also apply the ARDL bounds test approach to empirically study the impact of mobile money on income velocity of circulation in Tanzania, Kenya and Uganda. Our DSGE models enable us to predict that mobile money will have overall positive benefits to the economy and that the rural will take disproportionately larger share of the benefits. The primary income channel transmits the benefits of real and policy shocks evenly to all rural households through increase in wages, while the secondary income channel delivers higher benefits to the recipients of remittances in the rural. With regard to monetary policy the DSGE models show that mobile money integrates the rural economy more into the national economy, thus demanding relatively more aggressive policy reaction to real shocks, under the mobile money scenario. The empirical estimations reveal statistically significant positive relationship between mobile money and the income velocity of circulation, which points to the need for central banks to review money supply downwards to avoid inflationary outcomes. The increase in velocity also impairs the ability of governments to raise seigniorage, but on the other side, mobile money lends itself as an instrument of improving efficiency in revenue collection, therefore, governments need to embrace it.

List of abbreviations

ATM	Automatic teller machine
B2P	Business-to-person
CGAP	Consultative Group to Assist the Poor
CPI	Consumer price index
CICO	Cash-in-cash-out outlets
EAC	East African Community
FSDT	Financial Sector Deepening Trust (Tanzania)
G2P	Government-to-person
GSMA	Global System for Mobile Communications commonly referred to as GSM Association
KES	Kenyan shilling
KIPPRA	Kenya Institute for Public Policy Research and Analysis
LSMS-ISA	Living Standard Measurement Studies – Integrated Survey on Agriculture
M2	Broad money supply, consisting the sum of currency in circulation and bank deposits, all denominated in the country's national currency
M3	Extended broad money supply, consisting M2 and foreign currency deposits held by residents.
MNO	Mobile network operator
MSME	Micro, small and medium enterprises
P2B	Person-to-business
P2G	Person-to-government
P2P	Person-to-person or peer-to-peer
POS	Point of sale
SMS	Short message service
SSA	Sub-Saharan Africa
TZS	Tanzanian shilling
UNDP	United Nations Development Programme
USSD	Unstructured supplementary service data

Chapter 1
Introduction

In this Chapter, we give a review of the literature regarding the definition of mobile money, the reasons for its growth and its impact. It ends with identification of gaps in literature and the plans for this work to make a contribution.

1.1 Growth and definition of mobile money

A sizeable number of developing countries have experienced phenomenal growth in mobile money since it was introduced in Kenya in 2007.[1] According to the Global System for Mobile Communications report (GSMA (2020)), the registered number of mobile money accounts grew to over one billion in 2019, with nearly half of them being in the Sub-Saharan Africa (SSA) region.[2] Subscribers to the service now exceed one third of the SSA population, with mobile money agents reaching out 20 times more than bank branches and 7 times more than ATMs.[3] Eight out of ten African countries, hosting about 90 per cent of African population have mobile money presence. While the SSA region has dominated the growth of mobile money, notable developments have also been registered in East Asia and Pacific; South Asia; Latin America and the Caribbean; and Middle East and North Africa. In 2019, one third of the adult population was reached by mobile money in East Asia and Pacific countries, while in South East Asia the figure was about a quarter of adult population.[4] Figure A1 shows the global evolution of mobile money from 2001 to 2019 and Figure A2 (IMF financial access survey, 2019) shows the regional ranking by access to mobile money. These developments have been followed by a growing body of literature seeking to understand their economic and social implications.

[1] The first mobile money system was introduced in Philippines in 2001, but it was until it was introduced in Kenya in 2007 that its growth begun to draw global attention.
[2] GSMA is a non-profit organization representing the interests of mobile network operators worldwide. The acronym stands for Global System for Mobile Communication, or more commonly GSM Association.
[3] Mobile money usage in the East African countries is higher than those of other regions. According to Ahmad *et al.* (2020) mobile money usage in Kenya was 58.4 per cent in 2015, while in Somalia it was 37.1 per cent, Uganda 35.1 per cent and Tanzania 32.4 per cent. Financial Inclusion Insight (2021) data shows that 72 per cent of adult Kenyans had mobile money account ownership, while Tanzanians were 55 per cent and Ugandans 43 per cent.
[4] State of mobile money industry in Asia 2019.

Mobile money is defined as a form of electronic money that allows transactions to be made through a mobile phone (Aron, 2017).[5] It is issued in exchange for equivalent cash;[6] it is electronically recorded on a mobile device account;[7] it is redeemable for cash, and its electronic value may be accepted as a means of payment by parties other than the issuer. Mobile money is used for various transactions such as person-to-person transfers (P2P), person-to-business (P2B) or business-to-person (B2P), and government-to-person (G2P) or person-to-government (P2G) (Ahmad *et al.*, 2020; Batista and Vicente, 2021; Mattern and McKay, 2018; Mawejje and Lakuma, 2019).[8] P2B transactions are mostly payments for goods and services through a platform known as "pay by mobile money". B2P are often bulk payments made by businesses to individuals such as salaries and payments for supplies. The mobile money platform is run by mobile network operators (MNOs), such that it allows transactions to be carried out without requiring the parties involved to own bank account. This feature distinguishes mobile money from mobile banking, which requires transacting parties to have bank accounts (Ahmad *et al.*, 2020).

The mobile money electronic value is backed up by equivalent funds deposited in one or more banks depending on banking or other regulations. This is to make the electronic money redeemable whenever the customer wants to do so. The account in which these funds are deposited may be called an escrow account or a trust account depending on whether the account is under the name of the issuer or the name of a trustee appointed by the issuer (GSMA 2019). In Philippines, there is a further requirement of 100 per cent reserves cover against mobile money balances in banks (Jack and Suri, 2011). Unlike the mobile financial services of the advanced economies, which are linked with pre-existing bank accounts, the mobile money services that have emerged in developing economies draw most of their users from the unbanked population. This makes mobile money services uniquely suitable for cash-based economies (Aron, 2018).

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[5] Mobile money is also referred to as e-float (Eijkman *et al*., 2010; Mbiti and Weil, 2016).

[6] Interoperability arrangements with banks also allow account holders to transfer money from bank account into mobile money account and back using USSD commands. This part of services falls in the definition of mobile banking, also referred to as SMS banking (Bank of Tanzania, 2020), which differs from that of most advanced countries in that it can be operated on any type of mobile phone—basic, featured and smart (Lee *et al*., 2021). Examples of this are the CRDB Bank SimBanking and Stanbic Bank Mobile Banking services in Tanzania.

[7] The mobile money is electronically tied to subscriber's identity module (SIM card), which makes it possible for one to become a mobile money account holder without necessarily having a mobile phone, or to have multiple mobile money accounts with one mobile phone.

[8] Person-to-person transactions are elsewhere referred to as peer-to-peer transactions (Economides and Jeziorski, 2017; Lepoutre and Oguntoye, 2018; Munyegera and Matsumoto, 2016).

At the beginning mobile money transactions were dominated by domestic transfers, but over time, these transactions have expanded into other areas including payment of utility bills, rent, taxes, school fees and retail purchases. Special arrangements have also been used to expand mobile money usage to business in areas such as loan repayments and business-to-business transactions (Aron, 2017; Ahmad *et al.*, 2020). According to the GSMA (2020), there is a growing integration of mobile money providers with third parties, which is increasingly encouraging more value entering the mobile money system to remain digital. The report shows that in 2019, mobile money providers were on average integrated with 98 billers, including 17 government agencies and 11 utility companies, 52 organisations for bulk disbursements and over 13 thousand merchants. In countries where mobile money services are provided by different MNOs like Tanzania, interoperability arrangements have been made to allow seamless flow of mobile money across different MNO networks without additional costs. This, therefore, is another example of arrangements that have encouraged digital money to remain digital (Gilman, 2016).[9]

1.2 Factors behind the growth of mobile money

Literature cites the unique characteristics and pre-existing gaps in the countries where most growth has been observed as the reasons for rapid growth of mobile money. The major factors include: i) limited access to traditional banking services; ii) the spread of mobile telephony; iii) enabling regulatory environment and; iv) the simplicity and affordability of the technology behind mobile money. We discuss each of these factors briefly in the next sub-sections in the context of SSA region, where most of the growth has occurred.

1.2.1 Limited access to traditional banking services

The limited access to traditional banking services leaves large part of SSA population financially excluded. Beck and Cull (2013) use the medians of three standard measures of banking services, namely liquid liabilities to GDP, bank deposits to GDP and private credit to

[9] Tanzania had six mobile money services in 2022, namely Airtel Money by Airtel, Ezy Pesa by Zantel, HaloPesa by Halotel, M-Pesa by Vodacom, Tigo-Pesa by Tigo, and T-PESA by Tanzania Telecommunications Limited (TTCL).

GDP, to show that these indicators for SSA were all less than 70 per cent of those of developing countries outside Africa. The authors utilized four more indicators, namely bank accounts per 100 adults; bank branches per 100,000 adults; proportion of firms with line of credit to total firms and proportion of adults with account at formal financial institution to show that access and use of financial services in SSA countries were far less compared to those of developing countries outside Africa. They further identify four characteristics that make traditional banking more difficult in SSA region compared to other regions as: the small size of the economies; dominance of informal activities; volatility of income streams and governance problems. The low level of incomes and low population density outside major cities make large part of African population commercially unviable to traditional banking services. Informality and volatility of incomes increases the cost and risks for financial institutions thus excluding large segment of population from formal financial services.

Hughes and Lonie (2007) points out that the rapid uptake of mobile money is a clear indication of the gap in the market for which mobile money has provided a solution. That is to enable the unbanked population to affordably save, and send and receive money quickly and securely across vast geographical distances. The mobile money services blend well with mobile communication services, both provided by the mobile phone, to unleash the social insurance potential among the poor and financially excluded, by opening the channels of risk sharing through social and family networks (Ahmad *et al.*, 2020).

1.2.2 The spread of mobile telephony

The spread of mobile telephony that preceded the introduction of mobile money provided a perfect platform for the growth of this form of money. SSA experienced enormous growth in mobile telephony, raising from virtually unconnected region in the 1990s, to one with mobile phone network that reached out to over 70 per cent of the population in 2010 (Aker and Blumenstock, 2015). According to GSMA annual report (2013), about a third of the population of SSA had active mobile phone subscription. Jack and Suri, 2011 use World Bank data to show that mobile phone is one of the few technologies that reached 80 per cent of global population coverage in less than 20 years. Meanwhile, about half of global mobile phone operators with mobile money platforms, operated in SSA (Aker and Blumenstock, 2015). With the spread of mobile phone subscription, and the attendant expansion of agent network, a platform that reached out to the unbanked population was set. The potential offered by this platform for delivering services other than voice and text communication, was soon observed by MNOs and mobile phone subscribers.

For instance, as mobile phones became widespread in Kenya and Tanzania, and peer-to-peer airtime transfer was enabled, subscribers quickly begun to send airtime directly to recipients as a kind of informal remittance, payment for goods and services and or repayment of loans (Comninos *et al*., 2008; Hughes and Lonie, 2007; Jack and Suri, 2011; Mattern and McKay, 2018; Suri and Jack, 2016). This practice of airtime repurposing by the end user has been referred to by Maurer (2012) as airtime trading, which can also be viewed as monetization of the consumer commodity—airtime.[10] Similar findings were made for Rwanda by Blumenstock *et al.* (2011), as they observed that some mobile phone subscribers transferred more airtime to earthquake victims around lake Kivu in Rwanda in 2008, at the time when the airtime transfer service had only been launched in Rwanda. Indeed, the eventual development of mobile money services drew some of its inspiration from the airtime trading practiced by subscribers.

1.2.3 Enabling regulatory environment

The third factor that drove the growth of mobile money in SSA is the enabling regulatory environment. Countries that have registered higher success in the adoption and usage of mobile money are known to be those that adopted the telecom-led model such as Tanzania, Kenya and Uganda, as opposed to countries that adopted bank-led models such as Nigeria (Ondiege, 2015). In the telecom-led model, the mobile network operator (MNO) introduces the mobile money services and may thereafter partner with a bank to interweave the services with other banking services such as savings and credit. This approach is credited for giving greater space for innovation to lead the search for solutions and therefore, has higher potential to deliver practical outcomes. In Tanzania for instance, the central bank gave no objection to MNOs to start the mobile money services and thereafter introduced regulations to support financial inclusion and manage risks. Similar approach was followed by the central banks of Kenya and Uganda. This approach has also been referred to as “test and learn” or “market led” approach.

[10] The airtime sharing feature meant that mobile phone service subscribers were enabled to transfer value among themselves as airtime top-up. In addition, subscribers were able to send scratch card airtime value to each other by using voice or SMS service to pass the access code to another subscriber. This way, the mobile phones were not only offering wireless voice and SMS services to their subscribers, but these services were also being used as means of transferring value from one person to another.

Tables A1, A2 and A3 show the timelines of mobile money related innovations and regulatory shocks in Tanzania Kenya and Uganda (Di Castri and Gidvani, 2014; FSDT, 2018; Muthiora, 2015).

In the case of bank-led model, an MNO works as a business correspondent of a bank by providing the electronic platform of mobile phone communication and agent network for the bank to interface directly with its customers. In contrast to the telecom-led model, the bank-led approach tends to be heavily tied to the prevailing formal banking regulations, such as high know-your-customer (KYC) requirements. Such regulations tend to thwart exploration into novel solutions for the unbanked poor, living in sparsely populated areas—a typical characteristic of the countries where mobile money has seen most of its growth.

1.2.4 Simplicity and affordability

Participating in mobile money services is both simple and affordable. Mobile money can operate on the most rudimentary mobile phones, employing unstructured supplementary service data (USSD) protocol to carry out basic operations on the mobile account such as checking balance and making transactions (Adam and Walker, 2015). It allows subscribers to transact electronically without having a bank account or internet connection. All transactions are authorized and recorded in real time by issuing a guided set of simple instructions on the mobile phone, using secure short message service (SMS). This, makes execution of mobile money transaction nearly as easy as texting with mobile phone (Eijkman *et al.*, 2010). Opening up a mobile money account is also far easier compared to opening a bank account. Setting up mobile money account in Kenya for instance, requires only a proof of identity and no other validation documents typically necessary when opening a bank account (Jack and Suri, 2011). Mobile money accounts are also free from other barriers to formal bank account such as minimum balance and account fees (Ahmad *et al.*, 2020).

Once registered the mobile phone number becomes an electronic wallet capable of saving as well as sending and receiving electronic money. The mobile money account holder loads electronic money into his/her mobile wallet from a mobile money agent in exchange for cash or bank deposit. Special arrangements with banks also enable mobile account holders to transfer money from their bank account into their mobile account, using text commands on their phones. A mobile account holder can cash-in and cash-out the electronic balance on his/her mobile phone at mobile money agents, who are also referred to as cash-in-cash-out (CICO) outlets (Ahmad *et al.*, 2020). The electronic money balance is registered in the account holder's mobile phone and becomes instantaneously available for phone-based transactions. Access to mobile money services therefore enables the account holder to transact instantaneously with other mobile money account holders across vast geographical distances, any time, any day, securely and at affordable cost, even for small values. By removing the barriers of distance and time among transacting parts, mobile money addresses the problem posed by low population density, while at the same time broadening outreach of its services to low-income agents and low value transactions. In recognition of its simplicity and affordability mobile money has been credited as a solution that has changed the economics of small accounts (Veniard, 2010). For the poor who rely on transfers from other individuals and institutions as major source of income, a mobile money account becomes a gateway to support and therefore a vital livelihood instrument.

1.3 The impact of mobile money

The areas of the impact of mobile money that feature most prominently in literature include: i) demand for money, velocity of money and money multiplier; ii) growth of bank deposits, credit and the quantity of money; iii) increase in remittances and stabilization of income; iv) price dispersion, inflation and production; v) reduction of illicit transactions and increase in revenue collection, and vi) financial inclusion, poverty reduction and women empowerment. Each of these areas is briefly discussed in the following sub-sections.

1.3.1 Demand for money, velocity of money and money multiplier

Studies of the impact of mobile money on monetary policy have focused on demand for money, velocity of money circulation, money multiplier and monetary transmission mechanism. Ndirangu and Nyamongo (2015) used autoregressive distributed lag and vector error correction on the Kenya statistics to study the effect of financial innovations on the conduct of monetary policy by testing the stability of income velocity of money, money multiplier and the money demand. The authors also investigated whether innovations had impacted the monetary policy transmission. They found that velocity of the extended broad money supply (M3) was trending down, while the money multiplier was trending up over time.[11] Testing for stability they found evidence of instability in velocity in the period 2009-2010, and in money multiplier and demand for money after 2007, which they suggested could be attributed to financial innovations, most prominent of which was the introduction of mobile money in Kenya. The authors carried out impulse response analysis and found improved effectiveness of monetary policy on GDP compared to previous studies, which they consider to be an indication that there was improvement in the effectiveness of monetary policy after mobile money was introduced.

Nampewo and Opolot (2016) also used autoregressive distributed lag methodology to study the impact of financial innovation on velocity of money in Uganda and found that financial innovations were having negative effects on velocity of broad money supply (M2) in the short-run and positive effects in the long-run. Using monthly data (Mbiti and Weil, 2016) showed that there was a significant upward trend in the transaction velocity of mobile money (M-Pesa) in Kenya.[12] They measured M-Pesa velocity as the total value of person-to-person transfers (per unit of time) divided by the average outstanding balance of mobile money. Their estimate suggested that M-Pesa had a velocity of five in a month, i.e. mobile money was transacted five times per month. However, when the authors compared their result with the velocities of other components of money, they concluded that M-Pesa velocity did not stand out as being much higher and hence there were no significant implications of mobile money for the conduct of monetary policy in Kenya.

Simpasa and Gurara (2012) raised concerns that the rise of mobile money could lead to elevated inflation risks, working through acceleration of velocity of circulation. The authors observed an upturn in velocity of broad money in Tanzania, Kenya and Uganda from around 2009, which they attributed to the rise in mobile money usage in the region. They argued that this development had contributed to the rise in inflation in East Africa in 2010-11. These concerns though, were later disputed by Aron *et al.* (2015) who developed inflation forecasting model for Uganda and found no sufficient evidence to support the claim that mobile money is inflationary.

[11] Extended broad money supply (M3) is a broad measure of money supply that consists of currency in circulation, transferable deposits, and non-transferable deposits including foreign currency deposits held by residents.
[12] M-Pesa is a mobile money system that was initiated by UK Vodafone Plc. subsidiary in Kenya, Safaricom, in 2007 with support of donation from DFID. Ever since it has expanded to Tanzania, Mozambique, DRC, Lesotho, Ghana, Egypt, Afghanistan, South Africa and Ethiopia (Aron, 2017; Bateman *et al*., 2019).

Aron *et al.* (2015) dispute the claim of mobile money being inflationary for two main reasons: first the mobile money velocity-inflation nexus suggested by Simpasa and Gurara (2012) was made on the basis of five years of data and therefore, was subject to high level of uncertainty. Second, there could be countervailing effects where mobile money improves productivity and economic efficiency, arising in part from lower transaction costs. Such effects could lead to higher output without inflation, or even with lower inflation. This argument aligns with the findings of the study by Jafarey and Master (2005), that reduction in transaction costs increases frequency of trade, which is manifested as increase in velocity of money. At the same time, the reduction in transaction costs increases production, which counters the inflationary pressures that arise from the increase in velocity leading to ambiguous consequences on output and prices.

In their study on mobile money and monetary policy in East African countries, Adam and Walker (2015) point out the importance of understanding and taking into account its impact on the conduct of monetary policy, arising from changes in velocity of money and/or changes in money multiplier. They however, argue that the rise of mobile money in the developing world does not fundamentally differ from the innovations of the 1980s in the developed world, that were considered to undermine the monetary targeting frameworks of monetary policy employed by those countries then. They argue that the emphasis on understanding the velocity of money and money multiplier is justified in the context of the prevailing monetary policy frameworks in the East African region, that target quantity of money. Considering that the East African countries were in the process of adopting interest rate as their primary instrument of monetary policy, the authors are of the opinion that this emphasis may not be warranted for these countries.[13] They also considered that a backward-looking empirical study would date quickly given the rapid pace at which mobile money services were evolving. For this reason, they used an alternative methodological approach that does not depend on analysis of historical data. They instead, developed a theoretical DSGE model using the structural characteristics of the East African economies to analyse how the economy would be impacted by mobile money.

[13] The central banks of the three founding members of East Africa Community, Tanzania, Kenya and Uganda, have migrated from using money supply rule to interest rate rule, in their policy frameworks. The Bank of Uganda was the first to adopt interest rate rule in 2011, followed by the Central Bank of Kenya in 2023 and lastly the Bank of Tanzania in 2024 (Bank of Tanzania, 2024; Central Bank of Kenya, 2023; International Monetary Fund, 2011).

1.3.2 Growth of bank deposits, credit and the quantity of money

Since the electronic value of mobile money balances is fully backed by money deposited by the MNOs in banks, it is arguable that there is no new money created in the process of issuing mobile money. However, substantial part of the electronic value is acquired in exchange for cash implying that, the increase in mobile money is accompanied by increase in bank deposits (Waweru and Kamau, 2017). This is in line with Mbiti and Weil (2016) findings that, besides making money transfers, subscribers of mobile money in Kenya were using their mobile accounts to save money and that the increase in mobile money balances was drawing from informal savings. The authors also report that mobile money users were depositing money in their mobile accounts for safety, especially when travelling. Although there is no money created when MNOs issue mobile money, the additional deposits arising from acquisition of mobile money may be utilized by banks to increase lending and therefore, broad money supply (Adam and Walker, 2015).

The GSMA (2020) indicates that digital-to-digital transactions have been increasing over time, which implies that there is an increase in the stability of the deposits arising from acquisition of mobile money. The report shows that, in 2019 there was one digital based transaction for every three cash-based transactions among countries with mobile money, an increase of 50 per cent from 2017. According to the report, out of the total value entering the mobile money system in 2019, 57 per cent came out in digital form, which is an indication of net increase in mobile money related deposits.

Mobile money may also drive increase in money supply through credit creation, if the microcredit window grows to have significant impact on aggregate credit. Several microcredit products have been established by mobile money providers, opening channels for digital microcredit to traditionally unbanked community. According to Consultative Group to Assist the Poor (CGAP) definition, a digital credit is one for which all procedures from application, processing, delivery and repayment are automated and carried out remotely with little human involvement. Digital loans are acquired within short period of application (from few seconds to 24 hours). They are short-term (typically maturing within 1 week and a month) and bear very high interest rates compared to conventional loans (from 2 per cent to as high as 10 per cent per month). Tanzania, Kenya, Ghana, Zimbabwe and Philippines are among countries where digital loan products have been introduced (Hwang and Tellez, 2016).[14] The micro loans are backed by ratings based on transactions records. While micro credit might lead to increase in aggregate bank credit, these loans have had little impact to the aggregate so far, partly because they are not collateralized—a factor that limits their growth (Aron, 2018).

A study by Emran *et al.* (2017) indicates that there is a limit to how large micro credit can grow, owing to the fact that micro enterprises tend to become unfeasible once they expand to a point of requiring labour beyond that supplied by the owner(s). The micro enterprises in developing countries often operate with under-priced, off the market labour. This partly explains their ability to service high interest micro loans, but as these enterprises grow and begin to hire from the market, their ability to service such loans diminishes. This argument conforms with the observed slow growth of digital microcredits. With time though, if the credit scores improve across large number of clients the microcredits could evolve to become a sizeable aggregate especially if other methods of easing constraints on this type of credit are introduced and a larger number of micro businesses access credit through this channel. It is pertinent at this point to mention that the mobile money infrastructure lends itself well, to facilitation of crowdfunding services, should there be properly tailored instruments and appropriate regulatory framework (Jenik *et al.* 2017). Growth of deposits and credit, therefore, remains an avenue through which the money supply could eventually be affected by the rise in mobile financial services.

1.3.3 Increase in remittances and stabilization of income

Mobile money has increased the flow of remittances thus facilitating consumption smoothing among the poor. This increase has occurred on account of reduced cost of sending and receiving money, and expansion of the sources of remittances facilitated by the mobile phone (Jack *et al*., 2013; Mbiti and Weil, 2016; Munyegera and Matsumoto, 2016). With mobile money, the recipients of remittances are able to reach out to a larger number of relatives and friends, as well as welfare agencies (Lenka and Bairwa, 2016). Morawczynski and Pickens (2009) carried

[14]These are some of the mobile money loan products: M-Shwari, Mkopo Rahisi (now Tala), Eazzy Loan and Branch in Kenya; M-Pawa, Timiza and Tigo Wekeza in Tanzania; Mjara in Ghana, Instaloan in Philippines and EcoCashLoan in Zimbabwe (Gilman, 2016; Hwang and Tellez, 2016).

out a 14-month ethnographic study[15] in two communities in Kenya—one an urban slum and another a related rural community. The urban slum had migrants from the rural community who came to town looking for job leaving behind relatives who they regularly supported with remittances. The authors observed that migrants having mobile money facility sent smaller, but more frequent remittances to recipients in the rural, which resulted into overall larger remittances compared to non-users of mobile money.

These findings align with the argument by Aker and Blumenstock (2015), that by reducing the cost of sending and receiving money relative to other methods, the mobile money services enable individuals to transfer money when and where they need, potentially increasing the frequency and amount of transfers received. In Uganda, a study carried out by Sekabira and Qaim (2017) using small holder coffee farmers panel data, found that rural non-farm incomes and agricultural marketing gained substantially from mobile money. On the side of reduction in the costs of receiving money, Mbiti and Weil (2016) argue that the savings made by recipients in the rural community for not having to travel to town centres to collect money from post office, add to the increase in the rural household welfare.

Abiona and Koppensteiner (2020) utilized the World Bank Living Standard Measurement Studies – Integrated Survey on Agriculture (LSMS-ISA) data, to carry out a two period panel-data investigation of the impact of mobile money in Tanzania. The authors found that mobile money enabled the poor households to smooth their expenditure during periods of rainfall shocks, preventing them from sliding into transient poverty, through combination of increase in remittances and welfare receipts facilitated through mobile money accounts. The remittances enabled the poor families with access to mobile money to preserve their investment in education by, among others, preventing school absenteeism in times of shocks. Mobile money has therefore improved the ability of the rural and/or the poor households to smooth consumption in times of shock and hence improved their livelihood.

[15] In ethnographic study, researchers immerse themselves in the lives, culture, or situation they are studying. Such studies are often lengthy.

1.3.4 Price dispersion, inflation and production

By allowing on-demand and immediate information transmission over vast geographic areas, mobile telephony promotes production, while mitigating inflationary pressures. Better information transmission is considered to decrease equilibrium price dispersion and improve market efficiency (Aker and Blumenstock, 2015). With reduced search costs, agents are more likely to engage in spatial arbitrage, which should facilitate movement of products from surplus to deficit markets and reduce inter-market price dispersions. Studies have associated mobile phones with reduction in price dispersion in India fish market and agricultural crops in Niger (Aker and Fafchamps, 2014; Jensen, 2007). In the case of fish market, Jensen (2007) conducted weekly surveys of 300 sardine fishing units in three districts of Kerala India, from 1996 to 2001. The author observed that adoption of mobile phones in these districts enabled fishermen to carry out virtual auctions of their fish across markets thus eliminating price difference across markets in that area. This brought permanent improvement in the functioning of the fish markets thus raising the welfare of the fishing community. It demonstrated the importance of information technology as a factor that contributes to improvement of other aspects of social wellbeing such as education and health, which are traditionally held with higher regard by authorities. The author argues that the effect of mobile phone communication is more pronounced in perishable goods markets, such as fish and milk, compared to relatively less perishable goods like grains.

In addition, by improving communication between firms and their suppliers, mobile phones function as means for firms to manage their supply chains more effectively and streamline their production processes. When the communication side of a mobile phone is combined with the mobile money services, the ability of mobile telephony to stimulate production is enhanced. In the study by Mbiti and Weil (2016), they found that on average, mobile money adoption in Kenya would increase employment by 12 percentage points, mostly in farms.[16] The authors suggest that the increase in urban to rural resource flows associated with mobile money is channelled toward farming, thus boosting the demand for labour and increasing employment. Plyler *et al*. (2010) made similar observation for Kenya, but they associated the increase in farming labour with not only mobile money inflow, but also by the time and financial relief

[16] This is echoed by Munyegera and Matsumoto (2016) who found that households that adopted mobile money in Uganda had their per capita consumption increased by 13 per cent.

that individuals got from not having to travel to town and stand in queues for bank services. This stimulation of production, could also contribute to mitigation of inflationary pressures that may come from the increase in transactions velocity.

From the savings side, Aron (2017) argues that mobile money could have a first round deflationary effect if a rise in private sector saving lowers expenditure relative to income. The author sees a possibility of the effects running in the opposite direction, if the need for precautionary saving declines because of lower perceived credit constraints. Such an outcome will reduce private saving rate, thus making it difficult to predict the effects on the aggregate saving, from these offsetting mechanisms.

1.3.5 Reduction of illicit transactions and increase in revenue collection

Payment through mobile money contributes to mitigation of illicit transactions and encourages compliance. In a survey about the relationship between petty corruption and alternative water bill payment channels, carried by Krolikowski (2014) to obtain qualitative data from 1,079 respondents in Dar es Salaam Tanzania, it was found that payment of water bills through mobile money reduced opportunities for petty corruption by minimizing the interactions between utility customers and staff. The author also argues that involvement of a third party companies supported the reduction of information asymmetries in the water related transactions by increasing the transparency of payment data, thus helping to ensure the integrity of alternative payment channels. Payment of taxes through mobile money has also been reported to have increased revenue collection. In Mauritius, for instance, a 12 per cent increase has been reported in revenue collection in the first year of adoption of mobile money for tax collection (Ahmad *et al.,* 2020). The combination of convenience, safety and transparency in payments made through mobile money increases the willingness to pay, and in turn the efficiency of revenue collection.

1.3.6 Financial inclusion, poverty reduction and women empowerment

Financial inclusion, is broadly viewed as the state in which large part of the population has access to formal financial services. It has elsewhere been defined with emphasis on the formal financial products reaching out to the weaker and vulnerable members of the society affordably (Mbutor and Uba, 2013; Ondiege, 2015; Sanderson *et al.*, 2018). As discussed earlier, countries that have seen rapid growth of mobile money have been characterized as having large part of their populations excluded from formal financial services for reasons such as limited bank branch network, relative high cost of servicing small deposits (and loans) and inadequacy of personal identification (Morgan, 2014). The coming of mobile money has overcome some of these challenges through provision of access to mobile money accounts, as well as mobile phone based banking services.

The increase in access to mobile money has therefore been accompanied with growth of financial inclusion. According to the World Bank Global Findex Database (2017), 43 per cent of adults in SSA had a bank account or a mobile money account in 2017—an increase from 34 per cent in 2014. The breakdown of these statistics shows that most of the growth occurred in mobile money accounts as the share of adults with bank accounts rose by only 4 percentage points from 2014 to 2017, while that of adults with a mobile money account almost doubled to 21 per cent from 12 per cent during that period. This growth has been accompanied by narrowing of gender inequality. Sekabira and Qaim (2017) found that female-headed households among the small farmers in central Uganda, were more likely to be using mobile money than male-headed households. Suri and Jack (2016) utilized household data collected over a period of 6 years from different locations in Kenya. They used panel regression to estimate the relationship between the household income and mobile money agent density, with other control variables and location fixed effects. The authors made conclusion that about 2 per cent of households in Kenya were lifted out of poverty on account of mobile money adoption, and that mobile money has been particularly effective in improving the economic lives of women. They suggest that this impact is primarily driven by change in financial behaviour and labour market outcomes. In particular, the change in financial behaviour is manifested in the increase in financial resilience and saving, while the labour market outcomes relates to broadened occupational choice characterised by increase in migration out of agriculture into business. By making basic financial services such as the ability to safely store and transact money available to the poor, mobile money appears to have boosted their wellbeing. In addition, by giving the poor direct access to remittances mobile money facilitates their graduation from subsistence farming to non-farm occupations.[17]

1.4 Gaps in the literature and motivation for this work

1.4.1 Summary

The increase in financial innovations and particularly e-finance has always been considered as a potential challenge to monetary policy. For instance, Hawkins (2001) pointed out that central bankers in advanced economies had been coping with significant and hard to predict changes in the nature of transmission mechanism due to the rise of electronic finance. The author saw that the general application of internet technology could accelerate the impact of monetary policy and thus it was important to understand the implications of the changing technologies on the conduct of monetary policy. This argument remains valid today particularly for the developing countries that are experiencing rapid changes in financial services, brought about by digital technology. The rise of mobile money observed in the developing countries may destabilize the way monetary policy actions are transmitted through money multiplier and velocity of money. However, literature so far suggests that the link between mobile money and instability in monetary transmission has not been empirically confirmed.

While the studies carried on Uganda by Nampewo and Opolot (2016) and Aron *et al*. (2015) are not conclusive about the impact of financial innovations on velocity of money and inflation, the studies carried out on Kenya by Ndirangu and Nyamongo (2015), and Mbiti and Weil (2016) seem to agree that mobile money has influenced velocity of money. Nonetheless, the data used in these studies represented short period of rapidly evolving mobile money services, hence they have been considered to be lacking in terms of robustness. Now the situation is more conducive for delivering robust results, since we have more than 10 years of data, from the time when mobile money was introduced in East Africa.

Another line of argument in literature considers the experience that developing countries are going through with financial innovation (including mobile money) as nothing different from

[17] The poverty reduction claims by Suri and Jack (2016) has been contested by Bateman *et al*., 2019, on grounds of inadequacy of the methodology used.

what the advanced countries had gone through in the 1970s and 1980s, when their monetary targeting frameworks had faced instability due to financial innovations. This line of argument postulates that the developing countries facing instability in money multiplier and velocity due to financial innovations, could address the problems caused on monetary policy by transiting from monetary targeting to interest rate targeting frameworks. It has also been argued that trying to use historical data to study the ongoing impact of financial innovations in developing countries, may not yield useful results because of the high pace at which the changes are occurring (Adam and Walker, 2015).

While migrating from monetary targeting to interest targeting framework helped to address the monetary policy problems arising from financial innovations in the advanced countries, it is arguable that adoption of interest rate targeting among developing countries may not necessarily yield similar results. This is partly because the innovations occurred in the developed countries while they were at different stage of economic development, compared to developing countries experiencing financial innovations today. For instance, while most advanced countries adopted interest rate targeting in the 1980s and 1990s with much larger proportion of their populations living in the urban and having access to formal financial services, developing countries are experiencing financial innovations, at a time when larger proportion of their population is still in the rural and without access to formal financial services. Adoption of interest rate targeting among these countries is likely to produce outcomes that are different from those of advanced countries and therefore, lessons from the way the monetary authorities dealt with financial innovation in advanced countries may not be sufficient to inform monetary authorities in the developing countries. Thus, studying the peculiarities of the monetary policy impact of the ongoing financial innovations in the developing countries, remains crucial.

1.4.2 Motivation for this work

This work seeks to contribute to the existing literature in two ways. First, is by using theoretical approach, to study the impact of mobile money working through the primary income channel, as opposed to secondary income channel. By primary income we mean transactions that go directly into compensation of factors of production, which we can also measure by the value of sales, while secondary income constitutes unrequited transfers like remittances made by one household to another. As we have seen, there is a growing use of mobile money for purposes other than making transfers. These include payment of utility bills, salaries, taxes and settlement for goods and services purchased (also referred to as merchant payments). Mobile money is therefore flowing not only as transfers, but also increasingly as primary income (Ahmad *et al.*, 2020; Aron, 2017; GSMA, 2020; Hinson *et al*. 2019).

Adam and Walker (2015) developed a new Keynesian DSGE model in which they distinguished the rural from the urban sector to capture the characteristics of SSA economies. In their model, households in the rural sector supply labour to perfectly competitive firms that produce flexible price goods, while those in the urban supply labour to monopolistically competitive firms that produce sticky price goods. The rural households receive transfers from urban households depending on fluctuations in the rural income. The coming of mobile money reduces the cost of making the transfers, leading to higher economic stability, with the benefits accruing mostly to the lower income households. The authors also argue that financial innovations help to reduce the incompleteness of markets and thus monetary authorities may find it useful to target core inflation. Their model therefore analyses the impact of mobile money through the transfers channel.

In this work we argue that, the drivers of changes in the flow of mobile money and its impact on the economy are likely to differ depending on the channel through which it flows. On the side of drivers, for instance, changes in remittance transactions are primarily driven by consumption smoothing motives between the sender and the recipient, because they are altruistic in nature. A negative shock in the income of the recipient like crop failure, may trigger an increase in the flow of remittances, even if there is no change in the income on the side of the sender. By contrast, changes in the flow of mobile money arising from purchase of goods and services are likely to be driven primarily by the income or the relative purchasing power of the consumer. A rise in the incomes of consumers is expected to increase their consumption and hence the flow of purchases including those made through mobile money, as long as this is a nontrivial means of payment. Regarding the impact of mobile money flow on the economy, recipients of unrequited transfers have bigger choice on how they spend the money, while receipts from sale of goods are directly tied to financing the production of the goods sold. The flow of mobile money through income (or purchase of goods) can therefore be viewed as impacting the supply side more, than the flow of mobile money through transfers.

Meanwhile, the reduction in transactions costs arising from adoption of mobile money, may lead to increase in transactions velocity of circulation and drive inflationary pressures up as posited by Simpasa and Gurara (2012). On the other hand, it may reduce the overall consumer price through reduction of price dispersions across markets and thus increase demand and production, in line with the findings by Jensen (2007), and Aker and Fafchamps (2014). The reduction in price dispersion may as well drive production up, through higher prices on the side of producers. The impact of mobile money adoption on prices and production will therefore depend on which of the different forces is stronger as suggested by Aron (2017). By developing a model to study the primary income channel, we hope to shed more light on the interplay of these forces and their implications to monetary policy. Since our primary interest is to identify policy implications of mobile money, we will apply monetary policy shocks to the model, and carry out estimation of optimal monetary policy rule defined as a rule that maximizes welfare. We hope that this work will also make contribution to the construction of frameworks for analysing the various aspects of mobile money.

Second, this work intends to use time series from the three East African countries, Tanzania, Kenya and Uganda, to carry out empirical analysis of the impact of mobile money on monetary policy. The countries chosen for analysis in this work are among the countries where mobile money has been adopted the longest and also among the leading countries for having large population of mobile money users. According to GSMA database (2020), the Eastern Africa sub region had 293 mobile money accounts, more than half of the 586 million accounts for the entire SSA region. Taking advantage of longer time series, this work hopes to improve on the robustness of the results found in earlier empirical studies.

This work is therefore planned as follows: In Chapter 2, we will develop a theoretical new Keynesian DSGE model along the lines of the study carried out by Adam and Walker (2015), with alteration to enable exclusive tracking of the flow of mobile money through the primary income channel. This will form the benchmark model that will be extended twice in Chapter 3. In the first extension we will add the secondary income channel of mobile money impact, i.e. the remittances channel, and in the second, we will add capital. The research question to be answered is whether the reduction of costs of making distant payments, brought about by mobile money usage, changes the way monetary policy needs to react to economic shocks, and how monetary policy should adjust to those changes. The additions to the benchmark model will help to provide more rounded insights about the impact of mobile money, and unveil specific effects of each of the three features.

In Chapter 4, we will use 22-year quarterly time series data from Tanzania, Kenya and Uganda to empirically seek an answer to the question: has the rise of mobile money in these countries impacted the transmission of monetary policy? In this chapter we will employ ARDL bounds test approach to cointegration, to estimate equations of income velocity of circulation, with a view to finding out whether mobile money has impacted the velocity in a statistically significant way. In Chapter 5 we will conclude this work by summarizing the findings and identifying policy implications.

Chapter 2
A benchmark DSGE model of the impact of mobile money through the primary income channel

2.1 Introduction

2.1.1 Overview of DSGE modelling

The dynamic stochastic general equilibrium (DSGE) modelling has gained appeal as an analytical tool that addresses the Lucas (1976) critique, by allowing incorporation of microfoundations in macroeconomic analysis. The DSGE models trace their origin from the classical economic theory, which considered real shocks as the primary cause of business cycles. The classical theory is premised on the assumption that the behaviour of economic agents is rational and that in their pursuit of their own self-interest, they are capable of keeping the markets at equilibrium, as well as correcting market distortions without government intervention. This is made possible by the assumption that prices and wages are fully flexible and therefore they will always adjust to bring supply and demand to equilibrium, hence keeping the economy at its full employment level. With this assumption the classical economic theory conforms with Say's Law, which postulates that supply creates its own demand (Blaug, 1997). According to this law the income generated by production is sufficient to purchase the resulting output, implying that savings are always equal to investment.

The neoclassical economic theory carries most of the assumptions of the classical theory with a major difference being its consideration of the behaviour of consumers as an important factor in the determination of the value of goods and services. It puts emphasis on the role played by the rational, forward-looking agents, and ushered in the use of rigorous Walrasian modelling foundations to the classical economic theory. This brought together macroeconomic and microeconomic analysis to a general equilibrium framework, enabling the economy to be analysed as a whole, in contrast to partial analysis. Under the neoclassical theory mathematical models became central to economic modelling. Both classical and neoclassical economic theories maintain that prices and wages are fully flexible and thus distortions in the markets can be resolved by the self-interest behaviour of economic agents, without government intervention.

Owing to the failure of the classical theory to explain the prolonged economic depression of the 1930s, the Keynesian view emerged that postulated that markets may not self-correct all the time because wages and prices are sticky downward. Specifically, this view held that in times of economic uncertainty, households reduce consumption, and businesses become hesitant to invest. Consumption and investment become interest inelastic because of low business confidence, alternatively referred to as weak market sentiments. If an economy enters a recession of this kind, government intervention will be needed to expedite restoration of equilibrium conditions.

In his seminal 1976 work, Lucas argued that parameters of macro-econometric models needed to take into account agents' expectations because they were likely to change in response to policy maker's behaviour. Afterwards, researchers began to incorporate agents' expectations and equilibrium conditions in macroeconomic models, with assumptions of perfect competition (Rudebusch, 2005). The classical real business DSGE models grew out of these changes in macroeconomic research.

Beginning early 1990s, economists combined the elements of New-Keynesian economics with the RBC models. This combination, also referred to by Paul Samuelson as the new neoclassical synthesis, put together the dynamic aspects of the RBC with the imperfect competition and market rigidities of the New Keynesian models, giving rise to the New Keynesian DSGE models. The key elements of the new synthesis are intertemporal optimization, rational expectations, imperfect competition, and various real and nominal frictions (Tamborini *et al*., 2014). Real frictions include limited access to bond market; habit formation in consumption; existence of adjustment costs in investment; and under-utilization of maximum installed capacity. Nominal frictions introduce sluggishness in the response of prices and wages to interest rate shocks. With these frictions, real variables become responsive to anticipated and unanticipated shocks, in the short to medium term (Gali, 2015). The New Keynesian DSGE models have been regarded by economists as more sensible, because they are more transparent and thus they more supportive of policy debate than RBC models (Christiano *et al*., 2018). Another strength of these models is their emphasis on central bank credibility, achieved through rules-based policy, like inflation targeting. The structural setting of DSGE models allows identification of impact and transmission of policy interventions; while the optimizing and forward looking behaviour of households and firms facilitates analysis of forecast scenarios (Peiris and Saxegaard, 2007).

2.1.2 Price stickiness and access to bond market friction

The price friction that manifests itself as price stickiness in the model, arises from the assumption of existence of monopolistically competitive firms—firms that produce similar, but non identical goods. Such firms face negatively slopping demand curves, which give them some degree of price setting power. As these firms pursue profit maximization they end up choosing prices that exceed their marginal cost. Price stickiness is modelled by assuming that a fraction of the price setting firms keep their current period price unchanged next period. The rules for changing prices include, time-dependent rule and state-dependent rule. Under the time-dependent rule, the price runs for a fixed period of time before it is reviewed, while under the state-dependent rule, a preset threshold of deviation between equilibrium price and the actual price has to be reached for the price to be reviewed. State-dependent rule is more likely to be used in the environment of high and/or volatile inflation, where set-up costs are higher (Fregert, 2008). Example of time-dependent price setting model is that of Calvo (1983), where firms set their price knowing that their price will remain unchanged for some period to come. Such firms therefore, take into consideration all losses they may incur, while their price remains fixed. This price framework has been widely used in DSGE modelling (Adam and Walker, 2015; Anand and Prasad, 2010; Gali *et al*. 2004; Senbeta, 2011). When prices are sticky, changes in interest rate influence the value and expected return on financial assets, which in turn influences the consumption and investment decisions of economic agents. This leads to real changes in employment and output, thus making money non-neutral in the short-run (Christiano, 2011; Costa, 2018; Gali, 2015; Plosser, 2012).

Regarding friction in access to bond market, the standard approach is to include non-Ricardian consumers alongside Ricardian consumers in the model. Ricardian consumers have access to financial market, which enables them to make intertemporal transfer of their incomes through savings and credit. This allows them to optimize their utility across time. Non-Ricardian households on the other hand do not have access to the financial market and, therefore, they are unable to exercise intertemporal utility maximization (Costa, 2018). Ricardian consumers have elsewhere been referred to as optimizing consumers, while the non-Ricardian consumers have also been referred to as rule-of-thumb, or hand-to-mouth consumers.

The case for existence of non-Ricardian consumers has been supported by studies such as that carried out by Campbell and Mankiw (1989) on the United States of America data, where they found strong connection between current income and consumption, contrary to what would have been predicted by permanent income hypothesis. They attributed these findings to existence of rule-of-thumb behaviour among consumers, which they estimated to account for about 50 per cent of income in the United States of America and other advanced countries including Canada, France, Germany, Italy and Japan. On the part of forward looking consumers, the authors concluded that the intertemporal elasticity of substitution in consumption was close to zero.

The behaviour of rule-of-thumb households is, in essence, shielded from changes in real interest rate. Gali *et al.* (2004), show that a non-negligible presence of the rule-of-thumb consumers, has implications to monetary policy, which they identify as requiring stronger interest rate response to contemporaneous inflation, on one hand, and a less than one-to-one response to expected inflation, on the other. Anand and Prasad (2010) draw two conclusions regarding presence of rule-of-thumb consumers. First they argue that, in the presence of such consumers, targeting core inflation does not maximize welfare and second, stabilization of inflation does not sufficiently stabilize output. The authors argue that flexible targeting of headline inflation with due weight placed on output gap, constitutes an optimizing monetary policy rule in the presence of credit constrained consumers.

While in advanced economies the rule-of-thumb behaviour among consumers may be seen as voluntary personal choice, in low-income economies this may be predominantly caused by inaccessibility of formal financial services. Based on World Bank database (2020), 11 out of 15 countries with largest adult population receiving remittances, had more than 50 per cent of their population in the rural in 2019 where access to formal financial services is limited (Figure A3). We thus consider it to be appropriate to model these economies with rural and urban sectors as it was done by Adam and Walker (2015) and Anand and Prasad (2010).

2.1.3 Payment friction

Besides the price and bond market frictions, our objective in this Chapter is to add payment friction to the model, in order to facilitate analysis of the impact of mobile money through the primary income channel. To achieve this, we adopt the approach used by Adam and Walker (2015), henceforth referred to as AW. In AW, the money transfer technology is used for remittances only, thus the coming of better technology like mobile money, reduces the cost of sending remittances and thus, encourages the urban households to make more remittances. The main departure of our benchmark model from that of AW, therefore, is that it will be developed to track the effect of mobile money through purchase of goods and services only.

This is to recognize the growing use of mobile money for that purpose. For instance, in the Tanzania FinScope Survey (2023), respondents were asked about the electronic instrument that they used in the past month to pay for goods and services. The proportion of respondents that used mobile money was found to be 13 per cent, way above any other electronic instrument. The other instruments were debit cards (2 per cent), bank transfer (1 per cent), credit card (0.3 per cent) and cryptocurrency (0.4 per cent) (Figure B1) (FinScope Tanzania, 2023). This gives a feel of the enormous importance of mobile money relative to other electronic payment instruments. However, it is important to note that the average value of mobile money transactions is much smaller than those of other instruments. Jack and Suri (2011) observed that the average mobile money transaction in Kenya was about a hundred times smaller than the average cheque transaction and about half of the average value of ATM transaction. This is also reflected in the size of mobile money balances relative to bank deposit balances. In Tanzania, for instance, the number of active mobile money accounts in 2020 was 76 per cent higher than that of bank accounts, yet the total balance in mobile money accounts was only 3 per cent of the balance in bank accounts.

A better estimate of the role played by mobile money in transactions could be drawn from its share in total transaction balances, which for Tanzania was 7 per cent in 2022 (Bank of Tanzania, 2022).[18] Currency in circulation accounted for 32 per cent and transferable deposits for 61 per cent. Assuming that each component of transaction balances supports a matching

[18] Total deposit balances cover all types of deposits, while transactions balances include transferable deposits only.

proportion of GDP transactions, we have around 7 per cent of GDP being transacted in mobile money. In addition, if we consider the findings by Mbiti and Weil (2016) that mobile money has higher velocity of circulation than other forms of money, we could also assume that mobile money supports a share of GDP that is higher than its weight in total transaction balances. This makes 7 per cent the lower boundary of the share of GDP transacted in mobile money.

As we have seen in Chapter 1, there is a consensus in literature that mobile money has increased the flow of remittances from the urban to the rural. This does not mean that there are no urban-to-urban or rural-to-rural remittances. Rather it means that when the urban and rural sectors are considered in their totality the net flow of remittances becomes urban-to-rural. In the same vein, we assume that in aggregate, the net primary payments through mobile money flows from the urban-to-rural.[19] It is on this premise that we split the rural industries into farming and non-farming, and assume that the non-farming industry produces for the urban and gets paid through the mobile money. The assumption that the rural non-farming industry has inclination towards producing for urban consumers is consistent with the findings that rural households engage more in non-farm activity the closer they are to the urban and/or the more accessible they are through transport infrastructure (Fafchamps and Shilpi, 2003; Reddy, 2006; Soderbom, 2008). Proximity to the urban give rural communities advantage of not only being able to supply its labour directly to the urban, but also to produce products that the urbanites can pay for using distant payment technologies, like mobile money, because in such places, the products can easily be delivered to buyers. To inform our construct of the rural activity structure, we dedicate the next section to discussion of rural occupational choices in Africa.

2.1.4 Rural occupational choice in Africa

In the rural Africa, individuals can choose between wage employment or entrepreneurship, but wage employment is rare. The primary occupation for the rural population is farming. It is common though, to find rural households engaging in non-farming activity, mostly self-employed. The choice of occupation is influenced by individual competences or abilities, the state of the labour market, and social and cultural orientation (Nagler, 2015; Reddy, 2006).

[19] Mobile money serves as a form of transaction balances which agents use for both primary income and secondary income transactions. Our argument is that the net flow of funds in each type of these transactions is from urban to the rural.

Individuals with higher levels of skills and education have wider choices of occupation, while social and cultural factors such as religion, gender, kinship and tribe can set limits to occupational opportunities available to a household. The choice of occupation can be made by individual or collectively by a family. Collective family decision, in part reflects the common practice of family based enterprises in rural areas.

With farming as the primary form of occupation, decision to engage in non-farming activity is often motivated by some push and pull factors. In the rural, the main push factors are the absence of social protection or insurance schemes and labour surplus in the family. This motivates households to seek diversification of family activity into non-farming as a way of coping with adverse shocks, as well as seasonal fluctuations in farming income. In a study of rural Nepal, Menon (2009) found that where rain was less certain, the chances of the head of family and other members of family dividing themselves into different occupations increased. As for the pull factors, the main one is demand. If demand for non-farm products that fall within the ability of a household to produce emerge, the household may take that opportunity depending on how economically feasible it is, relative to farming. Household flexibility in taking such opportunities depends in turn on quantity and abilities of its labour (Reddy, 2006; Sumner, 1981). Thus households with matching abilities in producing the non-farm products, and those with surplus labour are more likely to move into and out of non-farm activities in response to demand. Engagement in non-farm activities for risk diversification on the other hand, comes as a necessity and therefore it is likely to be less responsive to changing circumstances. Existence of surplus labour can push a household into non-farming activity, while at the same time making the household more responsive to non-farm opportunities.

Nagler (2015) used the LSMS-ISA data to study rural occupational choice in Africa and found that the overwhelming majority of rural non-farm enterprises were family based and operated intermittently. These findings complement those of Sekabira and Qaim (2017) that, in Uganda, rural non-farm incomes and agricultural marketing gained substantially from mobile money. They also resonate with the observations made by Suri and Jack (2016) that mobile money facilitated rural labour migration from farming into business. Our view is that the observed good performance of non-farm activities, in the presence of mobile money, in part reflects higher demand for non-farm goods, mirrored by allocation of more rural resources in that industry—akin to fulfilment of the Keynes' Law of demand creating its own supply.

The fact that non-farm activities appear to alternate with farm activities seasonally and cyclically is an indication of labour mobility between these activities. That is, during farming low season, or in times of negative shock in farming, households engage more in non-farm activity and *vice versa*. Note that, for some households this may also mean that they change the relative amount of labour hours they supply in one of the two industries, depending on circumstances. Canagarajah *et al*. (2001) made similar conclusion that non-farming industry functioned as an alternative to farming in Ghana. Studies have shown that the strategy of rural household diversifying its labour into farming and non-farming delivers positive results, for rural households. For example, Newman and Canagarajah (2000) found that households engaging in non-farm activities in Ghana and Uganda, experienced lower levels of poverty compared to other households in the rural. Likewise, Nielsen *et al*., (2013) observed that income diversification in the rural was a norm in Bolivia, Nepal and Mozambique, and that non-farm income contributed significantly to higher household income.

Against the backdrop of the foregoing, we make extrapolation by assuming perfect labour mobility between farming and non-farming. We do this for reasons of tractability and because our focus is on the net primary income payments, that take place between urban and the rural. We further assume that such payments are directed towards purchase of non-farm goods, which conforms with the observed better performance of the non-farming industry in the context of mobile money. Since the purchase of goods and services goes directly into compensation of factors of production, we expect mobile money in our benchmark model to raise primary incomes in the rural more compared to the urban and, therefore, provide all rural households with access to its benefits. This is in contrast to transfers that may benefit the transfer-receiving households more than other households in the rural. Thus, another area of this model's departure from those of AW and Anand and Prasad (2010), is the split of the rural firms into farming and non-farming industries. This will help to reveal the relative effect of mobile money between these activities and other variables of interest.

The rest of this Chapter is organized as follows: in Section 2.2, we set up the model, after which we discuss calibration of parameters in Section 2.3. In section 2.4 we carry out simulations and discuss results, and finally we conclude in Section 2.5.

2.2 New Keynesian DSGE model with payment friction in the primary income

The benchmark model developed in this chapter, henceforth referred to as Model 1, assumes an economy that has three types of agents: households, firms and a government agent—a central bank responsible for setting interest rate and issuing bonds. The economy has two sectors—rural and urban.[20] The rural sector in this model has two types of firms: firms producing farm goods and firms producing non-farm goods. Farm goods are assumed to be homogenous and consumed by all households in the economy. The non-farm goods are assumed to be mostly artisanal, and consumed by urban households only.[21] The urban sector on the other hand, has one type of firms—firms producing differentiated non-food goods, that are consumed by all households in the economy. We refer to these goods as manufactured goods. There is no labour mobility across sectors, meaning that households provide labour to firms within their respective sector only. However, in the rural there is perfect labour mobility between farm and non-farm goods production. The assumption of labour mobility within the rural is based on the fact that most of labour in farm and non-farm activities is either unskilled or semiskilled. In countries with vast arable land like those of East Africa, this type of labour tends to move in and out of small scale farming, depending on the relative viability of non-farming activities, compared to farming.

All goods in the rural are produced by perfectly competitive firms, thus their prices are perfectly flexible and for this reason, the rural produced goods are collectively referred to as flexible price goods. The trading of these goods though, is differentiated such that farm goods are traded in a frictionless market, while non-farm goods are paid for using the prevailing distant payment technology, which is subject to some transaction cost. The buyer of non-farm goods, therefore,

[20] The term sector is used in this work as a convenient way of referring to the rural and urban parts to which the modelled economy is divided, rather than the standard definition given in the System of National Accounts (SNA 2008).

[21] Examples of non-farm goods include rural produced physical items such as hand weaved mats, rugs and baskets as well as house items made out of plants such as bamboo and mangrove trees. The most relevant of these goods would be those ordered by urban consumers and paid for to initiate production for later delivery or collection. These goods fit the non-perishability, an important property for goods produced for selling directly to distant consumers. They also include services carried out in the rural, but paid for by the urban households. Such services may include developing a rural property owned by an urban dweller or making deliveries in the rural by orders given by urban dwellers. These activities are carried out by semiskilled workers, who alternate between farming and non-farming depending on relative profitability of the two industries (Siddiqui, 2004). All in all, the non-farm goods category is used as a convenient way of making reference to goods purchased directly using distant payment technology.

pays transaction fees, thus making the consumer price higher than the cost of producing these goods. Mobile money comes in as innovation that reduces the transaction fees for making distant payments.

Like farm goods, the manufactured goods are assumed to be traded in a market without payment friction, but they are produced by monopolistically competitive firms. Urban firms are, therefore, able to maximize their profit by selling their goods at a price that is higher than their marginal cost. A fraction γ_m of urban firms sell their goods at the previous period price, while the remaining fraction $1-\gamma_m$ sell their goods at the prevailing market price thus making the price of urban manufactured goods sticky. Because of this, manufactured goods are also referred to as sticky price goods.

2.2.1 Households

There is a continuum of infinitely lived households with the urban households normalized to 1 and the rural households to 2, to approximate the structure of economies where mobile money has boomed. The AW model employed similar proportions to approximate the structure of East African countries. The rural households are credit constrained, while the urban sector households have access to bond market, where they can buy one period risk free bonds. The urban households also hold monetary assets, which they use to facilitate transactions (Can *et al*., 2021).

2.2.1.1 Rural households

A representative rural household seeks to maximize its lifetime utility, given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(C_t^{rr}, N_t^{rr})] \tag{2.1}$$

where: $\beta \in (0,1)$ is subjective discount factor; C_t^{rr} is a composite consumption in period t; and N_t^{rr} is labour supplied by the household.

The instantaneous utility function is given by:

$$u(C_t^{rr}, N_t^{rr}) = \frac{(C_t^{rr})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{rr})^{1+\psi}}{1+\psi}, \tag{2.2}$$

where σ is the inverse of the elasticity of intertemporal substitution; ψ is the inverse of Frisch elasticity of labour supply and ϕ is a scaling factor on the disutility of labour supplied.

The rural household budget constraint is given by:

$$P_t^r C_t^{rr} = W_t^r N_t^{rr}, \tag{2.3}$$

where P_t^r is the aggregate price index of the basket of goods consumed by representative rural household[22]; W_t^r is wage level in the rural sector and N_t^{rr} is the labour supplied by the rural household.

The rural household composite consumption is defined as:

$$C_t^{rr} = \left[\gamma^{\frac{1}{\eta}}\left(C_{f,t}^{rr}\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}}\left(C_{m,t}^{rr}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{2.4}$$

where $C_{f,t}^{rr}$ is rural household consumption of farm goods, $C_{m,t}^{rr}$ is its consumption of manufactured goods and $\eta \in [0, \infty]$ is elasticity of substitution between flexible price (rural produced) goods and manufactured goods.

The optimal demand for farm goods by the rural household is given by:

$$C_{f,t}^{rr} = \gamma\left(\frac{P_t^r}{P_{f,t}}\right)^{\eta} C_t^{rr}, \tag{2.5}$$

where $P_{f,t}$ is the price of farm goods, and the optimal demand for manufactured goods by the rural household $C_{m,t}^{rr}$ is defined as:

$$C_{m,t}^{rr} = (1-\gamma)\left(\frac{P_t^r}{P_{m,t}}\right)^{\eta} C_t^{rr}, \tag{2.6}$$

[22] The notation P_t^r is used to denote the price index of the basket consumed by rural household (which contains farm and manufactured goods) and is distinguished from $P_{l,t}$ which is the consumer price index of all flexible price goods (farm and non-farm goods).

where $P_{m,t}$ is the price of manufacture goods.

The labour supplied by rural household is given by:

$$\phi \frac{(N_t^{rr})^{\psi}}{(C_t^{rr})^{-\sigma}} = \frac{W_t^r}{P_t^r}, \tag{2.7}$$

and is composed of labour in farming, $N_{f,t}^r$, and labour in in non-farming, $N_{a,t}^r$.

2.2.1.2 Urban households

A representative urban household utility function differs from that of the rural household in that it has real money balances, commonly specified as a money in the utility function (Can *et al*., 2021; Lai, 2018):

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(C_t^{zz}, M_t/P_t, N_t^{zz})] \tag{2.8}$$

where C_t^{zz} is a composite consumption of the urban household in period t; M_t/P_t is real money balances; and N_t^{zz} is labour supplied by the urban household.

The instantaneous utility function of the urban household is defined as:

$$u(C_t^{zz}, M_t/P_t, N_t^{zz}) = \frac{(C_t^{zz})^{1-\sigma}}{1-\sigma} + \frac{(M_t/P_t)^{1-\upsilon}}{1-\upsilon} - \phi \frac{(N_t^{zz})^{1+\psi}}{1+\psi}, \tag{2.9}$$

where υ is marginal elasticity of demand for real money balances.

The household seeks to maximize its utility subject to budget constraint

$$\begin{aligned} P_t C_t^{zz} + M_t + B_t \\ = \int_0^1 W_{m,j,t}^z N_{m,j,t}^{zz}\, dj + \int_0^1 D_{m,j,t}^{zz}\, dj + M_{t-1} + R_{t-1} B_{t-1} \\ + S_t^{zz}, \end{aligned} \tag{2.10}$$

where P_t is the aggregate price index of the basket of goods consumed by the urban household;[23] B_t is one-period nominal risk-free bond bought at time t and maturing at time $t+1$; $W^{z}_{m,j,t}N^{zz}_{m,j,t}$ is nominal wage from manufacturing firm j; $D^{zz}_{m,j,t}$ is the dividend received from manufacturing firm j's, and S^{zz}_t is the transaction fees paid to purchase non-farm goods. The fees are paid lump sum to the urban households on assumption that the money transfer business is solely owned by urban households. This assumption has been made for simplicity, but a more appropriate way of handling the transaction services would be to assign them to a separate entity with proper microfoundations.

The first order solution for the urban household consumption yields the standard Euler equation

$$(C^{zz}_t)^{-\sigma} = \beta E_t\left[(C^{zz}_{t+1})^{-\sigma}\frac{R_t}{\Pi_{t+1}}\right], \tag{2.11}$$

where: $\Pi_t = \frac{P_t}{P_{t-1}}$ is gross headline inflation.

The composition of the urban household consumption basket is defined as:

$$C^{zz}_t = \left[\gamma^{\frac{1}{\eta}}\left(C^{zz}_{l,t}\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}}\left(C^{zz}_{m,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{2.12}$$

where $C^{z}_{l,t}$ is urban household consumption of rural produced goods, which contains farm and the non-farm goods; and $C^{z}_{m,t}$ is the urban household consumption of manufactured goods.

The optimal demand for rural produced goods by the representative urban household is given by:

$$C^{zz}_{l,t} = \gamma\left(\frac{P_t}{P_{l,t}}\right)^{\eta} C^{zz}_t, \tag{2.13}$$

and demand for urban manufactured goods is:

[23] The price index of the basket consumed by the urban household appears without superscript z because the urban household consumes all goods produced in the economy.

$$C_{m,t}^{zz} = (1-\gamma)\left(\frac{P_t}{P_{m,t}}\right)^{\eta} C_t^{zz}. \tag{2.14}$$

The urban household consumption of the rural produced goods $C_{l,t}^{z}$ is, in turn, composed of farm goods $C_{f,t}^{z}$ and non-farm goods $C_{a,t}^{z}$, in the form

$$C_{l,t}^{zz} = \left[\gamma_z^{\frac{1}{\eta_z}}\left(C_{f,t}^{zz}\right)^{\frac{\eta_z-1}{\eta_z}} + (1-\gamma_z)^{\frac{1}{\eta_z}}\left(C_{a,t}^{zz}\right)^{\frac{\eta_z-1}{\eta_z}}\right]^{\frac{\eta_z}{\eta_z-1}} \tag{2.15}$$

where: $\gamma_z \in (0,1)$ is the weight of farm goods in the rural produced goods part of the urban household consumption basket; and $\eta_z \in [0,\infty]$ is the elasticity of substitution between farm and non-farm goods.

The optimal demand for farm goods by the representative urban household $C_{f,t}^{z}$ is given by:

$$C_{f,t}^{zz} = \gamma_z\left(\frac{P_{l,t}}{P_{f,t}}\right)^{\eta_z} C_{l,t}^{zz}, \tag{2.16}$$

while the optimal demand for the non-farm goods by the representative urban household $C_{a,t}^{zz}$, is given by:

$$C_{a,t}^{zz} = (1-\gamma_z)\left(\frac{P_{l,t}}{P_{a,t}^{z}}\right)^{\eta_z} C_{l,t}^{zz}, \tag{2.17}$$

where $P_{a,t}^{z}$ is the consumer price of the non-farm goods, which is defined as:

$$P_{a,t}^{z} = (1+\mu)P_{a,t}. \tag{2.18}$$

where $P_{a,t}$ is the producer price of non-farm goods and $\mu \in [0,1)$ is the transaction fees incurred when purchasing non-farm goods, expressed as proportion of $P_{a,t}$.

Household demand for money balances satisfies the condition:[24]

$$\frac{(C_t^{zz})^{\sigma}}{(M_t/P_t)^{\upsilon}} = 1 - \frac{1}{R_t} \tag{2.19}$$

The labour supplied by the representative urban household to firm j is given by:

$$\phi \frac{\left(N_{m,j,t}^{zz}\right)^{\psi}}{(C_t^{zz})^{-\sigma}} = \frac{W_{m,j,t}^{z}}{P_t}. \tag{2.20}$$

2.2.2 Firms

Each household owns a firm, with production in each firm being linear in labour and subject to product-specific productivity shock.

2.2.2.1 Rural firms

Production function for rural farming firms is defined as:

$$Y_{f,t}^{r} = A_{f,t} N_{f,t}^{r}, \tag{2.21}$$

where $Y_{f,t}^{r}$ is production of farm goods; $A_{f,t}$ is productivity in farming firms; and $N_{f,t}^{r}$ is labour employed in farming firm.

The farm goods producer seeks to maximize farm profit $\Omega_{f,t}^{r}$

$$\max_{N_{f,t}^{r}} \Omega_{f,t}^{r} = P_{f,t} Y_{f,t}^{r} - W_{f,t}^{r} N_{f,t}^{r} \tag{2.22}$$

by choosing labour $N_{f,t}^{r}$, subject to the production function equation number (2.22).

[24] Since $R_t = 1 + r_t$, then equation (2.19) can also be presented as $P_t C_t^{\sigma} / M_t^{\upsilon} = r_t / (1 + r_t)$, where r_t is net nominal interest rate on bonds (Arrau *et al*., 1995; Calvo and Leiderman, 1992; Ivanov *et al*., 2014; Nampewo and Opolot 2016; Can *et al*., 2021; Khramov, 2012; Walsh, 2017).

Solving this problem, the farm goods producer sets demand for labour to satisfy equation number (2.23).

$$P_{f,t} = \frac{W_{f,t}^r}{A_{f,t}^r}. \tag{2.23}$$

Likewise, the production function for non-farm goods is given by:

$$Y_{a,t}^r = A_{a,t} N_{a,t}^r, \tag{2.24}$$

where $Y_{a,t}^r$ is production of non-farm goods; $A_{a,t}$ productivity in non-farm firms and; $N_{a,t}^r$ is labour employed in non-farm firm.

The producer of non-farm goods chooses labour $N_{a,t}^r$ to maximize profit $\Omega_{a,t}^r$,

$$\max_{N_{a,t}^r} \Omega_{a,t}^r = P_{a,t} Y_{a,t}^r - W_{a,t}^r N_{a,t}^r \tag{2.25}$$

subject to production function number (2.25).

Demand for labour in non-farm goods firms is set to satisfy

$$P_{a,t} = \frac{W_{a,t}^r}{A_{a,t}^r}. \tag{2.26}$$

2.2.2.2 Urban firms

Production function for manufactured goods is given by:

$$Y_{m,t}^z = A_{m,t} N_{m,t}^z, \tag{2.27}$$

where $Y_{m,t}^z$ is aggregate production of manufactured goods; A_t^z is productivity in the urban sector; and $N_{m,t}^z$ is labour employed by urban firms.

The urban wholesale firm j sets its demand for labour to satisfy equation number (2.28)

$$MC_{m,j,t}^{z} = \frac{W_{m,j,t}^{z}}{A_{m,t}} \tag{2.28}$$

where $MC_{m,j,t}^{z}$ is the marginal cost of producing manufactured good j and $W_{m,t}^{z}$ is wage level in the urban sector.

The Dixit-Stiglitz aggregation technology is used by the urban retail firms to aggregate wholesale goods $Y_{m,j,t}^{z}$ into a retail good $Y_{m,t}^{z}$,

$$Y_{m,t}^{z} = \left[\int_{0}^{1} Y_{m,j,t}^{z}{}^{\frac{\eta_m - 1}{\eta_m}}\, dj\right]^{\frac{\eta_m}{\eta_m - 1}} \tag{2.29}$$

where $\eta_m > 1$ is the elasticity of substitution between intermediate goods. This parameter governs the degree of monopolistic competition among intermediate goods.
Solving the objective function of choosing $Y_{m,j,t}^{z}$ to maximize profit $\Omega_{m,t}^{z}$

$$\max_{Y_{m,j,t}^{z}} \Omega_{m,t}^{z} = P_{m,t}^{z} Y_{m,t}^{z} - \int_{0}^{1} P_{m,j,t}^{z} Y_{m,j,t}^{z}\, dj \tag{2.30}$$

the retail firm sets its optimal demand for wholesale good j as:

$$Y_{m,j,t}^{z} = \left(\frac{P_{m,t}^{z}}{P_{m,j,t}^{z}}\right)^{\eta_m} Y_{m,t}^{z}. \tag{2.31}$$

2.2.3 Prices and inflation

2.2.3.1 Price setting by urban firms

The urban firms set price in Calvo fashion, with probability $(1 - \gamma_m)$ that each period price will be set optimally at $P_{m,t}^{*}$ and if the price is not re-optimized, it is kept as was in the previous period.[25] Each retail producer's objective is to choose a price that maximizes discounted real profits, defined by equation (2.32), subject to the demand equation number (2.31).

[25] The optimizing firms are also referred to as forward looking, and those carrying over last period price to the present are referred to as backward looking firms (Senbeta, 2011).

$$\mathbb{E}_t \sum_{i=0}^{\infty} \gamma_m^i \, \Lambda_{t,t+i} Y_{m,j,t+i}^z \left[P_{m,j,t}^* - P_{t+i} MC_{m,j,t+i}\right] \tag{2.32}$$

where $\Lambda_{t,t+i} = \beta^i \left(\frac{C_{t+i}^z}{C_t^z}\right)^{-\sigma} \frac{P_t}{P_{t+i}}$ is stochastic discount factor and $Y_{m,j,t+i}$ is the output of firm j in period $t+i$.

The ratio of price chosen by price setting firms to aggregate price index becomes

$$\frac{P_{m,j,t}^*}{P_t} = \frac{\eta_m}{(\eta_m - 1)} \frac{\mathbb{E}_t \sum_{i=0}^{\infty} (\gamma_m \beta)^i \, \Lambda_{t,t+i} \left(\frac{P_{m,t+i}}{P_{m,t}}\right)^{\eta_m} MC_{m,j,t+i} Y_{m,t+i}^z}{\mathbb{E}_t \sum_{i=0}^{\infty} (\gamma_m \beta)^i \, \Lambda_{t,t+i} \frac{P_t}{P_{t+i}} \left(\frac{P_{m,t+i}}{P_{m,t}}\right)^{\eta_m} Y_{m,t+i}^z} \tag{2.33}$$

where γ_m is the share of urban firms that are able to set their price; $MC_{m,j,t}$ is the real marginal cost of producing manufactured good j; and $\left(\frac{\eta_m}{\eta_m - 1}\right)$ is a constant mark-up over the marginal cost.

2.2.3.2 Consumer price indices

The aggregate consumer price index P_t is defined as:

$$P_t = \left[\gamma \left(P_{l,t}\right)^{1-\eta} + (1-\gamma)\left(P_{m,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{2.34}$$

with the price index for flexible price goods $P_{l,t}$ being

$$P_{l,t} = \left[\gamma_z \left(P_{f,t}\right)^{1-\eta_z} + (1-\gamma_z)\left(P_{a,t}^{\mathrm{z}}\right)^{1-\eta_z}\right]^{\frac{1}{1-\eta_z}} \tag{2.35}$$

and the price index for sticky price goods $P_{m,t}$,

$$P_{m,t} = \left[\gamma_m \left(P_{m,t-1}\right)^{1-\eta_m} + (1-\gamma_m)\left(P_{m,t}^*\right)^{1-\eta_m}\right]^{\frac{1}{1-\eta_m}}. \tag{2.36}$$

The price index of the rural consumer basket P_t^{r}, is defined as:

$$P_t^{\mathrm{r}} = \left[\gamma\left(P_{f,t}\right)^{1-\eta} + (1-\gamma)\left(P_{m,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}. \quad (2.37)$$

2.2.3.3 Relative prices, wage-price ratios and inflation

The relative prices, wage-price ratios and inflation in this model are listed with their respective descriptions, in Table 2.1.

Table 2.1: Defining relative prices, wage-price ratios and inflations

$\frac{P_{l,t}}{P_t}$	The consumer price of rural produced goods relative to aggregate price index
$\frac{P_{m,t}}{P_t}$	The price of manufactured goods relative to aggregate price index
$\frac{P_{f,t}}{P_{l,t}}$	The price of farm goods relative to consumer price of rural produced goods
$\frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}}$	The consumer price of non-farm goods relative to consumer price of rural produced goods
$\frac{P_{a,t}^{\mathrm{z}}}{P_{a,t}}$	The consumer price of non-farm goods relative to their producer price
$\frac{P_{m,t-1}}{P_{m,t}} = \frac{1}{\Pi_{m,t}}$	The inverse of core inflation
$\frac{P_{m,t}^*}{P_{m,t}}$	The price chosen by manufacturing firm relative to the aggregate price of manufactured goods
$\frac{P_{f,t}}{P_t^{\mathrm{r}}}$	The price of farm goods relative to the price index of rural household consumer basket
$\frac{P_{m,t}}{P_t^{\mathrm{r}}}$	The aggregate price of manufactured goods relative to the price index of rural household consumer basket
$\frac{P_{m,t}^*}{P_t} = \frac{P_{m,t}^*}{P_{m,t}}\frac{P_{m,t}}{P_t}$	The price chosen by manufacturing firm relative to aggregate price index
$\Pi_t = \frac{P_t}{P_{t-1}}$	Gross headline inflation: the ratio of aggregate price index of period t to the index of period $t-1$.
$\Pi_{m,t} = \frac{P_{m,t}}{P_{m,t-1}}$	Gross core inflation: the ratio of the price of manufactured goods in period t to the index of period $t-1$.

$\frac{W_t^{\mathrm{r}}}{P_{f,t}} = \frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}}\frac{P_t^{\mathrm{r}}}{P_{f,t}}$	The ratio of rural wage to the price index of the rural consumption basket
$\frac{W_t^{\mathrm{z}}}{P_{m,t}} = \frac{W_t^{\mathrm{z}}}{P_t}\frac{P_t}{P_{m,t}}$	The ratio of urban wage to aggregate price index

Relationship between headline inflation and core inflation

$$\Pi_t = \Pi_{m,t}\frac{P_t}{P_{m,t}}\frac{P_{m,t-1}}{P_{t-1}} \tag{2.38}$$

2.2.4 Monetary policy

The central banks of Tanzania, Kenya and Uganda have historically used money supply rule (MSR) in their monetary policy frameworks. They have employed reserve money as their monetary policy operational target, for the most part of their market based monetary policy history. This framework relies on the assumptions that there is a stable and/or predictable relationship between reserve money and broad money supply, which serves as an intermediate target. It also assumes a stable or predictable relationship between broad money supply and inflation—the ultimate objective of monetary policy. Developments in the financial sector including financial innovations resulted in a growing uncertainty in these assumptions, and in response, these countries have migrated into interest rate rule (IRR) based frameworks. The Bank of Uganda was the first to adopt IRR in 2011, followed by the Central Bank of Kenya in 2023 (Central Bank of Kenya, 2023; International Monetary Fund, 2011). The Bank of Tanzania adopted IRR in January 2024 (Bank of Tanzania, 2024). In recognition of these developments we apply both policy rules. We define the IRR as:

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_i \log\left(\frac{R_{t-1}}{\bar{R}}\right) + \rho_\pi \log\left(\frac{\Pi_t}{\bar{\Pi}}\right) + \rho_y \log\left(\frac{Y_t}{\bar{Y}}\right) - \xi_{p,t}, \tag{2.39}$$

where ρ_i is the weight of interest rate smoothing; ρ_π is the weight of deviation of inflation from its target; ρ_y is the weight of output gap and $\xi_{p,t}$ is an AR(1) shock with constant variance.

As for the MSR, we define it as in Ascari and Ropele (2013):

$$\log(M_{g,t}) = m\rho_m \log(M_{g,t-1}) + \log(\overline{\Pi}) - m\rho_\pi \log\left(\frac{\Pi_t}{\overline{\overline{\Pi}}}\right) - m\rho_y \log\left(\frac{Y_t}{\overline{\overline{Y}}}\right) + \xi_{p,t}, \qquad \xi_{p,t} \sim i.i.d.\left(0, \sigma_{ap}^2\right) \tag{2.40}$$

where $M_{g,t}$ is growth rate of a monetary aggregate, $m\rho_m$ is a smoothing parameter for money supply growth, $m\rho_\pi$ is the inflation gap parameter and $m\rho_y$ is output gap parameter. Both rules are aimed at stabilizing the headline inflation, but they are referred to as flexible inflation targeting rules, as opposed to purely inflation targeting, because they take into account the need to close the output gap as well (Anand and Prasad, 2010). These rules can be changed into flexible core inflation targeting by changing the inflation term to $\log\left(\frac{\Pi_{m,t}}{\overline{\Pi}_m}\right)$. Core inflation is, in this model, defined as the rate of change of the price index of the manufactured goods. The choice of manufactured price index for measurement of core inflation is premised on the argument that inflation is a monetary phenomenon and the suggestion, in literature, that a measure of inflation that excludes volatile components of the consumer basket such as food and energy is the most ideal measure of inflation (Wynne, 1999). In this model the price of rural produced goods, $P_{l,t}$, is fully flexible and thus more volatile, hence its exclusion in measuring core inflation.

Money supply is given by

$$M_{s,t} = M_{g,t} M_{s,t-1}, \tag{2.41}$$

and the clearing equation for the money market is given by

$$M_{s,t} = M_{h,t}. \tag{2.42}$$

2.2.5 Productivity process

Productivities for all goods are defined by stationary first order autoregressive process such that, that of farming firms $A_{f,t}$, is:

$$\log A_{f,t} = \rho_{af} \log A_{f,t-1} + \xi_{f,t}, \qquad \xi_{f,t} \sim \mathrm{i.i.d.}\left(0, \sigma_{af}^2\right), \tag{2.43}$$

where $\rho_{af} \in (0,1)$ is persistence of farming productivity shock; that of non-farm firms $A_{a,t}$, is:

$$\log A_{a,t} = \rho_{aa} \log A_{a,t-1} + \xi_{a,t}, \qquad \xi_{a,t} \sim \mathrm{i.i.d.}\,(0, \sigma_{aa}^2), \tag{2.44}$$

and that of manufactured goods $A_{m,t}$, is:

$$\log A_{m,t} = \rho_{am} \log A_{m,t-1} + \xi_{m,t}, \qquad \xi_{m,t} \sim \mathrm{i.i.d.}\,(0, \sigma_{am}^2). \tag{2.45}$$

The parameters and variables in the non-farm and manufacturing productivity equations take respectively, definitions that correspond to those of the farming industry.

2.2.6 Clearing equations

Rural labour supplied N_t^r is aggregated as

$$N_t^r = N_{f,t}^r + N_{a,t}^r, \tag{2.46}$$

while production and consumption of farm goods are cleared by

$$\lambda Y_{f,t}^r = \lambda C_{f,t}^{rr} + C_{f,t}^{zz}, \tag{2.47}$$

production and consumption of non-farm goods by

$$\lambda Y_{a,t}^r = C_{a,t}^{zz}, \tag{2.48}$$

and production and consumption of manufactured goods by

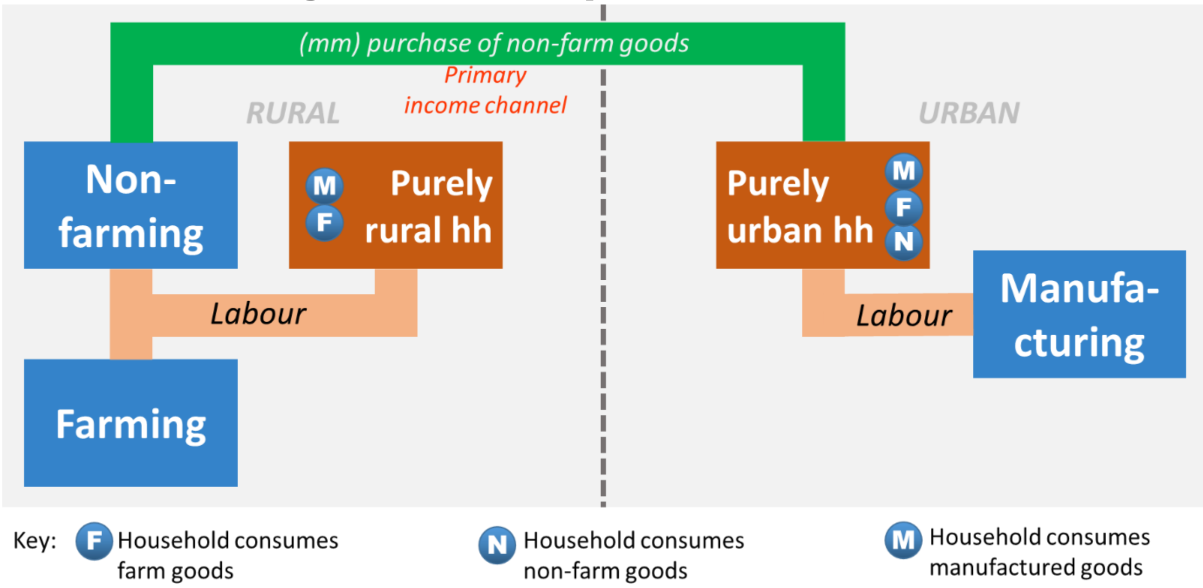
$$Y_{m,t}^z = \lambda C_{m,t}^{rr} + C_{m,t}^{zz}. \tag{2.49}$$

Total output is obtained by aggregating output of individual goods as:

$$Y_t = C_t = \lambda\left(\frac{P_{f,t}}{P_t}Y_{f,t}^r + \frac{P_{a,t}^z}{P_t}Y_{a,t}^r\right) + \frac{P_{m,t}}{P_t}Y_{m,t}^z. \tag{2.50}$$

In summary, Model 1 IRR version, has 45 endogenous variables presented in Table 2A1 and 46 independent endogenous equations, presented in the Table 2A3. As for the MSR version, the number of endogenous variables and equations increase to 48 because in this version, there is urban household demand for money condition, and money market clearing equation. Figure 2.1 presents the model schematically.

Figure 2.1: Schematic presentation of Model 1



The route through which mobile money flows is marked (mm).

The primary income channel works through the value of non-farm goods purchased by the purely urban household.

2.3 Calibration of parameters for Model 1 baseline scenario

The calibration exercise seeks to relate the model parameters and/or its results with the stylized facts of the economies we are interested in, as well as maintaining theoretical consistency (Senbeta, 2011; Stähler and Thomas, 2012). Two approaches are commonly used in literature: one is to estimate the parameters from the actual data of the economies concerned and two, is to borrow them from economies that have similarities with the one(s) modelled. In DSGE modelling it is common to use both approaches, and that is what has been used in this work.

The time frequency used is quarterly, and the baseline scenario is assumed to represent the economy before introduction of improved payment technology—mobile money. To determine the baseline cost of sending money, we turn to the study by Comninos *et al*. (2008), where the cost of sending 1,000 Kenyan shillings (KES 1,000 equivalent to USD 14), through Western Union was reported to be 50 per cent of the value sent in 2008. Another related study by Sander (2004) observed that the cost of sending equivalent of USD 10 in East Africa, through official money transfer services, ranged from 20 per cent to 30 per cent of the value sent. The author also observed that informal means such as courier services provided by buses, and traveling friends and relatives offered such services at relatively lower cost. With this in mind, we consider two more factors. First, is the presence of undisclosed costs of collecting money from formal service providers. Formal providers of money transfer services like post office, banks and Western Union are commonly located in urban areas where typical rural recipients of money transfers have to incur costs in terms of traveling fare and time, queuing time and other inconveniences such as obtaining official identification. Second, are the risks of theft and unreliability involved in using informal means. These also work as additional, non-monetary cost of using traditional money transfer services. On account of the foregoing, we consider all traditional means as costing higher than their declared price and, thus, we take an adjusted value of $\mu = 0.3$, (i.e. 30 per cent of the value sent) as our baseline cost of sending money. Considering that the average value of mobile money transaction is small, about TZS 30,000 or USD 14 in Tanzania in 2022, it is arguable that the cost of sending money using the traditional means would have been prohibitive, for small amounts. This is in agreement with the observation by Morawczynski and Pickens (2009), and Aker and Blumenstock (2015), that after introduction of mobile money, the average amount of money transfer per transaction dropped, but the total amount remitted became higher because of increase in the frequency of transactions.

For the mobile money scenario, we reduce the cost to $\mu = 0.05$. This is obtained from the average of the cost of transferring TZS 30,000 by Tanzania Vodacom M-Pesa and Tigo-Pesa in 2021/22, which was 0.013 of the value transferred, if the recipient was a registered customer and 0.088, if the recipient was an unregistered customer. Vodacom and Tigo accounted for 58 per cent of the mobile network operators market in Tanzania in 2022 (Tanzania

Communications Regulatory Authority, 2022). The computation of the value of μ for the mobile money scenario is summarized in Table D1.

To set the share of flexible price goods in the consumption basket, two considerations have been made. First, the shares of food and non-alcoholic beverages in Tanzania (28 per cent), Kenya (36 per cent), and Uganda (28 per cent) have been used to set $\gamma = 0.3$ (Bank of Tanzania, 2021; KIPPRA, 2020; Uganda Bureau of Statistics, 2021). Second, estimating the elasticities of substitution between flexible price goods and sticky price goods requires historical data on production, disaggregated enough to distinguish rural farm and non-farm goods, and/or detailed CPI historical data to establish the extent to which household consumption of farm and non-farm goods has changed, following the introduction of mobile money. Such data though, is not readily available and therefore a different approach has been used, guided by the need to replicate three facts. One is to keep the share of food in the overall consumption basket around its actual level of 30 per cent. Two is to produce a share of GDP transacted in mobile money that is close to the observed share of mobile money in transactions balances in Tanzania (7 per cent); and three is to produce a stronger growth of rural non-farming activity, after the introduction of mobile money, as observed by Sekabira and Quaim (2017), and Suri and Jack (2016). These facts have been closely replicated by setting the elasticity of substitution between flexible price goods and sticky price goods at $\eta = 5$, coupled with the share of farm goods, in the urban household sub-utility at $\gamma_z = 0.5$, and the elasticity of substitution between farm and non-farm goods at $\eta_z = 0.5$.[26]

Assumption of an annual real interest rate of 4 per cent is used to set the discount factor at 0.9902. Besides being widely used in literature, this rate also matches Tanzania's real 12-month deposit rate for 2022/23 (Bank of Tanzania, 2023). The number of households in the rural sector is set to account for two thirds of all households in the economy as in AW. This matches the share of rural population in Tanzania, which was 66 per cent in 2017 (Figure A4). It is also in line with the argument about existence of higher levels of credit constrained consumers in the emerging economies, discussed earlier. The inverse of Frisch elasticity of labour supplied

[26] The alternative for setting the value of elasticity of substitution between flexible price and sticky price goods would be to borrow it from AW (η=0.6). This however, produces much smaller values for the targeted shares. The share of farm goods in the consumption basket becomes 12 per cent instead of 30 per cent, while the share of GDP transacted in mobile money becomes 5 per cent instead of 7 per cent. As far as we know, our model is the first to have two industries in the rural sector, with urban household sub-utility for rural produced goods. It is therefore, not easy to find comparable values for parameters γ_z and η_z, in the literature.

is kept at $\psi = 10$ as in AW. Likewise, the inverse of the elasticity of intertemporal substitution is set at $\sigma = 2$ as in AW and Can *et al.* (2021). The weight of output gap in the interest rate rule is set at $\rho_y = 1$, while that of inflation is set at $\rho_\pi = 2$ as in AW, signifying the primacy of price stabilization in the central bank objective. Similar policy rule parameters are used under MSR. The persistence of productivity shock in both farming and non-farming industries is set at $\rho_{aa} = \rho_{af} = 0.75$, same as that of food sector in AW and fairly high, in line with the findings by Walsh (2011) that persistence in food inflation was higher compared to non-food inflation, particularly in lower-income countries. On assumption that shocks in the non-farming industry might last less than those of farming, partly because the non-farming is not susceptible to prolonged factors, such as those associated with climate change, a lower value of non-farming persistence $\rho_{aa} = 0.5$ is also tested. The persistence of farming supports targeting headline inflation, since if the shocks were short-lived in farming, they would not be worthy of a policy reaction. The persistence of manufacturing productivity shock is kept at $\rho_{am} = 0.95$ as in AW. For the household money demand, the marginal elasticity of demand for money is set at $\upsilon = 20$, with a view to replicate the ratio of GDP to money close to those found in data.[27] The parameters of Model 1 and their calibrated baseline values are shown in Table 2A2.

2.4 Simulations and results

2.4.1 Simulations

The simulations are carried out in two scenarios: first is the calibrated scenario of high payment friction and second, is the alternative scenario, where the transaction fees parameter is reduced to $\mu = 0.05$. We henceforth refer to the high payment friction scenario as baseline scenario and the reduced payment friction scenario as the mobile money scenario. We apply one-time positive productivity shock to production of each of the three goods and examine the impulse response of selected variables. We simulate the model over a period of 20 quarters for farm and non-farm goods shocks and a period of 80 quarters for manufacturing productivity shock. These periods correspond to the time it takes for the impact of shocks in respective industries to die out. Our interest is to analyse the behaviour of production, household labour supply, consumption, welfare, relative prices and wages, and inflation and interest rate. In the next

[27] The ratio of GDP to money (a measure of income velocity of circulation) produced by this parameter value is 2.3, which is close to actual average of 2.5 for Kenya.

section, we discuss the results of the simulations, beginning with comparison of steady-state values of the selected variables between the two scenarios. Thereafter, we discuss the impulse response functions of the selected variables for each of the three shocks applied in the context of the two payment friction scenarios. Please note that for easy of presentation, we use m-money to represent mobile money in the results tables.

2.4.2 Steady state results

Introduction of mobile money leads to a steady state increase in the aggregate real GDP by 0.4 per cent, almost entirely driven by non-farm goods, which grow by 19.7 per cent in real terms, against a drop of 4 per cent in the farming output (Table 2.2). By cutting down the money transfer fees, mobile money reduces the consumer price of non-farm goods by 12.1 per cent, which is sufficiently large to more than offset the impact of the price of farm goods that increase by 8.8 per cent. As a result, the combined price of rural produced goods declines by 2.6 per cent, thus raising the demand for these goods by the urban households. Within the rural, labour migrates from farming to non-farming, where it gets higher remuneration. The increase in the price of farm goods exceeds that of manufactured goods, leading to higher demand for manufactured goods from the rural household, which helps to increase the volume of manufactured goods produced by 1.47 per cent. Thus mobile money increases the trade volume between the two sectors, with the urban households demanding more from the rural and rural demanding more from the urban.

It is worth noting how the drop in the price of non-farm goods keeps the increase in the consumer price of non-farm goods at 5.17 per cent, far below its increase of 30.21 per cent at producer price. This makes the increase of rural output at factor cost higher than the increase of urban output. Labour income increases by 8.43 per cent in the rural, while increasing by 5.07 per cent in the urban. This helps to show that the primary income channel delivers the benefits of mobile money to all rural households by raising equilibrium wage there. The model, therefore, shows that as long as there are goods and services produced in the rural and paid for by using distant payment technology by the urban households, mobile money will drive their demand up, and all rural households will experience higher increase in their primary income, implying that the effect of mobile money through the primary income channel is more inclusive. The zero transaction cost column in Table 2.2 shows that production changes in the same direction as it does between the baseline and the mobile money scenario. As expected, the ratio of the value of GDP at consumer price to GDP at producer price exceeds 1 when transaction cost is positive. This ratio drops with transaction cost and becomes 1 when transaction cost becomes zero.

Table 2.2: Production, all firms

Item	Transaction scenario			Change	
	Baseline	M-money	Zero Cost	Baseline to M-money	Baseline to Zero cost
Constant steady state prices [a]					
GDP	1.4315	1.4368	1.4385	0.37%	0.49%
Rural total	0.8628	0.8598	0.8591	-0.35%	-0.43%
Farming	0.7285	0.6991	0.6922	-4.04%	-4.98%
Non-farming	0.1343	0.1607	0.1668	19.67%	24.26%
Manufacturing	0.5687	0.5770	0.5794	1.47%	1.89%
Current consumer price [b]					
GDP	1.4717	1.5417	1.5578	4.76%	5.85%
Rural total	0.9031	0.9442	0.9527	4.56%	5.50%
Farming	0.7285	0.7607	0.7677	4.41%	5.38%
Non-farming	0.1745	0.1836	0.1850	5.17%	6.00%
Manufacturing	0.5687	0.5975	0.6051	5.07%	6.40%
Current factor cost					
GDP	1.4315	1.5330	1.5578	7.09%	8.82%
Rural total	0.8628	0.9355	0.9527	8.43%	10.42%
Non-farming	0.1343	0.1748	0.1850	30.21%	37.80%
Ratio GDP at consumer price to GDP at factor cost	1.0281	1.0057	1.0000	-2.18%	-2.74%

[a] Under the constant steady state price, all quantities a converted to values using their respective steady state prices.
[b] Under the current price, all quantities are converted to values using the prices of the scenario in which the quantity belongs.

Although labour increases by 19.67 per cent in non-farming, the steady state aggregate labour used in the rural declines by 0.35 per cent, because more leaves farming than that which joins non-farming (Table 2.4). Note that the 4.04 per cent drop in farming labour more than offsets the increase in the non-farming industry because farming is way larger compared to non-farming. Labour increases by 1.47 per cent in manufacturing. Consistent with the higher rural income gain, the value of consumption increases more in the rural than in the urban (Table 2.5). Mobile money narrows the rural-urban income by boosting the rural non-farming industry, consistent with the findings by Newman and Canagarajah (2000), that the increase in rural non-farm activity was related to reduction in poverty levels in Ghana and Uganda. It also conforms with the findings that associated mobile money with growth of non-farm activity in Kenya and Uganda (Sekabira and Qaim, 2017; Suri and Jack, 2016).

Table 2.3: Generation of primary income

Item	Baseline	M-money	Change
GDP income side	0.5887	0.6167	4.76%
Rural firms	0.4314	0.4677	8.43%
Farm goods	0.3643	0.3803	4.41%
Non-farm goods	0.0671	0.0874	30.21%
Urban firms	0.5687	0.5975	5.08%
Manufacturing paid to labour	0.5118	0.5378	5.07%
Manufacturing dividends	0.0569	0.0598	5.10%

Table 2.4: Labour supplied from households and in firms

Item	Baseline	M-money	Change
Labour from households			
Rural household quantity	0.5717	0.5697	-0.35%
Urban household quantity	0.5125	0.5201	1.47%
Rural household value	0.4314	0.4677	8.43%
Urban household value	0.5118	0.5378	5.07%
Labour in firms			
Farming quantity	0.4827	0.4632	-4.04%
Non-farming quantity	0.0890	0.1065	19.67%
Manufacturing quantity	0.5125	0.5201	1.47%
Farming value	0.3643	0.3803	4.41%
Non-farming value	0.0671	0.0874	30.21%
Manufacturing value	0.5118	0.5378	5.07%

Within the rural produced goods consumed by the urban households, the non-farm goods increase by a noticeably larger percentage compared to farm goods. Introduction of mobile money, therefore, results in a broad based increase in consumption, that benefits both the urban and the rural, with the rural households taking larger part of that increase.

Table 2.6 also shows that relative wage in the urban changes by 3.55 per cent, same rate as the relative price of manufactured goods, while in the rural relative wage changes by 8.81 per cent, same rate as relative price of farm goods, because the price of farm goods is not affected by the payment friction. The relative wage in the urban is less than the relative price of manufactured goods by amount equal to the monopolistic mark-up. In the rural though, the wage equals the cost of producing farm and non-farm goods, which is in turn equal to the relative consumer price of farm goods. Through the primary income channel, mobile money closes the gap between the consumer price of farm goods and that of non-farm goods by simultaneously lowering the price of non-farm goods and rising the price of farm goods. The primary income channel, therefore, helps to show that mobile money benefits households in both sectors. It raises the wage for the rural households and make rural goods cheaper for the urban households. Nonetheless, because the urban wage increase by much smaller rate than that of rural, the purchasing power of the urban household drops relative to that of rural household, thus causing the urban household to supply more labour. In welfare terms, the increase in urban household labour offsets its gain from the consumption side. The welfare increase in the rural is however sufficiently large to make the aggregate welfare results of introducing mobile money positive. Thus mobile money increases welfare in our model economy while redistributing it in favour of the rural sector (Table 2.7).

Table 2.5: Consumption – quantities and values

Item	Baseline	M-money	Change
Farm goods quantity	0.3218	0.3088	-4.04%
Rural household	0.3813	0.3541	-7.12%
Urban household	0.2029	0.2182	7.54%
Farm goods value	0.2428	0.2536	4.41%
Rural household	0.2877	0.2908	1.06%
Urban household	0.1531	0.1791	17.01%
Non-farm goods quantity			
Urban household	0.1779	0.2129	19.67%
Non-farm goods value			
At consumer price	0.1746	0.1836	5.17%
At producer price	0.1343	0.1748	30.21%
Manufactured goods quantity	0.1708	0.1734	1.47%
Rural household	0.1295	0.1540	18.95%
Urban household	0.2535	0.2120	-16.39%
Manufactured goods value	0.1896	0.1992	5.07%
Rural household	0.1437	0.1770	23.17%
Urban household	0.2813	0.2435	-13.42%
Aggregation value			
Rural household	0.4314	0.4677	8.42%
Urban household	0.5687	0.5975	5.07%

Table 2.6: Relative prices and wages

Item	Baseline	M-money	Change
Prices			
Rural household basket	0.9289	0.9752	4.98%
Rural produced goods	0.8641	0.8415	-2.62%
Farm goods	0.7546	0.8211	8.81%
Non-farm goods	0.9810	0.8622	-12.12%
Manufactured goods	1.1095	1.1489	3.55%
Urban household basket	1.0000	1.0000	0.00%
Wages per unit of labour			
Rural households	0.7546	0.8211	8.81%
Urban households	0.9985	1.0340	3.55%

Table 2.7: Lifetime welfare

	Change
Aggregate	0.64%
Rural household	1.42%
Urban household	-1.39%

2.4.3 Impulse response results

In this section we discuss the impulse response results, based on 2 standard deviations positive shock, applied to each industry's productivity process, under the two payment scenarios, with particular interest on how endogenous variables are impacted by the presence of mobile money. We focus on a selected set of variables, namely production, consumption, welfare, relative prices and wages, inflation and interest rate. The selected impulse response graphs are presented in Appendix C. The graphs are presented in pairs such that those produced under the IRR can be easily compared with those produced under the MSR. It turns out that most of endogenous variables respond to shocks in qualitatively similar way under the two policy rules. This similarity can be explained by the fact that both rules prescribe policy on the basis of common information about the shocks hitting the economy. In line with observation made by Anand and Prasad (2010), that targeting core inflation in the presence of credit-constrained consumers does not maximize welfare, we keep headline inflation as our primary monetary policy target. For the sake of clarity, the main part of the discussion of impulse responses will be based on IRR and headline inflation targeting. The areas of difference between the policy rules and policy targets will be discussed under the monetary policy section.

2.4.3.1 Farming productivity shock

Production and generation of primary income

The value of total GDP responds with an increase to farming productivity shock, driven solely by the value of farm goods, as the values of non-farm and manufactured goods produced decline (Figure C1A). The three variables converge monotonically to their corresponding steady-state levels afterwards. The decrease in the value of non-farm goods produced is explained by the fact that, higher productivity in the farming industry makes labour in farming more remunerating compared to the non-farm goods industry and, therefore, the rural labour is reallocated in favour of farming (Figure C1D). The higher remuneration in farming is explained by the domination of quantity produced over the drop in the price of farm goods, induced by higher supply. Given the labour mobility between farming and non-farming, adjustment to this shock involves relatively large increase in the price of non-farm goods in a bid to retain labour in the non-farming industry, which translates to relatively larger increase in rural wages, compared to other shocks.

It is worth noting that in aggregate, the labour supplied in the rural declines in response to farming productivity shock (Figure C1D), because the increase in rural income arising from this shock allows rural households to reduce the aggregate amount of labour hours supplied, without suffering loss in consumption. Indeed, rural labour declines in both firms, but more is retained in farming than in non-farming.

The value of manufactured goods produced declines in response to farming productivity shock, because the substitution of cheaper farm goods for manufactured goods by the rural households drives down the relative price of manufactured goods sufficiently (Figure C1F) to dominate the near neutral response in the volume of manufactured goods produced (Figure C1D).[28] Accordingly, wage in manufacturing responds with a decline to the farming shock. Meanwhile, the shrinkage in the production of non-farm goods drives their relative price sufficiently up, to the extent of offsetting the decline in the relative price of farm goods and thus causing a marginal increase in the aggregate price of rural produced goods (Figure C1F).

[28] In this model the quantity produced is equal to the quantity of labour employed unless there is productivity shock.

If this shock occurs under the mobile money scenario, the increase in the aggregate value of goods produced is amplified, all due to higher increase in the value of rural produced goods, that outweighs a marginally larger decline in the value of manufactured goods (Figure C1A). Within the rural sector, the larger increase in the value of output is contributed by the value of farm goods that increase by more, and the value of non-farm goods that decline by less (when measured at consumer price). The larger increase in the value of farm goods happens on account of smaller decrease in the quantity produced (Figure C1D) as the rural sector retains more labour in farming. This up shift in the quantity of farm goods produced offsets a slightly larger drop in their relative price (Figure C1F). These developments sum up into a larger increase in rural wages, when the farming shock occurs in the context of mobile money.[29]

The value of manufactured goods produced decline more, under the mobile money scenario, because the urban households face lower cost of their consumption basket and, therefore, are able to supply less labour, without compromising their consumption (Figure C1D). The lower cost of urban household consumption comes from less increase in the price for rural produced goods and a marginally larger decline in the price of manufactured goods.

Occurrence of farming productivity shock in the context of mobile money, therefore, shifts up the production of farm goods, while lowering production of both non-farm and manufactured goods. This outcome is driven by the dominance of farming productivity in the factors determining labour allocation in the rural and aggregate output. It exemplifies a case of pent-up supply potential (in farming) that is released first, at any increase in aggregate demand. Although the increase in demand in this case is driven by decline in the price of non-farm goods, the supply response is disproportionally larger in farm goods production. It also suggests that the increase in farming employment that has been associated with mobile money in Kenya, could as well be explained through the primary income channel (Mbiti and Weil 2016; Plyler *et al*. 2010).

[29] Although the farming shock causes larger quantity of rural labour to be reallocated in favour of farming activity under mobile money scenario, this reallocation occurs on already elevated steady state labour supply in the non-farm goods industry, which translates to lower percentage decline of labour under the mobile money scenario. This also helps to explain the reduced decline in the value of non-farm goods.

Consumption and welfare

In line with increase in the value of total output produced, farming productivity shock increases the aggregate value of consumption, but at sectoral level, a notable increase occurs in the rural, while the urban households realize marginal decline (Figure C1C). This also reflects the sectoral response of the primary incomes to the farming shock. The rural households benefit from decline in both the prices of farm and manufactured goods (Figure C1F). As for urban households, the decline in consumption, arise from the price of non-farm goods that increases so much to the extent of cancelling out the gain from the declining prices of farm and manufactured goods.[30]

The presence of mobile money raises the response of the total value of consumption, which is mostly experienced by the rural household, as the urban consumption does not show discernible difference between the scenarios (Figure C1C). Within the urban household's basket, more expenditure is made on non-farm goods and less on farm and manufactured goods, when mobile money is present. The larger increase in rural consumption is again in agreement with the higher increase in the value of goods produced under the mobile money scenario (Figure C1A).

Regarding welfare, on aggregate it responds with an increase to the farming productivity shock, but at sectoral level, the increase occurs in the rural only, with the urban households realising a relatively marginal decline (Figure C1C). This loss of the urban household's welfare is consistent with the fact that it has to supply more labour, from the second quarter, in order to recover the loss in its consumption (Figure C1D). Mobile money appears to reallocate the response of welfare in favour of the urban household, but the difference is visually minor.

2.4.3.2 Non-farming productivity shock

Production and generation of primary income

Two values of persistence of non-farming productivity shock (0.75 and 0.5) were tested as explained under the calibrations section. Results arising from these persistence values did not reveal notable difference in the response of the variables of interest. In this section, we discuss

[30] Since the urban household consumption basket is taken as a numeraire, its price remains constant.

the results arising from the higher value of persistence. Figure C2A shows that, a positive productivity shock in the non-farming industry is received with an increase in the value of all goods produced. The shock draws labour from farming into non-farming industry for the reason of higher remuneration, causing a decrease in the quantity of farm goods produced (Figure C2D). Meanwhile, the price of farm goods registers a more than offsetting increase (Figure C2F), thus leading to an increase in the value of farm goods produced. Similar response occurs in manufactured goods, where the volume produced declines, but the price increases by a larger magnitude, leading to increase in the value of manufactured output. Like in the case of farming productivity shock, the shock in non-farming results in decline in total labour supplied in the rural. However, owing to more than offsetting increase in wage, labour income responds with an increase in the rural. Urban wage responds to the shock with a positive deviation first, followed by a drop to the negative side before converging to steady state. This combined with a small drop in urban labour supply causes the labour income to respond by jumping above its steady state first then dropping to the negative in quarter 2 and converge to steady state afterwards (Figure C2D).

If this shock occurs under the mobile money scenario, the value of manufactured goods produced increases by noticeably more, while the value of rural produced goods at consumer’s price increase by marginally less. Despite the marginal decrease in the value of total rural production, individual rural produced goods respond differently under the mobile money scenario. The decline in production of farm goods is weakened, while on the side of non-farm goods the increase is enhanced. The higher increase in production of non-farm goods mirrors the higher consumption of those goods in the urban. If measured at factor cost, the value of rural output increases by more under the mobile money scenario, implying that the primary income in the rural responds with a larger increase if the shock hits when mobile money is present.

As for the urban, the larger increase in the value of manufactured goods is driven by both the volume produced, which registers a smaller decline, and the relative price, which responds with larger increase to non-farming productivity shock, when mobile money is present. In line with the value of manufactured goods, the response of urban labour income is affected positively by mobile money. Non-farming productivity shock in the context of mobile money, therefore, enhances the value of output and income in both sectors.

Consumption and welfare

Regarding consumption, both rural and urban households experience increase from the productivity shock in the non-farming industry, with most of the increase occurring in the rural (Figure C2C). If this shock occurs in the presence of mobile money the positive response of consumption in the rural is enhanced albeit marginally. Rural households consume more of farm goods, while the urban household consume more of non-farm goods. The changes in the response of individual goods consumed, due to the presence of mobile money seems to cancel out ending up with response in total household consumption and welfare, that is broadly similar across both payment scenarios.

2.4.3.3 Manufacturing productivity shock

Production and generation of primary income

The manufacturing productivity shock increases the total value of GDP, driven almost entirely by increase in the value of manufactured output. The value of rural output increases by a much smaller margin and it all comes from non-farm goods (Figure C3A). The rural allocates more labour into non-farm goods (Figure C3D), to meet relatively higher demand for those goods, thus reducing the value of farm goods produced. This is compatible with the increased purchasing power of the urban households, the sole consumers of non-farm goods. If this shock occurs under the mobile money scenario we see even larger rural labour reallocation into the production of non-farm goods, as demand for these goods rises more, in response to lower consumer price. Although the presence of mobile money appears to reduce the extent to which the value of rural output increases (when all production is measured at consumer price), if measured at factor cost we see larger increase (Figure C3B). Thus mobile money affects the response of rural income through non-farm goods positively, although this becomes largely offset by the negative effect that comes through farming goods. As in the previous two shocks, rural wage responds with an increase to manufacturing shock and mobile money enhances the increase (Figure C3G).

Consumption and welfare

Manufacturing productivity shock results in a broad based increase in consumption. All households respond with higher consumption, but most of it occurs in the urban sector (Figure C3C). The presence of mobile money does not seem to change the response of the value of consumption much. The shock increases welfare to both the rural and urban households, with the urban benefiting most. Under the mobile money scenario, aggregate welfare increases by marginally more, driven by a noticeably higher increase in the rural. It is noteworthy that the upward shift in rural welfare is driven by reduced labour supply (Figure C3D) rather than increased consumption.

2.4.3.4 Monetary policy issues

In this section we discuss the impulse responses of inflation and interest rate to productivity shocks, beginning with the farming shock. Next we discuss responses of selected endogenous variables to monetary policy shock.

Productivity shocks

The increase in supply of farm goods arising from the productivity shock in farming drives down headline inflation (Figure C1H). The decline in the price of farm goods relative to the price of manufactured goods reduces demand for manufactured goods, thus driving the core inflation down as well. The interest rate responds by jumping above its steady state level first and then drops below in period two, after which it converges to steady state gradually. The initial jump constitutes a response of policy to the change in the price of non-farm goods, which jumps above steady state first, then drops below in quarter 1, and thereafter converges to steady state smoothly. This is an outcome of having two labour sharing industries in the rural—not captured in standard models with single flexible price goods industry, and no labour mobility, like that of AW and Anand and Prasad (2010). This behaviour is observed when the policy target, i.e. the headline inflation, contains the price of non-farm goods. If the target is changed to core inflation though, the first jump in interest rate is eliminated, but this happens at the expense of increasing volatility in headline inflation (Figure C6). Targeting core inflation also increases stability in the response of manufacturing labour (and output) to farming shock.

In the mobile money scenario, the farming productivity shock delivers larger drop in headline inflation, for which the interest rate responds with larger drop too. A shock in the non-farm goods industry also causes decline in both headline and core inflation (Figure C2H), with interest rate being reduced to address the negative headline inflation gap. The decline in headline inflation becomes marginally larger if the shock occurs under the mobile money scenario, a behaviour similar to that observed under the farming shock. Accordingly, the interest rate is reduced more to stabilize inflation.

As for the manufacturing shock, the response of the headline inflation, core inflation and interest rate is negative as well (Figure C3H). In contrast to the preceding two shocks, the decline of the three variables due to manufacturing shock becomes less pronounced under the mobile money scenario, although the difference is small. This observation, viewed together with those of farming and non-farming productivity shocks suggests that, the payment friction in our model dampens the effect of the rural economy on headline inflation and thus, by easing it, we make the rural shocks more impactful. When the supply shock happens in the rural, under the mobile money scenario, it is the rural supply effect that is registered more strongly, thus enhancing the deflationary impact of the shock. On the other hand, when the supply shock happens in the urban, it elevates demand in the rural, and this elevated demand becomes even more impactful on inflation, under the mobile money scenario. This, therefore, dampens the deflationary effect of the positive manufacturing productivity shock.

The relative importance of the state of rural economy in the policy variables can also be viewed by assessing the relative weight of each shock in the variance of the policy variables (from the variance decomposition data), across the two payment scenarios. Table 2.8 presents the ratio of contribution of individual shocks to the variances of output, inflation and interest rate under the mobile money scenario, to their contribution under the baseline scenario. If the ratio exceeds 1, it means that the shock has more influence in the variance of the variable concerned, under the mobile money scenario than it has under the baseline scenario, and *vice versa*. As it can be seen, farming and non-farming shocks become more impactful on output and inflation under the mobile money scenario, than under the baseline scenario. At the same time, manufacturing shock becomes less impactful. As for interest rate farming shock appears to be neutral between the scenarios, but the non-farming shock becomes more impactful under mobile money scenario. This is in agreement with the fact that non-farm goods are the major player in the primary income channel, and thus a shock in that industry under the mobile money scenario, impacts the urban household—the sole consumer of this good—more heavily. By the virtue of being Ricardian, the urban household's behaviour transmits this shock more strongly to interest rate. In sum, the relative importance of the state of the rural economy in policy is enlarged under the mobile money scenario, consistent with the role played by mobile money in raising financial inclusion.

Table 2.8: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, under interest rate rule[31]

Item	Farming shock	Non-farming shock	Manufacturing shock	Policy shock
Output	1.301	1.100	0.964	1.000
Inflation	1.325	1.116	0.963	1.018
Interest rate	1.000	1.137	0.981	1.027

Monetary policy shock

We applied an expansionary monetary policy shock and observed that most of its impact falls on inflation. GDP responds with an increase, driven mostly by manufacturing and to a less extent non-farming. Owing to the forward looking behaviour of the agents, the price setting manufacturing firms become the strongest respondents to the monetary policy shock by increasing their price. This promotes production of manufactured goods, and accordingly, manufacturing hires more and urban wages increase (Figure C4A). Farming output, on the other side, responds with a drop, which in value terms is more than offset by the increase in non-farm goods. The aggregate value of rural output therefore, responds with an increase. The farming industry responds with a drop because labour in the rural gets reallocated in favour of non-farming. More labour leaves farming than that which is taken up by non-farming, leading to an overall drop in amount of labour supplied in the rural (Figure C4D). The change in favour of non-farm goods production is a reflection of the fact that the primary driver of production under this shock is the urban consumption, which responds with an increase. Total welfare responds to expansionary monetary policy shock with an increase, which occurs in the rural and urban under the baseline scenario (Figure C4C).

If the policy shock takes place under the mobile money scenario, income from non-farming responds with stronger increase, mirrored by a larger drop in farming income. The value of non-farm goods responds with a stronger increase both at factor and consumer price (Figure C4B). The decrease in rural labour supply becomes stronger under the mobile money scenario mirrored by larger increase in urban labour supply. This happens together with stronger response in inflation, as observed in the last column of Table 2.8, which again reflects the increased importance of the state of the rural economy to policy. Here the change in rural demand, due to expansionary monetary policy, exerts stronger upward pressure on inflation under the mobile money scenario.

[31] Corresponding results under MSR are presented in Table 2B1.

Consumption for both the rural and urban households respond with an increase to expansionary policy shock. The response of the rural household, however, is weaker relative to that of urban household, partly reflecting the urban household's sensitivity to interest rate and the larger increase in urban income. Within the urban, household consumption of all goods responds with an increase, while in the rural household consumption of manufactured goods increase and that of farm goods decrease. This implies that the trade volume between the rural and the urban responds to expansionary monetary policy shock, with an increase. If this shock occurs in the presence of mobile money, the increase in the household consumption become marginally stronger both in the rural and the urban (Figure C4C). The urban household consumption of rural produced goods becomes stronger, mirrored by stronger increase in the rural household consumption of manufactured goods. In other words, the trade volume between the two sectors responds with stronger increase under the mobile money scenario.

Total welfare responds with an increase in both scenarios. The rural household takes larger share of the welfare increase in both scenarios, with the urban household experiencing small increase in the baseline scenario and a small decrease in the mobile money scenario (Figures C4C). Mobile money therefore, reallocates the welfare benefits of expansionary monetary policy shock in favour of the rural households.

Policy options

In this section we highlight issues arising from the results of two sets of monetary policy options. First is comparison of MSR with IRR, and second is comparison of headline inflation targeting with core inflation targeting.

Money supply rule versus interest rate rule

As mentioned earlier, the impulse responses under the IRR and MSR, are qualitatively similar for most endogenous variables. The few responses that differ between the rules are summarized in Figure C5. These are the responses of the manufacturing industry, interest rate and inflation, to non-farming productivity shock. The initial response of policy to non-farming productivity shock under the MSR is strong enough to keep core inflation on a smooth path to its steady state level. Under IRR, on the other hand, policy prescription causes core inflation to drop in two steps to its minimum before returning to steady state. For this reason, inflation does not drop as much as it does under the MSR and therefore, IRR corrects the non-farming productivity shock with less volatility in the manufacturing output and inflation, than MSR. This happens whether monetary policy targets headline inflation or core inflation. Similar observation is made when the economy is hit by manufacturing and policy shocks. As for the farming shock, the differences between responses under MSR and IRR are not as discernible as they are for the other shocks. In sum, we observe that IRR performs better than MSR in terms of stabilization of inflation and output, particularly manufacturing output.[32]

Headline versus core inflation targeting

The performance of headline inflation targeting versus core inflation targeting is further evaluated on the basis of mean value of total welfare they produce. The results show that when core inflation targeting is applied, the welfare outcome is lower compared to if headline inflation targeting is applied. The difference in welfare between the two policy options is however very small (Table E1). Considering that only 33 per cent of households in Model 1 has access to the bond market, these results conform with the observation by Anand and Prasad (2010) that in an economy with high proportion of rule-of-thumb households, flexible headline inflation targeting becomes a welfare maximizing policy option.

2.4.4 Other observations

Since this model has been inspired by the model developed by AW, we complete this discussion by attempting to compare our results with those of AW's model. We begin by recalling the argument that remittance transactions are primarily driven by consumption smoothing motives between the sender and the recipient. Therefore, remittances represent redistribution of income, which helps to cushion the impact of the productivity shocks on consumption and labour supply across the households in the economy. This would imply that a model that is set up to analyse the effect of mobile money through transfers like the AW's model, would tend to produced relatively less volatile responses to productivity shocks than a model set up to analyse the effects through primary income. Table 2.9 presents a qualitative comparison of the impact of productivity shocks on selected variables between the AW's model and the current model. In

[32] This observation has to be taken with care though, because it may as well be rooted in the difference in the intensities of the policy prescriptions, rather than the difference in the policy frameworks.

this table we observe, as expected, that mobile money in the AW's model increases stability in the response of larger number of variables than in the current model, for all shocks.

Table 2.9: Qualitative comparison of AW's model with the current model for selected variables

	Mobile money over baseline for the current model and mobile money over restricted remittance for the AW model				
	AW model under food shock	Current model under farming shock	Current model under non-farm shock	AW model under non-food shock	Current Model under manufacturing shock
	How does mobile money affect the response				
Headline inflation	Dampens	Amplifies	Amplifies	Dampens	Dampens
Core inflation	Dampens	Amplifies	Amplifies	Dampens	Dampens
GDP	Dampens	Amplifies	Amplifies	Dampens	Neutral
Interest rate	Dampens	Amplifies	Amplifies	Dampens	Dampens
Rural consumption	Dampens	Amplifies	Amplifies	Dampens	Neutral
Urban consumption	Dampens	Amplifies	Amplifies	Amplifies	Neutral
Rural labour	Amplifies	Neutral	Dampens	Dampens	Amplifies
Urban labour	Dampens	Amplifies	Dampens	Dampens	Neutral

2.5 Conclusion

In this Chapter, we have built a benchmark new Keynesian DSGE model to analyse the impact of mobile money in emerging economies, through the primary income channel. We have characterized the modelled economy as a closed one, with two thirds of its households living in the rural and having no access to the bond market. The rest of the households live in the urban where they have access to bond market and, therefore, are able to optimize their welfare across time. Analysis of the role of mobile money in this economy has been made possible by making part of the goods produced in the rural—the non-farm goods—only consumed by the urban households and paid for directly using the existing distant payment technology. The rest of goods—the farm goods produced in the rural and manufactured goods produced in the urban—are traded in a frictionless market.

The prevailing distant payment service charge transaction fees, meaning that the price paid by the consumers of non-farm goods is higher than the amount received by the producers.

Introduction of mobile money represents improvement in the payment technology and, therefore, brings the consumer price closer to producer price, by reducing the fees. By altering the values of the transaction fees parameter, we have been able to predict the impact of mobile money on production, consumption, welfare and monetary policy. We have based our choice of baseline scenario transaction fees parameter on the study carried out by Comninos *et al*. (2008), to set its values at 30 per cent of the consumer price of non-farm goods. As for the mobile money scenario we have set the value at 5 per cent, based on Tanzania's M-Pesa and Tigo-Pesa tariffs in 2021/22.

Simulations have shown that, introduction of mobile money results in increase in steady state GDP, with the rural experiencing relatively larger increase in income, compared to the urban. The spread between the consumer and producer price of the rural produced goods at steady state is narrowed, manifesting as higher wages for the rural household and cheaper rural goods for the urban household. Consumption increases for all households, but the rural takes larger part. As for welfare, it responds with an increase in aggregate, while at the same time being redistributed such that the rural household experiences positive change and the urban household negative. The welfare experience by the urban household is explained by the relatively slower increase in the urban wage, which causes the urban household to supply more labour, with the rural household supplying less labour.

We then applied positive productivity shocks to each of the three goods produced in our model and analysed the results in two scenarios—the scenario with and without mobile money. We saw that, productivity shock in farming results in an increase in the value of GDP, driven solely by the quantity of farm goods produced. This shock drives rural income up, while the urban income responds with a decline. If the farming shock occurs under the mobile money scenario, the increase in the value of GDP becomes stronger on account of positive shift in the response of both farm and non-farm goods. Accordingly, the rural experiences stronger increase in both income and consumption, while the urban experiences larger decline. Thus mobile money increases output and consumption, while redistributing them in favour of the rural. In the case of welfare, the model has shown that the farming productivity shock increases the aggregate welfare, but as in the case of consumption, the benefit occurs in the rural. Mobile money helps to redistribute the benefits of the welfare gain, in favour of the urban, by marginally reducing the increase in the rural and dampening the loss in the urban.

In the case of productivity shock in the non-farming industry, the economy responds with a broad based increase in the aggregate production, with households in both sectors realizing increase in income and consumption. Mobile money enhances the increase in rural income and so it does to rural consumption. Regarding welfare, non-farming productivity shock leads to a broad based increase, with the urban receiving larger part of it. Manufacturing productivity shock also increases the aggregate output, which benefits consumption and welfare in all sectors, but most of the gain goes to the urban household. In the presence of mobile money, the shock delivers stronger increase in rural household welfare.

As for the monetary policy variables, the model predicts that headline inflation will respond with a decline to positive productivity shock in any of the three industries, under both payment scenarios. In line with the behaviour of inflation, interest rate responds to each of the shocks with a decline to boost demand and restore price stability. If the shock occurs in the context of mobile money, the response of inflation and interest rate to farming and non-farming shocks becomes stronger. The difference in the response to non-farming shock is not as discernible as that of farming shock partly because of the relative smallness of the non-farming industry. On the other hand, the response of inflation and interest rate to manufacturing productivity shock becomes marginally weaker under the mobile money scenario. These results suggest that mobile money integrates the rural economy more into the national economy, implying that policy authorities need to pay more attention to the state of rural economy under the mobile money scenario, relative to the baseline scenario.

Consistent with the observations under real shocks, mobile money strengthens the impact of monetary policy shock across the economy. This happens because the effect of the policy shock, on rural households' demand, exerts relatively more pressure on inflation. It also redistributes its welfare effect in favour of the rural sector. Regarding policy frameworks, we observed that whether the economy has mobile money or not, the IRR performs better than MSR in terms of stabilization of inflation and output, particularly manufacturing output. Likewise, headline inflation targeting produces higher level of welfare than core inflation targeting, under both payment scenarios.

This Chapter contributes to the existing literature in two major ways. First, while the AW's model tracks the impact of mobile money through the secondary income channel, our model tracks it through the primary income channel, which helps to show that mobile money benefits rural households, by raising the rural equilibrium wage relative to the urban wage. Mobile money also shifts up the response of rural income and consumption to positive productivity shock in any of the industries modelled. By impacting the rural primary income, the benefits of mobile money become accessible to all rural households evenly and, therefore, we can say that this channel is more inclusive. Second, both models divide the economy into rural and urban sectors, but our model goes a step further, to split the rural into two labour sharing sub-activities. This helps to capture the duality of rural activity in developing economies. Like the AW's model, our model predicts that introduction of mobile money will have overall positive benefits to the economy and that the rural will take disproportionately larger share of the benefits.

Chapter 2: Tables

Table 2A1: List of Model 1 variables

S/N	VARABLE	DESCRIPTION
1	C_t^r	Rural household total consumption
2	$C_{f,t}^r$	Rural household consumption of farm goods
3	$C_{m,t}^r$	Rural household consumption of manufactured goods
4	C_t^z	Urban household total consumption
5	$C_{l,t}^z$	Urban household consumption of rural produced goods
6	$C_{f,t}^z$	Urban household consumption of farm goods
7	$C_{a,t}^z$	Urban household consumption of non-farm goods
8	$C_{m,t}^z$	Urban household consumption of manufactured goods
9	N_t^r	Total labour in the rural
10	$N_{f,t}^r$	Labour in farming
11	$N_{a,t}^r$	Labour in non-farming
12	$N_{m,t}^z$	Labour in manufacturing
13	$\frac{P_{l,t}}{P_t}$	The consumer price of rural produced goods relative to aggregate price index
14	$\frac{P_{m,t}}{P_t}$	The price of manufactured goods relative to aggregate price index
15	$\frac{P_{a,t}^{\mathrm{z}}}{P_{a,t}}$	The consumer price of non-farm goods relative to their producer price
16	$\frac{P_{f,t}}{P_{l,t}}$	The price of farm goods relative to consumer price of rural produced goods
17	$\frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}}$	The consumer price of non-farm goods relative to consumer price of rural produced goods
18	$\frac{P_{f,t}}{P_t^{\mathrm{r}}}$	The price of farm goods relative to the price index of rural household consumer basket
19	$\frac{P_{m,t}}{P_t^{\mathrm{r}}}$	The aggregate price of manufactured goods relative to the price index of rural household consumer basket
20	$\frac{P_{m,t}^*}{P_{m,t}}$	The price chosen by manufacturing firm relative to the aggregate price of manufactured goods
21	$\frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}}$	The ratio of rural wage to the price index of the rural consumption basket
22	$\frac{W_t^{\mathrm{r}}}{P_{f,t}}$	The ratio of rural wage to the price of farm goods
23	$\frac{W_t^{\mathrm{r}}}{P_{a,t}}$	The ratio of rural wage to the price of non-farm goods
24	$\frac{W_t^{\mathrm{z}}}{P_t}$	The ratio of urban wage to aggregate price index

25	$\frac{W_t^z}{P_{m,t}}$	The ratio of urban wage to aggregate price index
26	Y_t,	Total GDP
27	$Y_{f,t}^r$,	Farm goods produced
28	$Y_{a,t}^r$	Non-farm goods produced
29	$Y_{m,t}^z$	Manufactured goods produced
30	Π_t	Gross headline inflation
31	$\Pi_{m,t}$	Gross core inflation
32	R_t	Interest rate
33	$A_{f,t}$	Productivity in farming
34	$A_{a,t}$	Productivity in non-farming
35	$A_{m,t}$	Productivity in manufacturing
36	$A_{p,t}$	Policy shock
37	za_t	Numerator for the manufactured relative price equation
38	zb_t,	Denominator for the manufactured relative price equation
39	$MC_{m,t}^z$	Marginal cost in manufacturing
40	v_t^r	Rural household lifetime welfare
41	v_t^z	Urban household lifetime welfare
42	v_t	Aggregate lifetime welfare
43	$Y_{fp,t}^r$	Value of farm goods in aggregate price terms
44	$Y_{ap,t}^r$	Value of non-farm goods in aggregate price terms
45	$Y_{mp,t}^z$	Value of manufactured goods in aggregate price terms
46	$M_{s,t}$	Money supply, only applicable under MSR
47	$M_{h,t}$	Money demand, only applicable under MSR
48	$M_{g,t}$	Growth of money, gross, only applicable under MSR

Table 2A2: List of Model 1 parameters

Notation	Value	Description
β	0.9902	Discount factor
γ	0.3	Share of flexible price goods in the consumer basket
γ_z	0.5	Share of non-farm goods in the flexible price goods part of the urban household consumer basket.
γ_m	0.5	Proportion of urban firms that keep the prices they set unchanged next period.

η	5	Elasticity of substitution between flexible price goods and sticky price goods
η_m	10	Elasticity of substitution between intermediate goods in manufacturing firms
η_z	0.5	Elasticity of substitution between farm goods and non-farm goods, in the urban household consumer basket
λ	2	The index of number of households in the rural sector
μ	0.3	Urban-rural payment transaction fees
$\overline{\Pi}$	1	Steady-state gross headline inflation
$\overline{\Pi}_m$	1	Steady-state gross core inflation
ρ_{af}	0.75	Persistence of productivity shock in farming industry
ρ_{aa}	0.5	Persistence of productivity shock in non-farming industry
ρ_{am}	0.95	Persistence of productivity shock in manufacturing
ρ_{ap}	0.9	Persistence of policy shock
ρ_i	0.7	Interest rate-smoothing term
$m\rho_m$	0.7	Money growth smoothing term
$\rho_\pi, m\rho_\pi$	2	Weight of inflation gap in the policy rule
$\rho_y, m\rho_y$	1	Weight of output gap in the policy rule
σ	2	Inverse of the elasticity of intertemporal substitution (risk aversion factor)
ϕ	20	Scaling factor on the disutility from labour supplied
ψ	10	Inverse of the Frisch elasticity of labour supplied
υ	20	Marginal elasticity of demand for real money balances, only applicable under MSR

Table 2A3: List of Model 1 equations programmed in Dynare 4.3.3

Model equations	Number

Rural household consumption

Rural aggregate consumption (budget constraint)

$$C_t^r = \frac{W_t^r}{P_t^r} N_t^r \qquad \text{M1}$$

Rural demand for *f*arm goods

$$C_{f,t}^r = \gamma \left(\frac{P_t^r}{P_{f,t}}\right)^{\eta} C_t^r \qquad \text{M2}$$

Rural demand for urban *m*anufactured goods

$$C_{m,t}^r = (1-\gamma)\left(\frac{P_t^r}{P_{m,t}}\right)^{\eta} C_t^r \qquad \text{M3}$$

Urban household consumption

Urban aggregate consumption, Euler equation

$$1 = \beta E_t \left[\left(\frac{C_{t+1}^z}{C_t^z}\right)^{-\sigma} \frac{R_t}{\Pi_{t+1}}\right] \qquad \text{M4}$$

Urban aggregate demand for flexible price goods

$$C_{l,t}^z = \gamma \left(\frac{P_t}{P_{l,t}}\right)^{\eta} C_t^z \qquad \text{M5}$$

Urban household demand for *m*anufactured goods

$$C_{m,t}^z = (1-\gamma)\left(\frac{P_t}{P_{m,t}}\right)^{\eta} C_t^z \qquad \text{M6}$$

Urban demand for *f*arm goods

$$C_{f,t}^z = \gamma_z \left(\frac{P_{l,t}}{P_{f,t}}\right)^{\eta_z} C_{l,t}^z \qquad \text{M7}$$

Urban demand for *non-farm* goods

$$C_{a,t}^z = (1-\gamma_z)\left(\frac{P_{l,t}}{P_{a,t}}\right)^{\eta_z} C_{l,t}^z \qquad \text{M8}$$

Urban household money demand condition

Note: Equation (M8b) is only applicable under the money supply rule (MSR)

$$\frac{C_t^z}{m^v} = -\frac{1 - R_t}{R_t} \quad \text{M8b}$$

Labour supplied

Rural labour supplied

$$\frac{W_t^r}{P_t^r} = \phi \frac{(N_t^{rr})^{\psi}}{(C_t^{rr})^{-\sigma}} \quad \text{M9}$$

Urban labour supplied to firm j

$$\frac{W_{m,t}^z}{P_t} = \phi \frac{\left(N_{m,j,t}^{zz}\right)^{\psi}}{(C_t^{zz})^{-\sigma}} \quad \text{M10}$$

Demand for labour in farming firms

$$P_{f,t} = \frac{W_t^r}{A_{f,t}} \quad \text{M11}$$

Demand for labour in non-farm firms

$$P_{a,t} = \frac{W_t^r}{A_{a,t}} \quad \text{M12}$$

Demand for labour in manufacturing firms, real marginal cost

$$MC_{m,t}^z = \frac{W_t^z}{P_{m,t} A_{m,t}} \quad \text{M13}$$

Price setting by manufacturing firms

Numerator for the manufactured relative price equation (16)

$$za_t = MC_t Y_{m,t}^z + (\gamma_m \beta) \left(\frac{C_{m,t+1}}{C_{m,t}}\right)^{-\sigma} \left(\frac{1}{\Pi_{m,t+1}}\right)^{-\eta_m} za_{t+1} \quad \text{M14}$$

Denominator for the manufactured relative price equation (16)

$$zb_t = Y_{m,t}^z + (\gamma_m \beta) \left(\frac{C_{m,t+1}}{C_{m,t}}\right)^{-\sigma} \left(\frac{1}{\Pi_{m,t+1}}\right)^{-\eta_m} \frac{1}{\Pi_{t+1}} zb_{t+1} \quad \text{M15}$$

Manufactured goods price setting

$$\frac{P_{m,t}^{*}}{P_t} = \left(\frac{\eta_m}{\eta_m - 1}\right)\frac{za_t}{zb_t} \tag{M16}$$

Production functions

Farming production function

$$Y_{f,t}^{r} = A_{f,t} N_{f,t}^{r} \tag{M17}$$

Non-farm goods production function

$$Y_{a,t}^{r} = A_{a,t} N_{a,t}^{r} \tag{M18}$$

Production function for manufactured goods

$$Y_{m,t}^{z} = A_{m,t} N_{m,t}^{z} \tag{M19}$$

Prices

Price index of rural consumption basket

$$1 = \gamma\left(\frac{P_{f,t}}{P_t^{\mathrm{r}}}\right)^{1-\eta} + (1-\gamma)\left(\frac{P_{m,t}}{P_t^{\mathrm{r}}}\right)^{1-\eta} \tag{M20}$$

Price index of flexible price goods

$$1 = \gamma_z\left(\frac{P_{f,t}}{P_{l,t}}\right)^{1-\eta_z} + (1-\gamma_z)\left(\frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}}\right)^{1-\eta_z} \tag{M21}$$

Price index of manufactured goods

$$1 = \gamma_m\left(\frac{P_{m,t-1}}{P_{m,t}}\right)^{1-\eta_m} + (1-\gamma_m)\left(\frac{P_{m,t}^{*}}{P_{m,t}}\right)^{1-\eta_m} \tag{M22}$$

Aggregate price index

$$1 = \gamma\left(\frac{P_{l,t}}{P_t}\right)^{1-\eta} + (1-\gamma)\left(\frac{P_{m,t}}{P_t}\right)^{1-\eta} \tag{M23}$$

Relative price of the consumer price of non-farm goods to their producer price

$$\frac{P^{\mathrm{z}}_{a,t}}{P_{a,t}} = 1 + \mu \qquad \text{M24}$$

Clearing equations

Labour in the rural adds up

$$N^r_t = N^r_{f,t} + N^r_{a,t}, \qquad \text{M25}$$

Consumption of farm goods equals production

$$\lambda Y^r_{f,t} = \lambda C^r_{f,t} + C^z_{f,t} \qquad \text{M26}$$

Consumption of non-farm goods equals production

$$\lambda Y^r_{a,t} = C^z_{a,t} \qquad \text{M27}$$

Consumption of manufactured goods equals production

$$Y^z_{m,t} = \lambda C^r_{m,t} + C^z_{m,t} \qquad \text{M28}$$

Rural wage-price relationships

$$\frac{W^{\mathrm{r}}_t}{P_{f,t}} = \frac{W^{\mathrm{r}}_t}{P^{\mathrm{r}}_t}\frac{P^{\mathrm{r}}_t}{P_{f,t}} \qquad \text{M29}$$

Urban wage-price relationships

$$\frac{W^{\mathrm{z}}_t}{P_{m,t}} = \frac{W^{\mathrm{z}}_t}{P_t}\frac{P_t}{P_{m,t}} \qquad \text{M30}$$

Non-farm goods price relationships

$$\frac{P^{\mathrm{z}}_{a,t}}{P_{a,t}} = \frac{P^{\mathrm{z}}_{a,t}}{P_{l,t}}\frac{P_{l,t}}{P_{f,t}}\frac{P_{f,t}}{W^{\mathrm{r}}_t}\frac{W^{\mathrm{r}}_t}{P_{a,t}} \qquad \text{M31}$$

Rural consumer price relationships

$$\frac{P_{m,t}}{P_t^{\mathrm{r}}} = \frac{P_{f,t}}{P_t^{\mathrm{r}}}\frac{P_{m,t}}{P_t}\frac{P_t}{P_{l,t}}\frac{P_{l,t}}{P_{f,t}} \quad \text{M32}$$

Relationship between headline and core inflation

$$\frac{P_t}{P_{t-1}} = \frac{P_{m,t}}{P_{m,t-1}}\frac{P_{m,t-1}}{P_{t-1}}\frac{P_t}{P_{m,t}} \quad \text{M33}$$

Output aggregation

Value of farm output

$$Y_{fp,t}^r = \frac{P_{f,t}}{P_{l,t}}\frac{P_{l,t}}{P_t}Y_{f,t}^r \quad \text{M34}$$

Value of non-farm output

$$Y_{ap,t}^r = \frac{P_{a,t}^z}{P_{l,t}}\frac{P_{l,t}}{P_t}Y_{a,t}^r \quad \text{M35}$$

Value of manufactured output

$$Y_{mp,t}^z = \frac{P_{m,t}}{P_t}Y_{m,t}^z \quad \text{M36}$$

Aggregate output

$$Y_t = C_t = \lambda\left(Y_{fp,t}^r + Y_{ap,t}^r\right) + Y_{mp,t}^z \quad \text{M37}$$

Equations M37 is used obtain Y_t, which is an input in the Taylor's rule equation number M38.

Monetary policy

Interest rate (Taylor rule) for flexible headline inflation targeting
Note: This equation replaces equation number (M38b) under the interest rate rule (IRR)

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_i \log\left(\frac{R_{t-1}}{\bar{R}}\right) + \rho_\pi \log\left(\frac{\Pi_t}{\overline{\Pi}}\right) + \rho_y \log\left(\frac{Y_t}{\bar{Y}}\right) - \log\left(A_{pt}\right) \quad \text{M38a}$$

Money supply rule for flexible headline inflation targeting

Note: This equation replaces equation number (M38a) under the MSR

$$\log(M_{g,t}) = m\rho_m \log\left(\frac{M_{g,t-1}}{\overline{M_g}}\right) + \log(\overline{\Pi}) - m\rho_\pi \log\left(\frac{\Pi_t}{\overline{\Pi}}\right) - m\rho_y \log\left(\frac{Y_t}{\overline{Y}}\right) + \log\,(A_{pt}) \qquad \text{M38b}$$

Money supply

Note: This equation is only applicable under the MSR

$$M_{s,t} = M_{g,t} M_{s,t-1} \qquad \text{M38c}$$

Money market clearing

Note: This equation is only applicable under the MSR

$$M_{s,t} = M_{h,t}. \qquad \text{M38d}$$

Productivity

Farming productivity process

$$\log A_{f,t} = \rho_{af} \log A_{f,t-1} + \xi_{f,t} \qquad \text{M39}$$

Non-farm goods productivity process

$$\log A_{a,t} = \rho_{aa} \log A_{a,t-1} + \xi_{a,t} \qquad \text{M40}$$

Manufacturing productivity process

$$\log A_{m,t} = \rho_{am} \log A_{m,t-1} + \xi_{m,t} \qquad \text{M41}$$

Monetary policy shock process

$$\log(A_{p,t}) = \rho_{ap} \log(A_{p,t-1}) + \xi_{p,t} \qquad \text{M42}$$

Welfare

Expected lifetime welfare, rural household

$$v_t^r = \frac{(C_t^r)^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^r)^{1+\psi}}{1+\psi} + \beta v_{t+1}^r \qquad \text{M43}$$

Expected lifetime welfare, urban household

$$v_t^z = \frac{(C_t^z)^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^z)^{1+\psi}}{1+\psi} + \beta v_{t+1}^z \qquad \text{M44}$$

Aggregate expected lifetime welfare

$$v_t = \lambda v_t^r + v_t^z \qquad \text{M45}$$

Table 2A4: Model 1 steady-state equations in recursive order

Steady-state values

$$\Pi = 1$$

$$\Pi_m = 1$$

$$\frac{P^*}{P_m} = 1$$

$$A_f = 1$$

$$A_a = 1$$

$$A_m = 1$$

$$A_p = 1$$

$$R = \frac{\Pi}{\beta}$$

$$\frac{P_a^z}{P_a} = 1 + \mu$$

$$\frac{W^r}{P_f} = A_f$$

$$\frac{W^r}{P_a} = A_a$$

$$\frac{W^z}{P_m} = \left(1 - \frac{1}{\eta_m}\right) A_m$$

$$C^r = \left[\frac{1}{\phi}\left(\frac{W^r}{P^r}\right)^{1+\psi}\right]^{\frac{1}{\sigma+\psi}}$$

$$N^r = \left(\frac{W^r}{P^r}\right)^{-1} C^r$$

$$N_f^r = N^r - N_a^r$$

$$N_m^z = \left(\frac{1}{\phi(C^z)^\sigma}\frac{W^z}{P}\right)^{\frac{1}{\psi}}$$

$$Y_f^r = A_f N_f^r$$

$$Y_a^r = A_a N_a^r$$

$$Y_m^z = A_m N_m^z$$

$$\frac{P_m}{P} = \left(\frac{W^z}{P_m}\right)^{-1}\frac{W^z}{P}$$

$$\frac{P_l}{P} = \left(\frac{1}{\gamma}\left[1-(1-\gamma)\left(\frac{P_m}{P}\right)^{1-\eta}\right]\right)^{\frac{1}{1-\eta}}$$

$$\frac{P_f}{P^r} = \left(\frac{W^r}{P_f}\right)^{-1}\frac{W^r}{P^r}$$

$$\frac{P_m}{P^r} = \left[\left(\frac{1}{(1-\gamma)}\right)\left[1-\gamma\left(\frac{P_f}{P^r}\right)^{1-\eta}\right]\right]^{\frac{1}{1-\eta}}$$

$$C_f^r = \gamma\left(\frac{P^r}{P^f}\right)^{\eta} C^r$$

$$C_m^r = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^r$$

$$C_l^z = \gamma\left(\frac{P_l}{P}\right)^{-\eta} C^z$$

$$C_f^z = \lambda\left(Y_f^r - C_f^r\right)$$

$$C_a^z = \lambda Y_a^r$$

$$C_m^z = (1-\gamma)\left(\frac{P_m}{P}\right)^{-\eta} C^z$$

Only applicable under the MSR

$$m = \left(\frac{(C^z)^{\frac{\sigma}{\upsilon}}}{\frac{1-R}{R}}\right)^{\frac{1}{\upsilon}}$$

$$\frac{P_f}{P_l} = \left(\frac{1}{\gamma_z C_l^z} C_f^z\right)^{-\frac{1}{\eta_z}}$$

$$\frac{P_a^z}{P_l} = \left[\left(\frac{1}{(1-\gamma_z)}\right)\left[1-\gamma_z\left(\frac{P_f}{P_l}\right)^{1-\eta_z}\right]\right]^{\frac{1}{1-\eta_z}}$$

$$MC = \frac{W^z/P_m}{A_m}$$

$$za = \frac{MC_m^z Y_m^z}{(1-\gamma_m \beta)}$$

$$zb = \frac{Y_m^z}{(1-(\gamma_m \beta))}$$

$$Y_{fp}^r = \frac{P_f}{P_l}\frac{P_l}{P}Y_f^r$$

$$Y_{ap}^r = \frac{P_a^z}{P_l}\frac{P_l}{P}Y_a^r$$

$$Y_{mp}^z = \frac{P_m}{P}Y_m^z$$

$$Y = \lambda\left(Y_{fp}^r + Y_{ap}^r\right) + Y_{mp}^z$$

$$v^r = \left(\frac{(C^r)^{1-\sigma}}{1-\sigma} - \phi\frac{(N^r)^{1+\psi}}{1+\psi}\right)/(1-\beta)$$

$$v^z = \left(\frac{(C^z)^{1-\sigma}}{1-\sigma} - \phi\frac{(N^z)^{1+\psi}}{1+\psi}\right)/(1-\beta)$$

$$v_t = \lambda v_t^r + v_t^z$$

$$C_a^z = (1-\gamma_z)\left(\frac{P_a^z}{P_l}\right)^{-\eta_z} C_l^z \qquad \text{F1}$$

$$Y_m^z = \lambda C_m^r + C_m^z \qquad \text{F2}$$

$$\frac{P_a^z}{P_a} = \frac{P_a^z}{P_l}\Big/\left(\frac{P_f}{P_l}\frac{W^r}{P_f}\right)\frac{W^r}{P_a} \qquad \text{F3}$$

$$\frac{P_m}{P^r} = \frac{P_f}{P^r}\frac{P_m}{P}\left(\frac{P_l}{P}\frac{P_f}{P_l}\right)^{-1} \qquad \text{F4}$$

The last 4 equations are solved by the fsolve function.

Table 2B1: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, under money supply rule

	Farming shock	Non-farming shock	Manufacturing shock	Policy shock
Output	1.299	1.106	0.965	0.958
Inflation	1.250	1.063	0.909	1.015
Interest	1.500	1.073	0.947	1.033
Money	1.500	1.073	0.952	1.034

Chapter 3
Extending the benchmark model to include altruistic remittances and industry-specific capital

3.1 Introduction

Model 1, developed in Chapter 2, enabled us to make predictions of the economic effects of mobile money, running through the primary income channel, i.e. through the purchase of goods and services. Through this channel, we saw that mobile money would have positive benefits to the economy, with all households in the rural appropriating a larger share. In addition to the primary income channel effect of mobile money, we have seen in Chapter 1 that mobile money has being credited by most authors, for its positive role in facilitating remittances and their attendant consumption smoothing effects, particularly among the poor (Jack *et al*., 2013; Lenka and Bairwa, 2016; Mbiti and Weil, 2016; Morawczynski and Pickens, 2009; Munyegera and Matsumoto, 2016). It therefore comes naturally to this work, that an extension to include remittances—the secondary income channel—in the model developed in Chapter 2, would serve to complete the picture of the economic impact of mobile money, and provide more rounded insights, as to how monetary policy may be affected by it. Such an extension will also shed more light, on the developmental role that may be played by mobile money (Hinson *et al*. 2019). This extension is dealt with in the first part of this chapter, followed by a second extension that adds capital to the model. To inform the setup of the extended models that we are going to build in this Chapter, we begin by reviewing the literature about rural-urban migration and remittances.

Migration refers to movement of people from one place to another, which takes place within and across countries globally, for various reasons. Migration occurring within a country is also referred to as internal migration, and can be rural-to-urban, rural-to-rural or urban-to-rural. All types of migration have been observed in sub-Saharan Africa, like in other regions of the world, but internal rural-urban is the most common. According to United Nations Development Programme (UNDP) 2009 estimates, the number of internal migrants in 2000 - 2002 was six times higher than the number of emigrants—people leaving a country to other countries with no intention to return. Most of internal migrants in sub-Saharan Africa are from rural-to-urban (Mercandalli *et al.*, 2019).

The motives for migration identified in literature include: search for higher paying job or income generating activities, pursuit of education, joining family, climate change, conflicts, better access to social services and amenities (Lucas 2015; Srivastava, 2011; UNDP, 2009). The flow of migrants from the rural to the urban is sustained by, among others, the fact that, on average, pay is relatively higher in the urban than rural, and that the chances of finding job in the urban increase when a person is located there (Lucas, 2015). In a study by Beegle *et al.* (2011) they found that migrants leaving the rural in Kagera Tanzania for places connected to urban areas, from 1991 to 2004, had their consumption increase by 66 percentage points above those who stayed. Likewise, de Brauw *et al.* (2013) found an even larger increase in the per capita consumption of rural-urban migrants in Ethiopia between 2004/05 and 2009, which was more than two times of those who did not migrate.

The decision to migrate can be made by an individual or collectively by a family and the migrant can be circular or permanent. A circular migrant leaves their place of origin with intention to return, either seasonally or after retirement (Bigsten, 1996; Stichter, 1985). Migrants arising from family decision often fall under the category of circular migrants, and maintain ties with their rural families primarily by sending remittances. While such migrants are likely to remit more, other migrants also remit as motives for doing so differ.

Lucas and Stark (1985) identify three motives behind the remittances made by migrants to their corresponding families in the rural. The first motive is pure altruism, under which the migrant draws utility from the utility of the members of their corresponding rural household. The second is pure self-interest. In this case migrants remit for their own gain, which may be based on: i) their aspiration for inheritance from their parents; ii) investment and maintenance of personal assets in the rural; iii) their intent to return to the rural in the future, whereby the migrant remit for acquisition and maintenance of such assets as land, house and livestock. The third is referred to by the authors as tempered altruism or enlightened self-interest. This motive has two components driving migration and remittances: investment and risk diversification. In the case of investment, a rural family incurs the cost of educating their children with intention of increasing their chance of finding better paying job in the urban and pay back. Such costs are viewed as loans given to the migrants, to be repaid through remittances once they get job in the urban. As for risk diversification, a rural family enters informal contract for some of its members to migrate into urban, where income risks are not correlated with those the rural, such as crop failure and animal disease (Mercandalli *et al.*, 2019). In this kind of arrangement, the flow of remittances become positively correlated with occurrence of adverse shocks, and can flow either way, but on average the net flows are expected to be from the urban to the rural, as urban income is expected to be higher than rural income.

The motives highlighted by Lucas and Stark (1985) have been corroborated by several empirical studies. For instance, Trager (1984) found that most rural-urban migrants in Philippines retained some ties with their rural families, and remitted money, some as high as 50 per cent of their incomes. Such remittances are used to increase rural household consumption as well as to invest in children education and production. Hoddinott (1994) found that most of rural-urban migrants in Kenya intended to return to their rural home in the future and, therefore, had incentive to maintain good relationship with their rural relatives and community through among others, remittances. The author also found that remittances depend on migrants' earnings, the expected land to be received from parents and the number of migrants in the family.

As we have seen in Chapter 1, money transfer technology is a key factor in the determination of remittances—the better the technology the higher the remittances. This also has implications on the relative amount of labour supplied by the sending *vis à vis* receiving households. For instance, Lee *et al.* (2021) carried out an experiment on the Bangladesh very poor rural families with migrant members in the city. They introduced mobile banking to these families and found that, one year after the intervention, active users of mobile banking account received 26 per cent higher remittances, while the receiving households had their per capita consumption increase by 7.5 per cent. They also observed increase in rural agricultural investment. This was mirrored by more reports of longer working hours among women and declines in self-reported health status in the city, manifesting the additional sacrifice the migrants had to make, in order to remit more.

In line with literature, the extensions that we make in this Chapter are based on assumption that the rural families with migrant members are able to enjoy higher consumption than rural families without, as well as owning and renting capital to rural firms. The rest of this Chapter is organized as follows: in section 4.2, we make the first extension to the Model 1 by adding remittances, and then, in section 4.3 we make the second extension by adding capital. In section 4.4 parameters pertaining to the extensions are calibrated and then in section 4.5 we carry out simulation and discuss results. We finally conclude the Chapter in section 4.6.

3.2 First extension: adding the secondary income channel to the benchmark model

To add remittances to Model 1, we introduce a new type of household, which we refer to as a mixed household, described in the next section. The rest of the households, i.e. the rural and the urban retain the characteristics assigned to them in Model 1, but to make them easily distinguishable, we refer to them as purely rural and purely urban households, respectively. In addition, we henceforth refer to the model developed in this section as Model 2.

3.2.1 Characterizing the mixed household

The mixed household has two types of members—a member living and working in the rural, who we refer to as mixed-rural household, and migrant member who lives and works in the urban, who we refer to as mixed-urban household.[33] This setting is premised on the theoretical view that treats the family of a migrant with the one left behind as one household, with unified decision making regarding the amount of labour hours to be supplied in the urban or rural, and a joint objective of benefiting the whole family (Bigsten, 1996). The choice of how much labour hours to supply in one sector relative to the other is achieved by decision about who works more and who works less, between the member of the household living in the rural and the migrant member living in the urban, rather than physical movement of people.

The two mixed households send remittances to each other, the size of which is determined by the difference in their earnings and their joint objective of maximizing equalized utility. The flow of resources within the mixed household is facilitated by the prevailing money transfer technology, which brings in the role of mobile money. The mixed-rural household lifetime welfare is defined as:

$$v_t^{xr} = \left[\frac{(C_t^{xr})^{1-\sigma}}{1-\sigma} - \phi\,\frac{(N_t^{xr})^{1+\psi}}{1+\psi}\right] + \beta E(v_{t+1}^{xr}) \tag{3.1}$$

where the parameters σ, ψ, ϕ and β retain the definitions they were assigned in Model 1. The variable C_t^{xr} is the mixed-rural household consumption and N_t^{xr} is labour supplied by the mixed-rural household.

[33] For computational reasons, each of the two members of the mixed household in this model is given a weight of one household.

Likewise, the mixed-urban lifetime welfare is defined as:

$$v_t^{xz} = \left[\frac{(C_t^{xz})^{1-\sigma}}{1-\sigma} - \phi\frac{(N_t^{xz})^{1+\psi}}{1+\psi}\right] + \beta E(v_{t+1}^{xz}) \tag{3.2}$$

where all notations retain their definitions with the index xr replaced by xz for the mixed-urban household.

The joint objective of the mixed-rural and mixed-urban households is to maximize the combined welfare for the two households:

$$\max_{C_t^{xr}, C_t^{xz}, N_t^{xr}, N_t^{xz}} (v_t^{xr} + v_t^{xz}), \tag{3.3}$$

by choosing consumption (C_t^{xr} and C_t^{xz}), and labour supply (N_t^{xr} and N_t^{xz}).

The combined welfare is maximized subject to two budget constraints. One is the budget constraint of the mixed-rural household, defined as:

$$C_t^{xr} = \frac{W_t^r}{P_t^r} N_t^{xr} + (1-\mu)F_t^{xz}, \tag{3.4}$$

where P_t^r is the price of the households' consumption basket, W_t^r is nominal wage in the rural, N_t^{xr} is the quantity of labour supplied by the mixed-rural household, and F_t^{xz} is the gross value of remittances sent by the mixed-urban household to the mixed-rural household, deflated by the price of their consumption basket. These remittances are made to equalize their utility, and μ is the transaction fees parameter, as was defined in Chapter 2.

The second budget constraint is that of mixed-urban household defined as:

$$C_t^{xz} = \frac{1}{P_t^r}\int_0^1 W_{j,t}^z N_{j,t}^{xz}\, dj + \int_0^1 D_{j,t}^{xz}\, dj + S_t^{xz} - F_t^{xz} \tag{3.5}$$

where W_t^z is nominal wage in the urban, D_t^{xz} stands for real value of dividends received, and S_t^{xz} is the real value of transaction fees paid when sending remittances to the mixed-rural household. Note that, applying similar assumption as in the budget constraint of the purely urban household, equation (2.10), the transaction cost for remitting money, S_t^{xz}, is entered on the right hand side of equation (3.5) as a way of refunding the mixed-urban household lump sum, assuming that it is a sole owner of the money transfer service.

Both mixed-households are hand-to-mouth agents, thus their consumption is equal to their current period disposable income. The mixed-rural household disposable income is made up of labour income and net remittances received from the mixed-urban household. The mixed-urban household's disposable income includes labour income and dividends minus gross transfers sent to the mixed-rural household.

Solving for gross remittances, F_t^{xz}, from equation number (3.4) we have:

$$F_t^{xz} = \frac{P_t^r C_t^{xr}}{(1-\mu)} - \frac{W_t^r N_t^{xr}}{(1-\mu)} \tag{3.6}$$

The loss incurred in the remittance process is determined as the difference between the remittance made by the mixed-urban household and that which is received by the mixed-rural household:

$$S_t^{xz} = F_t^{xz} - (1-\mu) F_t^{xz}. \tag{3.7}$$

Substituting (3.6) in (3.7), simplifying and rearranging we obtain equation number (3.8), that defines S_t^{xz} in terms of the mixed-rural household budget.

$$S_t^{xz} = \left(\frac{\mu}{(1-\mu)}\right)\left(C_t^{xr} - \frac{W_t^r}{P_t^r} N_t^{xr}\right) \tag{3.8}$$

Equation number (3.8) presents the loss of budget resources incurred by a pair of mixed households in the process of making remittances. Removing the loss, from the combined budget of the mixed household yields equation (3.9).

$$\frac{P_t^r C_t^{xr}}{1-\mu} + P_t^r C_t^{xz} = \frac{W_t^r N_t^{xr}}{1-\mu} + \int_0^1 W_{j,t}^z N_{j,t}^{xz}\, dj + \int_0^1 D_{j,t}^{xz}\, dj \tag{3.9}$$

The composite consumption of each of the mixed households has same structure as that of the purely rural household in Model 1.

$$C_t^i = \left[\gamma^{\frac{1}{\eta}}\left(C_{f,t}^i\right)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}}\left(C_{m,t}^i\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

where the index i stands for xr when referring to mixed-rural household consumption and xz when referring to mixed-urban household. Because the purely rural, mixed-rural and mixed-urban households have similar baskets, we refer to them collectively as rural basket households.

Substituting equation number (3.1) and (3.2) in (3.3) we have:[34]

$$\max_{C_t^{xr}, C_t^{xz}, N_t^{xr}, N_t^{xz}} \left[\left(\frac{(C_t^{xr})^{1-\sigma}}{1-\sigma} - \phi\frac{(N_t^{xr})^{1+\psi}}{1+\psi}\right) + \left(\frac{(C_t^{xz})^{1-\sigma}}{1-\sigma} - \phi\frac{(N_t^{xz})^{1+\psi}}{1+\psi}\right)\right] \quad (3.10)$$

Using equations number (3.9) and (3.10) we obtain first order condition for consumption that shows the relationship between the consumption of the mixed-urban and that of the mixed-rural household:

$$(C_t^{xz})^{-\sigma} = (1-\mu)(C_t^{xr})^{-\sigma} \quad (3.11)$$

Equation number (3.11) implies that there will be a positive flow of remittances from the mixed-urban to the mixed-rural household as long as the difference between the mixed-urban household consumption and mixed-rural household consumption exceeds the cost of sending money. The larger the income difference between the two households, the larger the amount of remittances needed to equate consumption across the two households.

First order condition for the mixed-rural household labour supply:

$$\phi\frac{(N_t^{xr})^{\psi}}{(C_t^{xr})^{-\sigma}} = \frac{W_t^r}{P_t^r} \quad (3.12)$$

and for the mixed-urban household:

[34] Similar setting of utility was used by Hart and Clemens (2019), but unlike this case where the two types of the mixed household members are rural and urban, in their case the members were native and migrant in a foreign country.

$$\phi\frac{(N_t^{xz})^{\psi}}{(C_t^{xz})^{-\sigma}}=\frac{W_t^z}{P_t^r} \tag{3.13}$$

The setting of the mixed household in this model establishes microfoundations for remittances, based on the altruistic motive, as identified in Lucas and Stark (1985). It therefore constitutes a further extension of AW who assume an ad hoc rule (albeit based on similar altruism).

The household characterized above gives rise to programme equations listed in the next section.

3.2.1.1 List of model equations arising from the introduction of mixed households

In this section, we provide the list of new and modified equations, that are applicable to programming in Dynare/Matlab, due to introduction of mixed household in the model.

Mixed household consumption

From equation number (3.11) we have a new equation that relates the consumption of the mixed-rural households with that of the mixed-urban households,

$$C_t^{xr}=\left(\frac{1}{(1-\mu)}\right)^{-\frac{1}{\sigma}}C_t^{xz}. \tag{3.14}$$

Consumption of farm goods by the mixed-rural

$$C_{f,t}^{xr}=\gamma\left(\frac{P_{f,t}}{P_t^r}\right)^{-\eta}C_t^{xr}, \tag{3.15}$$

and consumption of manufactured goods by the mixed-rural household

$$C_{m,t}^{xr}=(1-\gamma)\left(\frac{P_{m,t}}{P_t^r}\right)^{-\eta}C_t^{xr}. \tag{3.16}$$

The mixed-urban households' consumption is determined by equation number (3.5)

$$C_t^{xz}=\int_0^1\frac{W_{j,t}^z}{P_t^r}N_{j,t}^{xz}\,dj+\int_0^1 D_{j,t}^{xz}\,dj+S_t^{xz}-F_t^{xz}. \tag{3.17}$$

The mixed-urban household consumption of farm goods is defined as:

$$C_{f,t}^{xz} = \gamma \left(\frac{P_{f,t}}{P_t^r} \right)^{-\eta} C_t^{xz}, \tag{3.18}$$

and consumption of manufactured goods as:

$$C_{m,t}^{xz} = (1 - \gamma) \left(\frac{P_{m,t}}{P_t^r} \right)^{-\eta} C_t^{xz}. \tag{3.19}$$

Mixed households' labour supply

Labour supply decision by the mixed-rural households come from equation number (3.12)

$$N_t^{xr} = \left(\frac{1}{\phi} \frac{W_t^r}{P_t^r} \right)^{\frac{1}{\psi}} (C_t^{xr})^{\frac{-\sigma}{\psi}}, \tag{3.20}$$

and labour supply decision by the mixed-urban households come from equation number (3.13)

$$N_t^{xz} = \left(\frac{1}{\phi} \frac{W_t^z}{P_t^r} \right)^{\frac{1}{\psi}} (C_t^{xz})^{\frac{-\sigma}{\psi}}. \tag{3.21}$$

Mixed households' remittances

To compute the real value of the remittances made by the mixed-urban households to the mixed-rural households, using aggregate price level, we need a price ratio $\frac{P_t^r}{P_t}$, that does not exist in Model 1. We define it as:

$$\frac{P_t^r}{P_t} = \left(\frac{P_{f,t}}{P_t^r} \right)^{-1} \frac{P_{f,t}}{P_t}. \tag{3.22}$$

The welfare of the mixed-rural household is given by

$$v_t^{xr} = \frac{(C_t^{xr})^{1-\sigma}}{1 - \sigma} - \phi \frac{(N_t^{xr})^{1+\psi}}{1 + \psi} + \beta v_{t+1}^{xr}, \tag{3.23}$$

and the welfare of the mixed-urban household by

$$v_t^{xz} = \frac{(C_t^{xz})^{1-\sigma}}{1-\sigma} - \phi\frac{(N_t^{xz})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{xz}. \qquad (3.24)$$

Clearing equations

Given the parameters discussed under the calibration section and summarized in Table 3A2, we obtain the following aggregation equations.

Aggregate welfare of the mixed households

$$v_t^{x} = v_t^{xr} + v_t^{xz}. \qquad (3.25)$$

Aggregate welfare for all households

$$v_t = \alpha v_t^{r} + v_t^{x} + \varsigma v_t^{z}. \qquad (3.26)$$

To aggregate production and consumption of farm goods, we begin with equation of aggregate mixed households' consumption of farm goods

$$C_{f,t}^{x} = C_{f,t}^{xr} + C_{f,t}^{xz} \qquad (3.27)$$

then, a clearing equation for production and consumption of farm goods

$$\lambda Y_{f,t}^{r} = \alpha C_{f,t}^{r} + C_{f,t}^{x} + \varsigma C_{f,t}^{z}. \qquad (3.28)$$

Equation number (3.28) introduces the mixed household as well as the new household and workforce proportions.

The clearing equation for production and consumption of non-farm goods

$$\lambda Y_{a,t}^{r} = \varsigma C_{a,t}^{z}. \qquad (3.29)$$

This equation features new proportions for both producers and consumers of non-farm goods. Finally clearing equations for manufactured goods begin with aggregation of consumption by the mixed households,

$$C^{x}_{m,t} = C^{xr}_{m,t} + C^{xz}_{m,t}, \tag{3.30}$$

then, equation to clear production and consumption of manufactured goods for all households

$$\varrho Y^{z}_{m,t} = \alpha C^{r}_{m,t} + C^{x}_{m,t} + \varsigma C^{z}_{m,t}. \tag{3.31}$$

Like the equation for farm goods, number (3.28), equation number (3.31) introduces the mixed household as well as the new household and workforce proportions.

The aggregate output and consumption equation is then modified to:

$$Y_t = C_t = \lambda \left(\frac{P_{f,t}}{P_t} Y^{r}_{f,t} + \frac{P^{z}_{a,t}}{P_t} Y^{r}_{a,t} \right) + \varrho \frac{P_{m,t}}{P_t} Y^{z}_{m,t}. \tag{3.32}$$

Equation number (3.32) generates the value of Y_t that is used in the policy rule equation, applying the new workforce proportions.

Since labour in the rural and urban come from different households, we have two labour clearing equations. Equation to match labour from households in the rural with the labour in the rural firms:

$$\lambda \left(N^{r}_{f,t} + N^{r}_{a,t} \right) = a N^{rr}_{t} + N^{xr}_{t}. \tag{3.33}$$

Equation to match labour from households in the urban with the labour in manufacturing,

$$\varrho N^{z}_{m,t} = \varsigma N^{zz}_{t} + N^{xz}_{t}. \tag{3.34}$$

The money market clearing equation is modified to:

$$M_{s,t} = \varsigma M_{h,t}. \tag{3.35}$$

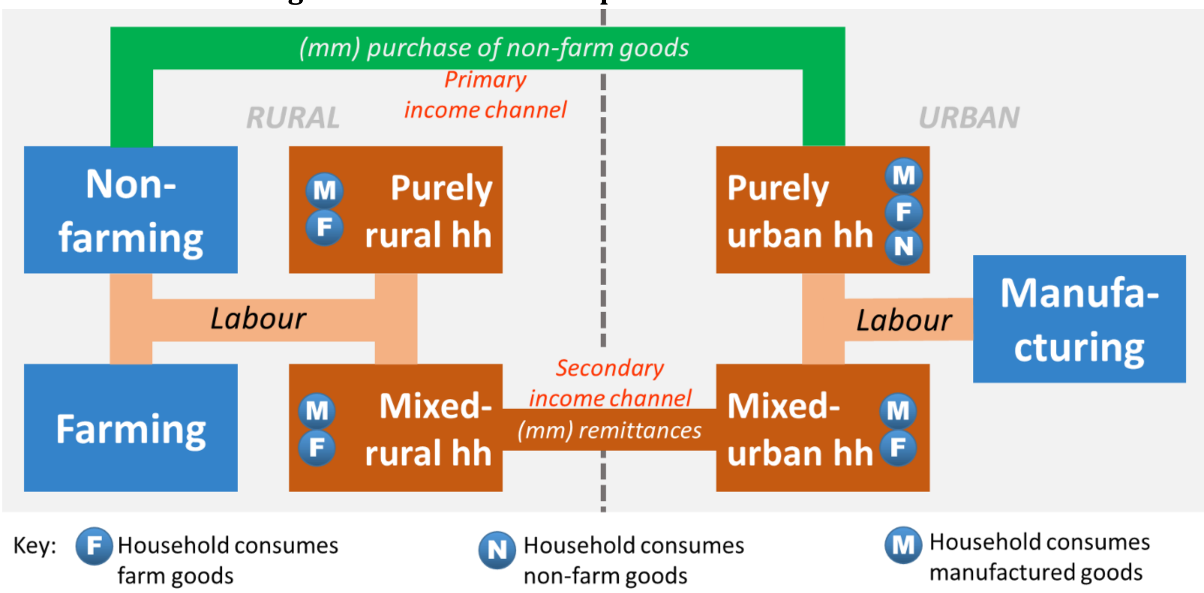
because the number of urban households change from 1 in Model 1, to $\varsigma = 3$.

Because the mixed-urban household consumes a basket that has similar structure as that consumed by the purely rural household, we need a ratio of manufacturing wage to the price index of this basket, which we also refer to as rural basket. The ratio is defined as:

$$\frac{W_t^z}{P_t^r} = \frac{W_t^z}{P_{m,t}} \frac{P_{m,t}}{P_t^r}. \tag{3.36}$$

Model 2 is completed by adding 19 new endogenous variables, 3 parameters and 19 new independent endogenous equations, to Model 1. The lists of Model 2 variables, parameters, model equations and their corresponding steady state equations are presented in tables 3A1 and 3A4. Figure 3.1 shows schematic presentation of Model 2.

Figure 3.1: Schematic representation of Model 2



The route through which mobile money flows is marked (mm).

The secondary income channel, that has been added to Model 1 in this section, works through the remittances made by the mixed-urban household to the mixed-rural household.

3.3 Second extension: adding industry-specific capital to Model 2

3.3.1 Characterizing the households with capital

In this section we develop Model 3 by adding capital to Model 2. To achieve this, we relax the assumptions of the households living in the urban, i.e. the mixed-urban and the purely urban households, to allow them to own capital. We assume that farming and manufacturing firms use labour and capital in production, while non-farming firms use labour only. The mixed-urban household is assumed to rent its capital to the farming industry, while the urban household is assumed to rent capital to manufacturing. All capital goods are sourced from manufactured goods. There is no capital mobility between the two sectors.[35] These assumptions lead to the changes discussed in the next section.

3.3.1.1 The mixed household

Since the budget for a representative mixed household (i.e. the mixed-rural and mixed-urban pair) is common, with the resource sharing being governed by the condition set in equation number (3.11),

$$(C_t^{xz})^{-\sigma} = (1-\mu)(C_t^{xr})^{-\sigma},$$

we extend the assumptions for the mixed household to allow it to accumulate capital and rent it to the farming firms. Capital is therefore added to the combined budget of the mixed household such that equation (3.9) becomes:

$$\begin{aligned}\frac{P_t^r C_t^{xr}}{1-\mu} &+ P_t^r C_t^{xz} + P_{m,t} I_t^{xz} \\ &= \frac{W_t^r N_t^{xr}}{1-\mu} + \int_0^1 W_{j,t}^z N_{j,t}^{xz}\, dj + \int_0^1 D_{j,t}^{xz}\, dj + R_{k,t}^r K_{t-1}^{xz}\end{aligned} \qquad (3.37)$$

where I_t^{xz} is investment by the mixed-urban household $R_{k,t}^r$ is return on capital for the farming firms and K_t^{xz} is the capital supplied to farming by the mixed-urban household. Please note we assume that the mixed-urban household is the one that makes decisions about investment and capital in the mixed household hence the superscript xz. The utility functions for the two

[35] This means that rural and urban investors obtain capital from separate markets, which allows return on farming capital to be different from that of manufacturing.

members of the mixed household remain as they were in Model 2 (equations 1 and 2). The joint mixed household objective now includes choice of capital.

$$\max_{C_t^{xr},C_t^{xz},N_t^{xr},N_t^{xz},K_t^{xz}} \left[\left(\frac{(C_t^{xr})^{1-\sigma}}{1-\sigma} - \phi\frac{(N_t^{xr})^{1+\psi}}{1+\psi}\right) + \left(\frac{(C_t^{xz})^{1-\sigma}}{1-\sigma} - \phi\frac{(N_t^{xz})^{1+\psi}}{1+\psi}\right)\right]$$

The law of motion of capital for the mixed household is therefore defined as:

$$K_t^{xz} = (1-\delta)K_{t-1}^{xz} + I_t^{xz} \tag{3.38}$$

From equations (3.37) and (3.38), the first order condition for the mixed-urban household capital becomes:

$$1 = \beta\frac{P_t^r}{P_{m,t}}\left(\frac{C_{t+1}^{xz}}{C_t^{xz}}\right)^{-\sigma}\left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}^r} + \frac{R_{k,t+1}^r}{P_{t+1}^r}\right] \tag{3.39}$$

3.3.1.2 The urban household

Adding capital to the purely urban household budget constraint produces equation number (3.40),

$$\begin{aligned} P_tC_t^{zz} + P_{m,t}I_t^{zz} + M_t + B_t \\ &= \int_0^1 W_{m,j,t}^z N_{m,j,t}^{zz}\,dj + R_{k,t}^z K_{t-1}^{zz} + \int_0^1 D_{m,j,t}^{zz}\,dj + M_{t-1} \\ &+ R_{t-1}B_{t-1} + S_t^{zz} \end{aligned} \tag{3.40}$$

Where I_t^{zz} is investment by the urban household, $R_{k,t}^z$ is return on capital rented to manufacturing and K_t^{zz} is the capital stock held by the urban household. Thus the objective of the purely urban household now includes choice of capital:

$$\max_{C_t^{zz},M_t,N_t^{zz},K_t^{zz}} \left(\frac{(C_t^{zz})^{1-\sigma}}{1-\sigma} + \frac{(M_t/P_t)^{1-\upsilon}}{1-\upsilon} - \phi\frac{(N_t^{zz})^{1+\psi}}{1+\psi}\right)$$

The urban household law of motion of capital is defined as:

$$K_t^{zz} = (1-\delta)K_{t-1}^{zz} + I_t^{zz} \tag{3.41}$$

The first order conditions for consumption and household labour supply remain as they were in the previous section. Solving for the first order condition for urban household capital we obtain:

$$1 = \beta \frac{P_t}{P_{m,t}} \left(\frac{C_t^{zz}}{C_{t+1}^{zz}}\right)^{\sigma} \left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}} + \frac{R_{k,t+1}^{z}}{P_{t+1}}\right] \tag{3.42}$$

Recalling from equation (2.12) that the urban household Euler equation is,

$$1 = \beta \mathbb{E}_t \left(\frac{C_t^{zz}}{C_{t+1}^{zz}}\right)^{\sigma} \frac{R_t}{\Pi_{t+1}},$$

then a no arbitrage condition between bonds and capital for the urban household becomes

$$R_t \frac{P_{m,t}}{P_t} = \beta \Pi_{t+1} \left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}} + \frac{R_{k,t+1}^{z}}{P_{t+1}}\right] \tag{3.43}$$

3.3.2 Firms

The farming production function with capital is given by:

$$Y_{f,t}^r = A_{f,t}\left(N_{f,t}^r\right)^{\omega_r}\left(K_{f,t-1}^r\right)^{1-\omega_r}, \tag{3.44}$$

where $\omega_r \in (0,1)$ is the elasticity of output with respect to labour in farming.
The objective of the firm is to maximize profit by choosing $N_{f,t}^r$ and $K_{f,t}^r$

$$\max_{N_{f,t}^r, K_{f,t}^r} \Omega_{f,t}^r = P_{f,t}A_{f,t}\left(N_{f,t}^r\right)^{\omega_r}\left(K_{f,t-1}^r\right)^{1-\omega_r} - W_t^r N_{f,t}^r - R_{k,t}^r K_{f,t-1}^r \tag{3.45}$$

The first order condition for labour demand in farming becomes

$$\frac{W_t^r}{P_{f,t}} = \omega_r \frac{Y_{f,t}^r}{N_{f,t}^r}, \tag{3.46}$$

and capital demand

$$\frac{R_{k,t}^{r}}{P_{f,t}} = (1-\omega_r)\frac{Y_{f,t}^{r}}{K_{f,t-1}^{r}} \tag{3.47}$$

As in the case of farming, the manufacturing production function with capital becomes

$$Y_{m,t}^{z} = A_{m,t}\left(N_{m,t}^{z}\right)^{\omega_z}\left(K_{m,t-1}^{z}\right)^{1-\omega_z} \tag{3.48}$$

where $\omega_z \in (0,1)$ is the elasticity of output with respect to labour in manufacturing, with the firm's objective being to maximize profit by choosing $N_{m,t}^{z}$ and $K_{m,t}^{z}$

$$\max_{N_{m,t}^{z},K_{m,t}^{z}} \Omega_{m,t}^{z} = P_{m,t}A_{m,t}\left(N_{m,t}^{z}\right)^{\omega_z}\left(K_{m,t-1}^{z}\right)^{1-\omega_z} - W_t^{z}N_{m,t}^{z} - R_{k,t}^{z}K_{m,t-1}^{z} \tag{3.49}$$

The first order condition for labour demand in manufacturing becomes

$$\frac{W_t^{z}}{P_{m,t}} = \omega_z\frac{Y_{m,t}^{z}}{N_{m,t}^{z}} \tag{3.50}$$

and capital demand

$$\frac{R_{k,t}^{z}}{P_{m,t}} = (1-\omega_z)\frac{Y_{m,t}^{z}}{K_{m,t-1}^{z}} \tag{3.51}$$

3.3.3 List of model equations arising from the introduction of capital

From the changes made to households and firms above, we draw the following list of new and modified equations, that are applicable to programming in Dynare/Matlab.

Law of motion of capital

Mixed-urban household

$$K_t^{xz} = (1-\delta)K_{t-1}^{xz} + I_t^{xz} \tag{3.52}$$

Urban household

$$K_t^{zz} = (1-\delta)K_{t-1}^{zz} + I_t^{zz} \tag{3.53}$$

Firms' demand for capital

Farming

$$\frac{R_{k,t}^r}{P_{f,t}} = (1-\omega_r)\frac{Y_{f,t}^r}{K_{f,t-1}^r} \tag{3.54}$$

Manufacturing

$$\frac{R_{k,t}^z}{P_{m,t}} = (1-\omega_z)\frac{Y_{m,t}^z}{K_{m,t-1}^z} \tag{3.55}$$

Condition for household capital accumulation

Mixed-urban household

$$1 = \beta\frac{P_t^r}{P_{m,t}}\left(\frac{C_{t+1}^{xz}}{C_t^{xz}}\right)^{-\sigma}\left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}^r} + \frac{R_{k,t+1}^r}{P_{t+1}^r}\right] \tag{3.56}$$

Urban household, condition for no arbitrage between bonds and capital

$$R_t\frac{P_{m,t}}{P_t} = \beta\Pi_{t+1}\left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}} + \frac{R_{k,t+1}^z}{P_{t+1}}\right] \tag{3.57}$$

Return to capital

Capital in farming

$$\frac{R_{k,t}^r}{P_t^r} = \frac{R_{k,t}^r}{P_{f,t}}\frac{P_{f,t}}{P_t^r} \tag{3.58}$$

Capital in manufacturing

$$\frac{R_{k,t}^z}{P_{m,t}} = \frac{R_{k,t}^z}{P_t}\left(\frac{P_{m,t}}{P_t}\right)^{-1} \tag{3.59}$$

Capital clearing equations

Farming capital

$$K_t^{xz} = \lambda K_{f,t}^r \tag{3.60}$$

Manufacturing capital

$$K_t^{zz} = \frac{\varrho}{\varsigma} K_{m,t}^z \tag{3.61}$$

List of modified equations

The following equations are found in the preceding model, but here they have been modified to accommodate capital:

The amount paid as dividends by manufacturing firms has been modified to become total sales minus payment to labour and capital

$$D_t^{xz} = \left(\frac{P_t^r}{P_t}\right)^{-1} \left(\frac{P_{m,t}}{P_t} Y_{m,t}^z - \frac{W_t^z}{P_t} N_{m,t}^z - \frac{R_{k,t}^r}{P_t} K_{m,t-1}^z\right) \tag{3.62}$$

The mixed-urban household budget has been modified to include rental income, $\frac{R_{k,t}^r}{P_t^r} K_{t-1}^{xz}$, and investment $\frac{P_{m,t}}{P_t^r} I_t^{xz}$

$$C_t^{xz} = \frac{W_t^z}{P_t^r} N_t^{xz} + \frac{R_{k,t}^r}{P_t^r} K_{t-1}^{xz} + D_t^{xz} + S_t^{xz} - F_t^{xz} - \frac{P_{m,t}}{P_t^r} I_t^{xz} \tag{3.63}$$

The farming production function now contains both labour and capital

$$Y_{f,t}^r = A_{f,t} \left(N_{f,t}^r\right)^{\omega_r} \left(K_{f,t-1}^r\right)^{1-\omega_r} \tag{3.64}$$

Likewise, manufacturing production function now contains labour and capital

$$Y_{m,t}^z = A_{m,t} \left(N_{m,t}^z\right)^{\omega_z} \left(K_{m,t-1}^z\right)^{1-\omega_z} \tag{3.65}$$

Labour demand in farming

$$\frac{W_t^r}{P_{f,t}} = \omega_r \frac{Y_{f,t}^r}{N_{f,t}^r} \tag{3.66}$$

Labour demand in manufacturing

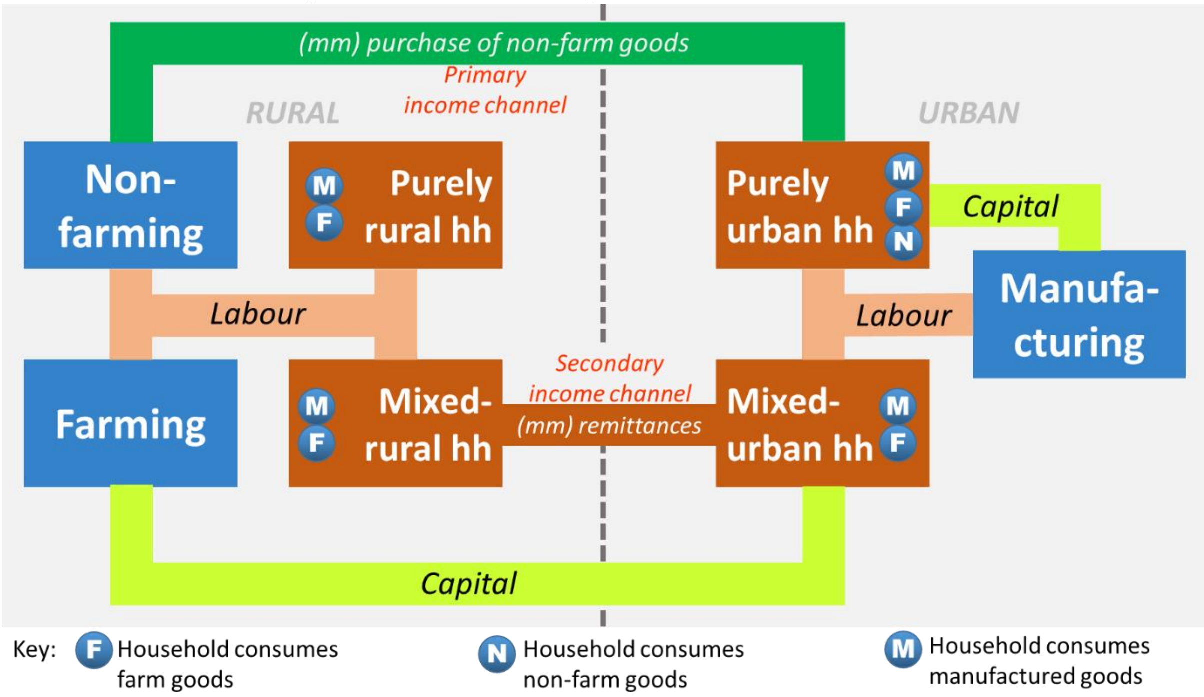
$$\frac{W_t^z}{P_{m,t}} = \omega_z \frac{Y_{m,t}^z}{N_{m,t}^z} \tag{3.67}$$

The clearing equation for manufactured goods is now made up of consumption and investment

$$\varrho Y_{m,t}^z = \alpha C_{m,t}^r + C_{m,t}^x + I_t^{xz} + \varsigma\left(C_{m,t}^z + I_t^{zz}\right) \tag{3.68}$$

The introduction of capital adds 12 new endogenous variables and 12 new independent endogenous equations to Model 2. It also adds 3 new parameters. The list of all variables and equations in Model 3, together with their corresponding steady state versions, is presented in tables 3B1 and 3B3. Figure 3.2 presents Model 3 schematically.

Figure 3.2: Schematic presentation of Model 3



The route through which mobile money flows is marked (mm).

Capital opens up a new route through which the urban interacts with the rural, as well as extending the ability to optimize utility across time to the mixed households.

3.4 Calibration of additional parameters for Model 2 and Model 3 baseline scenarios

Calibration of most of the parameters used in Model 2 and Model 3 has been discussed in Section 2.3, as these models are extensions of Model 1. In this section we will only discuss additional parameters and modifications made to some of those used in Model 1. To accommodate the secondary income channel, we change the assumption of the number of households living and working in the rural to account for 60 per cent of all households in the economy, living 40 per cent in the urban. This household structure is still within the range of the structure of the economies using mobile money the most, as it comes from an average of the top 15 countries with the highest population using mobile money in the world (Figure A4).[36] Out of the households in the rural $^5/_6$ are assumed to be purely rural. These are households that do not receive remittances. The rest of households are mixed-rural, or remittance receiving households. They account for 17 per cent of rural households, a proportion that we consider to be fairly close to 13 per cent reported by Oyvat (2017), as rural migrants to the urban in Kenya, based on Kenya Integrated Household Budget Survey 2005-2006. As for the urban households, ¾ are assumed to be purely urban and ¼ mixed-urban households. Thus the rural workforce accounts for 60 per cent of the entire workforce in the economy, while the urban workforce accounts for 40 per cent. If we normalize the number of households around the mixed-rural households, then the index for the mixed-urban households becomes 1, purely rural households 5, and the purely urban households 3.

Other parameters that need to be calibrated are depreciation of capital and elasticity of output in farming and manufacturing, with respect to labour. We set the rate of depreciation at $\delta = 0.025$ equivalent to 10 per cent per annum, for both farming and manufacturing. This is a rate that has been widely used in literature (Costa 2018; Gali *et al*. 2004; Peiris and Saxegaard, 2007). As for elasticity of output with respect to labour, the data available for Tanzania and Kenya is compensation of employees for all economic activities, which ranged between 25 and

[36] Gabon has been excluded because at 10 per cent its rural population stands out as an outlier among the rest of countries with highest mobile money usage in Africa.

37 per cent of GDP from 2015 to 2021 for Tanzania (National Bureau of Statistics Tanzania, 2022). This ratio for Kenya ranged between 29 and 32 per cent in the same period (Kenya Bureau of Statistics, 2022). While these ratios may be taken as reasonable measure of share of labour in GDP for advanced economies, it has been argued that using formal compensation of employees as a proxy for computation of labour share in primary income, in low-income countries, will tend to understate the true value, because of the prevalence of self-employment in the informal activities (Abu-Qarn and Abu-Bader, 2009; Gollin, 2002; Trapp, 2015). In low-income countries' compensation of employees in the informal sector is included in operating surplus and mixed income item of value added, computed as the difference between total value added and formal compensation of employees. Considering that the informal activities account for substantial part of the value added, the earnings of labour that are not explicitly distinguished in official statistics, may not be trivial. According to International Labour Organisation (ILO (2018)) report, 85.8 per cent of employment in Africa was in the informal sector—including agriculture—in 2016. The report also indicated that informal employment was higher in agriculture.

In attempt to address this problem, Trapp (2015) used social accounting matrices (SAMs) approach to measure the labour income share for 100 developing countries, from 1990 to 2011. The author used two methods proposed by Gollin (2002) to make adjustment to the ratio of compensation of employees to GDP. In the first method, it is assumed that all self-employed income is labour income and in the second it is assumed that self-employed income contains the same mix of capital and labour as the rest of the economy. Using the first adjustment the author found labour share that ranged from 0.26 to 0.87, and from the second adjustment it ranged from 0.21 to 0.73. We observe that, the labour share of 0.65 that has been widely used in literature falls within this range (Can *et al*., 2021; Costa, 2018; Gali *et al*., 2004). On this ground, we chose a share of 0.65 for manufacturing and, considering that agriculture is more labour intensive in low-income countries, we set it at 0.85 for farming. The parameter values arising from this discussion are summarized in Table 3A2.

3.5 Simulations and results

3.5.1 Simulations

As in Model 1, two scenarios of transactions costs—i.e. the baseline and the mobile money scenarios—are applied in the simulations of Model 2 and Model 3, to study the effect of remittances and capital on the impact of mobile money. The shocks in Model 2 are simulated over a period of 20 quarters for farming and non-farming and a period of 20 to 40 quarters in Model 3. The impact of manufacturing shock takes longer to die out, thus the simulation period is extended to from 80 quarters for Model 2 and 140 quarters for Model 3, as the presence of capital stretches the impact even further.

3.5.2 Steady-state results for Model 2 and Model 3

3.5.2.1 Non-mobile money differences between the models

We begin this section by identifying three overriding differences between Model 2 and Model 3 that are unrelated to mobile money. First, the economy represented by Model 3 has substantially larger output than that of Model 2, although they both have similar number of agents and structure (Table 3C1). This is mostly explained by manufacturing output, which in Model 3, is more than twice that of Model 2, partly because it in addition to consumer goods, it is responsible for producing capital goods. Second, remittances are substantially higher in Model 3 than Model 2 due to larger income gap between the urban and the rural in Model 3 (Table 3.4a).[37] The primary income of the mixed-urban household in Model 3 is more than double that of the mixed-rural household, while in Model 2 it is between 30 and 35 per cent larger. This difference between the two mixed households' incomes conforms with large urban-to-rural remittances observed in Philippines and Bangladesh, and the importance attached to income difference in the rural-urban migration literature (Lee *et al.*, 2021; Oyvat, 2017; Tragger 1984). It also matches the findings by de Brauw *et al.* (2013) in Ethiopia that migrants had incomes as high as two times that of those who did not migrate.

[37] Although the decisions about investment appear to be made by the mixed-urban household, the optimizing behaviour of the two mixed households implies that they both make their individual choices about consumption and labour supply in a manner that is optimally compatible with the amount of investment made. The mixed-urban household therefore makes investment decisions on behalf of the entire mixed household and thus, part of the income arising from the rented capital can be considered as belonging to the mixed-rural household. It is therefore arguable that the amount of remittances could be adjusted for the implied mixed-rural household rental income. Even with this kind of adjustment though, remittances in Model 3 will remain way higher than those of Model 2.

Third, each household supplies less labour in Model 3 than model 2, with the largest reduction occurring in the purely urban and mixed-rural households (Table 3C4). The purely urban household has the largest drop in labour supply because it receives income from capital and it does not remit. As for the mixed-rural household, it is able to reduce its labour supply substantially because it receives considerably larger remittances in Model 3. As a result of the foregoing, welfare is higher for all households in Model 3 than in Model 2 (Table 3C8). The largest gain in welfare, due to inclusion of capital, is in the urban household followed by the mixed-rural then mixed-urban and lastly purely rural household. In sum, the output and welfare levels of Model 3 are noticeably higher than those of Model 2.

Having seen the major differences between Model 2 and Model 3, we now turn to discussion of the steady-state results of introducing mobile money in each of the two models for selected variables, namely production, labour supply and income, consumption, and relative prices and wages.

3.5.2.2 Steady state impact of mobile money

Production and generation of primary income

When mobile money is introduced in Model 2 and Model 3, the value of GDP increases, driven by the non-farming industry (Table 3.1). The quantity of non-farm goods increases by 24.4 and 23.1 per cent in Model 2 and Model 3 respectively, while the quantity of farm goods declines by 4.7 and 5.9 per cent, in the same order. In manufacturing the quantity of output increases by 1.9 and 1.8 per cent in Model 2 and Model 3. Although the quantity of farm goods declines, the price increases sufficiently to make the change in their value positive. Compared to Model 1, the presence of mixed households in Model 2 and Model 3 moderates the difference in sectoral response to mobile money, by enabling supply of labour hours to change in favour of the urban. For this reason, the industrial distribution of the response to mobile money at steady state becomes more even when remitting households are present. If we compare the change in the income generated in rural firms with that generated in urban firms we see that, in Model 1, income from rural firms change by 8.4 per cent, while income from urban firms change by 5.1

per cent, a difference of 3.3 percentage points. In Model 2, the rates of change are 6.9 and 5.4 respectively, making a difference of 1.5 percentage points (tables 2.4 and 3.2).[38]

In line with production, the income generated in the rural increases more than the income generated in the urban, with most of the increase in the rural coming from non-farming industry (Table 3.2). In both models, the increase in the non-farming income comes from two sources: first from higher demand for those goods, owing to their lower consumer price after introduction of mobile money, and second, from the value recovered from transaction fees, which goes into raising labour income in the non-farming industry. This is reflected in the substantial reallocation of rural labour in favour of non-farming industry (Table 3.3a). In manufacturing, labour increases at much slower pace.

Despite the large increase in non-farming labour, overall labour in the rural declines when mobile money is introduced, as the labour that leaves farming exceeds that which is taken up by non-farming. Thus, both households living in the rural reduce their labour supply, but the mixed-rural household reduces the most because it receives larger amount of remittances from its counterpart in the urban (Table 3.3b). Meanwhile, both households living in the urban increase their labour supply, with the mixed-urban household increasing the most because its marginal contribution to the pooled resources of the mixed household becomes larger when the cost of remitting is lowered. In view of this, the mixed-urban works more than the purely urban household typically demonstrating the altruistic sacrifice behaviour of migrants, which becomes stronger when the technology used to remit money improves, consistent with findings by Lee *et al.* (2021) for Bangladesh. These results also agree with the argument that remittances may reduce labour supply of the receiving households (Bayangos and Jansen, 2011; Hossain and Sunmoni, 2021).

Since the effect of mobile money through the primary income channel is to raise the equilibrium rural wage, it benefits all households in the rural evenly. By contrast, the effect of mobile money through the secondary income channel goes directly into increasing the disposable income of the mixed-rural household, which like other rural basket households, it uses to increase consumption of manufactured goods at steady state (Table 3.6a). It deserves

[38] Comparison is made between Model 1 and Model 2 because they are both without capital.

to mention that labour incomes from farming and non-farming change at lower rate between the scenarios in Model 3 than in Model 2, but the change in the aggregate rural labour income is higher in Model 3 than in Model 2. This is explained by the fact that the weight of non-farming labour income in total rural labour income is higher in Model 3 than that of Model 2, because farming has capital, while non-farming does not.

Table 3.1: Change in production, all firms[39]

	Change from baseline to m-money	
Item	Model 2	Model 3
Constant steady state prices		
GDP	0.33%	0.67%
Rural total	-1.03%	-1.16%
Farming	-4.73%	-5.94%
Non-farming	24.39%	23.07%
Manufacturing	1.95%	1.80%
Current consumer price		
GDP	4.54%	3.52%
Rural total	3.84%	2.76%
Farming	2.95%	1.38%
Non-farming	8.56%	8.16%
Manufacturing	5.42%	4.01%
Current factor cost		
GDP	6.24%	5.06%
Rural total	6.94%	6.75%
Non-farming	34.41%	33.91%

See Table 3C1, for corresponding data in levels.

In Model 3, the urban households also increase investment when mobile money is introduced (Table 3.5). Capital in farming opens opportunity for the mixed household to tap into the rising price of farm goods by increasing its investment. As for the purely urban household, it increases investment by way more than it increases labour supply. It deserves mention that the change in investment by each household matches the change in the value of output of the industry they invest in, because each investing household is the sole supplier of capital to the industry concerned. Thus, the mixed-urban household investment increases by 1.38 per cent, same as the change in the value of farming output, and likewise, the purely urban household investment

[39] Although the models in this work represent closed economy and involve only non-resource goods, it is arguable that some of the steady state responses in the rural sector, to introduction of mobile money, manifest similar elements as those of Dutch disease, for the rural sector. That is, the non-farming industry expands on the expense of farming, and on aggregate, labour supply declines in the rural, as well as the real output in the rural economy (tables 2.2, 2.4, 3.1 and 3.3b) (Chowdhury and Rabbi, 2012).

increases by 4.01 per cent, same as the change in value of manufacturing output (tables 3.1 and 3.4).

Table 3.2: Generation of primary income

Item	Change from baseline to m-money	
	Model 2	Model 3
GDP income side, adjusted [a]	4.54%	3.52%
GDP income side	6.24%	5.06%
Rural firms	6.94%	6.75%
Paid to labour	6.94%	7.51%
Farm goods	2.95%	1.38%
Non-farm goods	34.41%	33.91%
Paid to capital farming		1.38%
Urban firms	5.42%	4.01%
Manufacturing paid to labour	5.42%	4.01%
Manufacturing paid to capital		4.01%
Manufacturing dividends	5.42%	4.00%

[a] Adjusted to remove transaction fees
See Table 3C2, for corresponding data in levels.

Table 3.3a: Change in labour and capital demanded by firms

Item	Change from baseline to m-money	
	Model 2	Model 3
Labour		
Farming labour quantity	-4.73%	-6.82%
Non-farming labour quantity	24.39%	23.07%
Manufacturing labour quantity	1.95%	1.80%
Farming labour value	2.95%	1.38%
Manufacturing labour value	5.42%	4.01%
Non-farming labour value	34.41%	33.91%
Rural wage	8.05%	8.81%
Urban wage	3.40%	2.17%
Capital		
Rented to farming		-0.78%
Rented to manufacturing		1.80%
Farming capital rental value		1.38%
Manufacturing capital rental value		4.01%
Farming rental price		2.17%
Manufacturing rental price		2.17%

See Table 3C3, for corresponding data in levels.

Table 3.3b: Change in labour supply by the households

Item	Change from baseline to m-money scenario	
	Model 2	Model 3
Rural		
Purely rural households quantity	-0.37%	-0.71%
Mixed-rural household quantity	-4.41%	-4.16%
Purely rural households value	7.66%	8.03%
Mixed-rural household value	3.29%	4.27%
Urban		
Mixed-urban household quantity	4.29%	3.90%
Purely urban household quantity	1.15%	0.94%
Mixed-urban household value	7.84%	6.16%
Purely urban household value	4.59%	3.13%
Selected aggregations		
Rural quantity weighted average	-1.03%	-1.19%
Urban quantity weighted average	1.95%	1.80%
Rural value weighted average	6.94%	7.51%
Urban value weighted average	5.42%	4.01%
Mixed household quantity	-2.37%	-2.24%
Mixed household value	5.49%	6.37%

See Table 3C4, for corresponding data in levels.

Despite the reduction in labour supply by the households living in the rural, they both experience positive increase in labour income, because the rural wage increase by way more, compared to the urban wage. Rural wage increases by 8.1 per cent in Model 2 and 8.8 per cent in Model 3, while the urban wage increase by 3.4 per cent and 2.2 per cent, respectively (Table 3.8). Owing to the difference in the wage increase, and the labour supplied by individual households, the purely rural household experiences the largest increase in income, followed by the mixed household, and lastly the purely urban household (Table 3.4b). This underscores the importance of recognizing the role played by the primary income channel in giving the purely rural households access to the benefits of mobile money.

Table 3.4a: Income by household

Item	Model 2		Model 3	
	Baseline	M-money	Baseline	M-money
Purely rural household disposable income [a]	0.4447	0.4788	0.4741	0.5121
Labour income	0.4447	0.4788	0.4741	0.5121
Mixed-rural household disposable income	0.4574	0.5239	0.6702	0.7634
Labour income	0.4365	0.4509	0.3764	0.3925
Net remittances	0.0208	0.0730	0.2938	0.3710
Mixed-urban household disposable income	0.5466	0.5375	1.0828	1.0689
Mixed-urban household total income	0.5675	0.6106	1.3766	1.4399
Labour income	0.5117	0.5518	0.8565	0.9093
Capital income			0.3933	0.3987
Dividends	0.0558	0.0588	0.1267	0.1318
Transaction fees for remittance	*0.0089*	*0.0038*	*0.1259*	*0.0195*
Purely urban household disposable income [a]	0.5548	0.5807	1.3622	1.4106
Labour income	0.4990	0.5219	0.7031	0.7251
Capital income			0.5323	0.5537
Dividends	0.0558	0.0588	0.1267	0.1318
Transaction fees for non-farm goods	*0.0337*	*0.0076*	*0.0518*	*0.0116*
Selected aggregates				
Rural disposable income	0.4469	0.4863	0.5068	0.5540
Urban disposable income	0.5527	0.5699	1.2923	1.3252
Households of rural origin income [a]	0.4611	0.4936	0.5890	0.6276
Mixed household income [a]	0.5020	0.5307	0.8765	0.9162
Ratio of income				
Primary income rural to urban	79.465%	80.612%	33.518%	34.711%
Disposable income rural to urban	80.843%	85.334%	39.213%	41.806%
Income of households of rural origin to urban	83.115%	85.007%	43.243%	44.489%

[a] Primary is equal to disposable income for these lines

Table 3.4b: Change in income by household

Item	Change from baseline to m-money	
	Model 2	Model 3
Purely rural household disposable income [a]	7.66%	8.03%
Labour income	7.66%	8.03%
Mixed-rural household disposable income	14.56%	13.91%
Labour income	3.29%	4.27%
Net remittances	250.78%	26.26%
Mixed-urban household disposable income	-1.66%	-1.28%
Mixed-urban household total income	7.60%	4.60%
Labour income	7.84%	6.16%
Capital income		1.38%
Dividends	5.42%	4.00%
Transaction fees for remittance	*-56.92%*	*-84.49%*
Purely urban household disposable income [a]	4.67%	3.56%
Labour income	4.59%	3.13%
Capital income		4.01%
Dividends	5.42%	4.00%
Transaction fees for non-farm goods	*-77.60%*	*-77.68%*
Selected aggregates		
Rural disposable income	8.83%	9.33%
Urban disposable income	3.10%	2.54%
Households of rural origin income [a]	7.05%	6.54%
Mixed household income [a]	5.72%	4.53%

[a] Primary is equal to disposable income for these lines

Table 3.5: Change in household expenditures

Item	Change from baseline to m-money	
	Model 2	Model 3
Purely rural household consumption	7.66%	8.03%
Mixed-rural household consumption	14.56%	13.91%
Mixed-urban household		
Consumption	-1.67%	-2.22%
Investment		1.38%
Net transfer	250.78%	26.26%
Transaction fees for remittance	*-56.92%*	*-84.49%*
Purely urban household		
Consumption	4.67%	3.43%
Investment		4.01%
Transaction fees for non-farm goods	*-77.60%*	*-77.68%*
Selected aggregation		
Mixed household	5.72%	5.13%

See Table 3C7, for corresponding data in levels.

Although the mixed-urban household experiences a substantial increase in its primary income, it remits more than offsetting amount to its counterpart in the rural, and thus, it ends up with a small negative change in its disposable income. This is mirrored by large increase in the disposable income of the mixed-rural household (Table 3.4b). The labour income of the mixed-rural household increases by 3.3 per cent and 4.3 per cent in Model 2 and Model 3 respectively, while its disposable income increases by 14.6 per cent and 13.9 per cent, respectively. The mixed-urban household mirrors this by having an increase of 7.6 per cent and 4.6 per cent, in its primary income, coupled with a decline of 1.7 per cent and 1.3 per cent in its disposable incomes, in the same order. It is worth mentioning that, on top of remitting more under the mobile money scenario, the mixed-urban household also invests more, in Model 3.[40] The combined disposable income of the households living in the rural increase by far more than the combined income of the households living in the urban (Table 3.4b), as the secondary income channel facilitates income redistribution in favour of the rural. Thus in all models, mobile money narrows the rural-urban disposable incomes. Nonetheless, within each sector, remittances widens the gap between the mixed and the native household disposable incomes. In Model 2, the disposable income of the mixed-rural household becomes 9 per cent higher under the mobile money scenario, compared to only 3 per cent under the baseline scenario, while the corresponding figures for Model 3 become 49 per cent and 41 per cent, respectively.

Consumption and welfare

In line with the impact of mobile money on income, the steady state value of consumption responds with an increase across both sectors, but the rural experiences larger increase (Table 3.6b). The drop in payment friction, does not only raise output, but also releases part of those resources that were held up as transaction fees, into consumption. All households, except the purely urban, consume more of manufactured goods and less of farm goods, because the price of manufactured goods increases relatively less compared to that of farm goods. The purely urban household on the other hand consumes more of rural produced goods than manufactured goods because the drop in the consumer price of non-farm goods dominates the increase in the price of farm goods, thus making them relatively cheaper. This behaviour matches that of

[40] Although investment in farming is not subjected to remittance fees, the prediction of Model 3 is still in agreement with the findings of Hossain and Sunmoni (2021) that the migrant resources have positive effect on the rural physical capital investment in Kenya and Nigeria.

Model 1, meaning that in any of the three models, mobile money increases trade between the rural and the urban sectors.

Together, the three models show that the rural sector will benefit more from mobile money, in terms of consumption at steady state, even if it does not receive remittances. The redistributive role played by the secondary income channel is also evident in welfare. In Model 1, aggregate welfare increases when mobile money is introduced, and so it does in Model 2 and Model 3. The increase occurs with redistribution in favour of the rural in all models, but the models with remittances it becomes stronger if the sectors are looked in isolation. However, if we look at the two mixed households as one household we see that welfare is distributed more evenly across the households in the models with remittances (Table 3.7). The purely rural household experiences stronger increase in Model 2 and Model 3, while the purely urban household experiences milder decrease. The combined welfare of the mixed households also becomes positive.

Relative prices and wages

All relative prices increase upon introduction of mobile money, except the consumer price of non-farm goods (Table 3.7). The price of farm goods increases the most, but the consumer price of non-farm goods drops substantially resulting in an overall decline in the price index of rural produced goods. The price of farm goods increase by 8.1 per cent and 7.8 per cent in Model 2 and Model 3, respectively, while the price of manufactured goods increase by 3.4 per cent and 2.2 per cent, in the same order. The combined price of rural produced goods on the other hand decrease by 3.3 per cent and 3.2 per cent. respectively, inducing higher consumption of these goods by the urban household. Likewise, the relative wages increase both in the rural and urban, but the increase is higher in the rural. The changes in relative prices and wages in Model 2 and Model 3 are qualitatively similar to those of Model 1.

It is worth mentioning at this point that, although introduction of mobile money benefits rural labour earnings more, just as rural productivity shocks do, the mixed-rural household responds with reduction of its labour supply when mobile money is introduced, while it responds with an increase when rural productivity shock occurs. In the case of introduction of mobile money, the mixed-rural household is simultaneously impacted positively through both channels. The primary income channel brings higher wage, while the secondary income channel brings higher remittances. It turns out that the gain it receives from remittances enables it to carry on with much less labour supply. In the case of rural productivity shock though, the impact coming through the primary income channels is positive, while that of the secondary income channel becomes negative and therefore, the mixed-rural household takes up the benefit of higher rural labour income in the rural by supplying more labour there.

Table 3.6a: Household consumption - quantities and values by good type

	Change from baseline to m-money	
Item	Model 2	Model 3
Farm goods quantity		
Purely rural households	-7.49%	-9.82%
Mixed-rural households	-1.56%	-4.90%
Mixed-urban households	-15.50%	-18.37%
Purely urban households	11.79%	11.13%
Non-farm goods quantity		
Purely urban households	24.39%	23.07%
Manufactured goods quantity		
Purely rural households	15.29%	5.47%
Mixed-rural households	22.68%	17.81%
Mixed-urban households	5.31%	24.23%
Purely urban households	-0.04%	6.64%
Farm goods value		
Purely rural households	-0.04%	-2.80%
Mixed-rural households	6.37%	2.50%
Mixed-urban households	-8.69%	-12.02%
Purely urban households	20.79%	19.78%
Non-farm goods value		
Purely urban households cp	8.56%	8.16%
Purely urban households tp	34.41%	33.91%
Manufactured goods value		
Purely rural households	19.21%	20.37%
Mixed-rural households	26.85%	26.93%
Mixed-urban households	8.89%	8.96%
Purely urban households	3.35%	1.84%

See Table 3C5, for corresponding data in levels.

Table 3.6b: Selected aggregation of consumption by good, household and sector

Item	Change from baseline to m-money	
	Model 2	Model 3
Selected aggregates value by good		
Total consumed in the rural	8.83%	9.33%
Farm goods	1.06%	-1.63%
Manufactured goods	20.52%	21.82%
Total consumed in the urban	3.11%	2.30%
Farm goods	7.22%	6.24%
Non-farm goods	34.41%	33.91%
Manufactured goods	-8.52%	-5.90%
Selected aggregate values by household		
Rural average	8.83%	9.33%
Purely rural households	7.66%	8.03%
Mixed-rural households	14.56%	13.91%
Urban average	3.11%	2.30%
Mixed-urban households	-1.67%	-2.22%
Purely urban households	4.67%	3.43%
Mixed household average	5.72%	5.13%
Households of rural origin average	7.05%	6.92%

See Table 3C6, for corresponding data in levels.

Table 3.7: Welfare comparison

Item	Change from baseline to mobile money	
	Model 2	Model 3
Aggregate welfare	0.69%	1.79%
Rural welfare	2.79%	3.64%
Purely rural	1.49%	2.91%
Mixed-rural	10.09%	9.66%
Urban welfare	-3.04%	-3.41%
Mixed-urban	-8.96%	-8.50%
Purely urban	-0.85%	-0.80%
Selected aggregation		
Mixed household	0.52%	0.09%

See Table 3C8, for corresponding data in levels.

Table 3.8: Relative prices, wages and return on capital

Item	Change from baseline to m-money	
	Model 2	Model 3
Prices		
Rural household basket	6.07%	4.98%
Rural produced goods	-3.29%	-3.20%
Farm goods	8.05%	7.78%
Non-farm goods	-12.72%	-12.12%
Manufactured goods	3.40%	2.17%
Urban household basket	0.00%	0.00%
Wages per unit of labour		
Rural households	8.05%	8.81%
Urban households	3.40%	2.17%
Return per unit of capital		
Mixed-urban households		2.17%
Urban household		2.17%

See Table 3C9, for corresponding data in levels.

3.5.3 Impulse response results for Model 2 and Model 3

The objective of this section is to discuss the impulse response results of Model 2 and Model 3, with a view to identifying key insights regarding the different features of each model, with particular attention to the way they affect the impact of mobile money. As in Chapter 2, we focus on selected set of variables, namely remittances, production, consumption, labour supply, welfare, relative prices and return on factors of production. The selected set of impulse response graphs from both models is presented in Appendix E.

3.5.3.1 Farming productivity shock

Response of remittances and non-farm goods

Both models predict that the farming productivity shock will be received with a decline in remittances, as the rise in the rural labour income leads to less demand for transfers (figures E1A and E5A). That is to say that, the secondary income channel allows the benefits of farming productivity shock to be transmitted more effectively to the urban by lessening the remittance burden on the mixed-urban household, consistent with the observation by AW. The decline in gross remittances becomes weaker in the mobile money scenario than in the baseline scenario, because the mixed-urban household becomes more inclined to remit when transaction fees are low. The corresponding behaviour of the remittance transaction fees manifest larger gap between the baseline and the mobile money scenarios, due to the fact that the fees, in the mobile money scenario, account for a smaller part of the gross amount remitted. While remittances respond similarly in both models the impact persistence, becomes much longer in Model 3.

Meanwhile, the value of non-farm goods purchased responds with a decline to farming productivity shock because rural labour migrates into farming, making non-farm goods scarcer, and therefore more expensive. If this shock occurs in the context of mobile money, the value of non-farm goods at consumer price drops by less, and so it does at factor cost in Model 3, but in Model 2, it drops by more at factor cost. It is worth noting that although it drops by more in Model 2 it does so from a higher steady state level. The steady state level of non-farm goods at factor cost is 34 per cent higher, under the mobile money scenario than the steady state level under the baseline scenario (Table 3.1). In sum, mobile money shifts up the response of remittances, while shifting down the response of the quantity of non-farm goods consumed, but given its higher level at steady state, we are able to conclude that, mobile money enhances the pass-through of the benefits of farming productivity shock from the rural to the urban, through both the primary and secondary income channels.

Response of output and income

The farming shock results to increase in GDP in both models, driven by the farming industry (figures E1B, E1C, E5B and E5C). Non-farm goods respond with a decline due to reallocation of rural resources from that industry to farming. Notably, the increase in production of farm goods is stronger in Model 3 than Model 2, consistent with the fact that, in Model 3, the mixed household supplies not only more labour, but also more capital to farming, when that industry is hit by positive productivity shock (figures E1D, E5D and E5L).

The value of manufactured goods produced also responds to farming shock with a decline as the labour in this industry declines. It is worth noting that although labour from the purely urban household increases, the total amount of labour in manufacturing declines in Model 2 and 3 because the mixed-urban household responds to farming productivity shock with substantial reduction in its labour supply (figures E1D, E1F, E5D and E5F). This is to say that, the presence of remitting household causes manufacturing to respond to farming shock with a decline instead of marginal increase as it was in Model 1, where the remitting household was not part. It is important to note that, unlike in Model 1, the drop in manufacturing output in

Model 2 and Model 3, takes place on already higher steady state level achieved, thanks to the presence of remitting household in the urban.

When mobile money is present the value of non-farm goods produced drops by less in response to farming shock, because demand for these goods becomes higher when transaction fees are low. Although the value of non-farm goods drops by less, the quantity produced drops by marginally more. The marginal decline in the quantity of non-farm goods produced can be explained by the fact that the higher factor cost of these goods shifts the rural earnings up, such that they can afford to produce less without compromising their consumption. Thus the reduced decline of the value of these goods at consumer price is primarily caused by the drop in price rather than increase in supply. The value of manufactured goods produced also decline by marginally more in the context of mobile money because the purchasing power of the purely urban households, that make up the majority of labour in this industry, increases allowing them to work less (Figure E1D). Meanwhile, the value of farm goods increase by more and, together with the reduced decline in the value of non-farm goods, result into a larger increase in the value of rural output and overall GDP at consumer price (figures E1B, E1C, E5B and E5C).

Response of labour supply

Regarding household labour supply, Figure E1D shows that, in Model 2, the purely rural household responds with relatively large decline, while the purely urban household responds with a small drop first followed by a small increase, and then smooth convergence to the steady state. The purely rural household supplies less labour because the higher wages arising from the shock enables it to maintain its consumption with less labour, while the purely urban household increases labour supply as the price of rural produced goods in its basket increases. The mixed-rural household on the other hand responds with an increase, while the mixed-urban household responds with a relatively larger drop. This behaviour is explained by the fact that the shock raises the marginal value of labour in the rural relative to the urban and therefore, the mixed household responds by directing more of its labour hours to the rural firms and less to the urban firms. Thus the mixed household response in each sector becomes opposite of the response of the native household. The response of the purely rural household dominates in the rural, while the response of mixed-urban household dominates in the urban, hence, in aggregate, labour supply drops in each sector, and then converges smoothly to steady state. When mobile money is present, the response of the mixed-rural household labour supply is amplified, while that of the purely urban household is dampened. This is partly explained by stronger increase in rural wage and a downward shift in the response of rural produced goods that go into the urban household's basket (figure E1I and E5I).

In Model 3, similar behaviour as that of Model 2 is observed in household labour supply, but the deviations from steady state are much smaller for the households living in the urban, and they take much longer to die out, signifying the smoothing effect afforded by the presence of capital (Figure E5D). The difference of labour supply between baseline and mobile money scenarios in Model 3 is not as discernible as it is in Model 2. Part of the reason for this is that, by being able to invest in farming, in Model 3, the mixed household chooses to supply more capital to that industry than labour (figures E5D and E5L).

The path taken by the response of urban household labour in Model 2 has to do with the structure of the rural economy, coupled with a policy framework that targets headline inflation. As the farming shock hits, the relative price of non-farm goods goes up sufficiently to drive the overall price of rural produced goods up (Figure E1I). The initial response of the price of rural goods, therefore, exerts an upward pressure on the headline inflation. In Model 2, the interest rate jumps up to counter this upward inflationary pressure, as in Model 1 (figures C1H and E1J). The purely urban household labour supply responds to the higher interest rate by dropping below steady state (Figure E1D). Higher interest rate increases the Ricardian household's expected return on bonds, causing it to reduce labour supply and *vice versa*. Once the initial inflationary pressure is tackled, the interest rates drops below steady state, to which the purely urban household responds by increase in its labour supply. From this point on, both variables converge to their steady state levels gradually. Therefore, a farming shock in our model produces more volatile response in interest rate, compared to models with one flexible price industry like that of AW, and Anand and Prasad (2010). This in turn causes the response of labour in the urban to be more volatile.

In Model 3 the reasons for the initial drop in the purely urban household labour supply are different from those of Model 2 and Model 1. First, in Model 3 interest rate does not begin with an increase as in Model 2, partly because the purely urban household is not faced by increase in its expenditure costs as it does in Model 2. Ther reason for this is that its expenditure in Model 3 contains investment goods (manufactured goods), whose price respond with a drop to farming shock. The share of investment goods in the purely urban expenditure is sufficiently large to neutralize the effect of the raising price of non-farm goods on the household's purchasing power (tables 3C5 and 3C7). Second, return on capital is added to the sources of the purely urban household income. Because capital is lagged, the household enters period 1 with relatively large amount of capital. This large amount of capital combined with savings that the household makes by cutting down its investment, allows it to drop its labour by far more than in Model 2, without compromising its consumption. Once the initial reduction of capital has taken effect, the household adjusts its labour up in period 2, and then stays on a smooth path to steady state from there onwards (Figure E5L).

Response of consumption

The response of consumption to farming productivity shock exhibits some dissimilarities across the two models. In Model 2 consumption responds positively to farming productivity shock in all households except the purely urban household (Figure E1G). The purely rural household experiences substantially larger increase, as it reaps the benefits coming through two sources, namely higher labour income and lower price of farm goods. The drop experienced by the purely urban household is partly explained by the fact that the shock leads to an increase in the combined price of rural produced goods, due to reduced supply of non-farm goods. This happens because the increase in the price of non-farm goods dominates the decrease in the price of farm goods, thus reducing the urban household demand for rural produced goods—a behaviour that was also observed in Model 1. By splitting the rural into two labour sharing activities therefore, our model is able to show how a positive shock in one of the rural industries might affect the urban households negatively, which would not be possible in a model with one rural industry like that of AW and Anand and Prasad (2010).

The mixed-urban household on the other hand, gains from the farming shock in two ways. First, it gets relief on remittances, owing to higher income in the rural and second, like the purely rural household, its consumption basket becomes cheaper due to lower price of farm goods. On the rural side, the mixed-rural household experiences increase in consumption for the same reasons as those of the purely rural household, thus together the consumption by the mixed household is impacted positively by the farming productivity shock, but by less intensity compared to that of purely rural household. For all households, in Model 2, consumption converges to steady state monotonically within 16 quarters.

If the shock occurs in the context of mobile money, in Model 2, consumption increases by more among the households living in the rural, while increasing by less for the mixed-urban household and dropping by marginally less for the purely urban household. For the mixed-rural household the larger increase is partly explained by higher demand of non-farm goods, which increases income more in the rural through higher wage (Figure E1I) and reduced cost of sending remittances, that together induce some reallocation of the consumption gain from the mixed-urban household to the mixed-rural household.

In Model 3, the response of consumption to farming productivity shock is much different. The initial impact is negative for all households except the purely rural household, which exhibits similar behaviour as in Model 2 (figures E1G and E5G). The initial impact on the mixed households' consumption is followed by an increase that crosses over into the positive region before returning to steady state. This is explained by the fact that these households take advantage of higher productivity in farming by investing more in that industry first as shown in Figure E5L. As investment converges back to steady state, consumption of the mixed households converges too, but by quarter 6 it crosses over to the positive region and continues to climb until quarter 12, when it begins to return to its steady state level smoothly, taking about twice as long to die out in Model 3, as in Model 2. This persistence in Model 3 signifies the ability of the mixed household to spread its consumption over a much longer period of time, when it is enabled to invest in capital.

As for the purely urban household, consumption drops in Model 3 as it does in Model 2, but this happens at a much smaller magnitude, because the household reduces its investment to smooth out the initial impact of the shock on its consumption. In Model 3, consumption exhibits marginal difference between the baseline and mobile money scenarios, but overall consumption in the rural increase by marginally more, while decreasing by marginally less in the urban (Figure E5G).

Response of welfare

In line with the response of consumption and labour supply to farming productivity shock, welfare responds with an increase in all households living in the rural, with the purely rural household reaping most of the gain in Model 2 (Figure E1H). In the urban, the purely urban household experiences a decline, while the mixed-urban household registers a notable increase. Taking each sector as a whole, the combined welfare of households in each sector increases, in response to farming productivity shock. This contrasts with Model 1 where the urban sector welfare responded with a drop, underscoring the role played by the secondary income channel in the transmission of the benefits of rural shocks to the households living in the urban. When the economy has mobile money, the rural households experience relatively weaker increase in welfare, while the mixed-urban household experiences stronger increase and the purely urban household a milder drop. In general, mobile money plays a role of reallocating part of the welfare gain obtained from farming productivity shock, from the rural to the urban.

In Model 3, we observe similar behaviour in the response of welfare to farming shock, but the impact on the mixed- and the purely urban households is noticeably milder and takes much longer to die out, reflecting the ability of these households to spread their welfare gains across time (Figure E5H). Together, the households living in the urban gain noticeably larger increase in welfare in the presence of mobile money.

3.5.3.2 Non-farming productivity shock

Response of remittances and non-farm goods

The response of remittances to non-farming productivity shock is broadly similar in Model 2 and Model 3. They drop for the same reason as in the farming shock, that the rural income increases hence requiring less remittances. The value of non-farm goods purchased though, responds with an increase as they become more abundant and their price declines (Figure E2A and E6A). Under this shock, therefore, both the primary and secondary income channels facilitate transmission of the positive welfare effects from the rural to the urban. This contrasts with the farming shock, where the effect transmitted to the urban through the primary income channel is negative and that of the secondary income channel is positive. Viewed from the rural households' side, these results show that, while the benefits flowing through the secondary income channel, i.e. remittances, are reduced by the non-farming shock, those flowing through the primary income channel are increased. This underscores the advantage of having both channels in the model.

Mobile money has similar effect on remittances in this shock as it does in farming shock. On the side of urban household purchase of non-farm goods, the value of non-farm goods at consumer price increases by less, although the quantity and value of these goods at factor cost increases by more. This is a reflection of the fact that the consumer price of these goods drops sufficiently to offset the effect of quantity in their consumer's value.[41]

Response of production

In both models, the value of GDP responds with an increase to non-farming productivity shock, which comes from all industries (figures E2B, E2C, E6B and E6C). Although the quantities of farm and manufactured goods produced decline, their relative prices increase by more than offsetting magnitude (Figure E2I). If mobile money is present the response in the value of GDP becomes more pronounced, on account of larger increase in the value of farm and manufactured goods. Although the quantity and value of non-farm goods at factor cost increase by more under the mobile money scenario, the decline in transaction fees causes the response of the value of these goods produced at consumer price to shift down.

Response of labour supply

Household labour supply portrays mixed responses to non-farming productivity shock, but moves in broadly similar way in both models. The purely rural household responds with a small decline, while the mixed-rural household responds with an increase (figures E2D and E6B). In the urban, both households respond with reduction in their labour supply, with that of purely urban household being more pronounced, as the decline in price of non-farm goods drives down the price of rural produced goods, allowing the urban household to reduce its labour supply without compromising its consumption. This is contrary to the farming productivity shock where the increase in the price of non-farm goods becomes dominant in the price of rural produced goods, thus raising the purely urban household's cost of living and hence inducing the household to increase its labour supply. It is also noteworthy that the purely urban household is able to reduce its labour supply more than the mixed-urban household in the face of non-farming productivity shock. This is explained by the fact that, while the purely urban household experiences decline in the price of the rural component of its consumption basket, the mixed-urban household experiences an increase, which implies that the shock reduces the purely urban household's cost of living by relatively more than it does for the cost of living of

[41] Although the relative consumer price of non-farm goods appears to drop less in the mobile money scenario (Figure E2I), it still becomes lower because the steady state base from which it drops is low also, about 12 per cent below its baseline steady state level (Table 3.8).

the mixed-urban household.[42] If this shock occurs in the context of mobile money, the mixed-rural household increases its labour supply by slightly less, while the purely urban household does the opposite also, but by slightly less. Overall labour supply declines more in the rural, while declining less in the urban. For all households, the response of the quantity of labour supplied occurs at relatively small scale.

Response of consumption

In both models, the non-farming productivity shock is received with an increase in consumption by all households (figure E2G and E6G). Among the households living in the rural, the purely rural household experiences larger increase. Consumption by the mixed-rural household falls behind as it receives less transfers. In the urban, the mixed-urban household experiences larger increase in consumption on account of its direct connection with the rural, which comes in form of reduced remittances. The purely urban household gains consumption because of reduced price of non-farm goods that outweighs the increase in the price of farm goods. When mobile money is present rural households gain more consumption from the non-farming shock, but among the urban households there is no a noticeable difference. Owing to the positive effect mobile money has on the mixed-rural household consumption, the response for the entire mixed household is boosted a little under the mobile money scenario.

Response of welfare

Regarding welfare, the households in the rural respond in divergent manner to non-farming productivity shock, while all urban households respond positively, albeit with a wide difference in magnitude (figures E2H and E6H). The purely rural household experiences a notable gain, while the mixed-rural household experiences loss. The loss experienced by the mixed-rural household is driven by three factors. First, the household supplies more labour because of relative increase in labour income in the rural, which dictates that the mixed household supply more labour hours in the rural, and less in the urban (figure E2D and E6D). Second, it experiences higher price of its consumption basket as the prices of both farm goods and manufactured goods increase (figures E2I and E6I), and third, it receives less remittances because, besides the response of labour income in the rural being higher, the non-farming

[42] The decline in the price of non-farm goods more than offsets the increase in the price of farm goods in the urban household consumption basket. The mixed-urban household though has the farm goods only in its basket, so it only sees price increase as a result of non-farming productivity shock.

productivity shock raises the cost of the mixed-urban household basket too. The mixed-urban household on the other hand, gets positive welfare benefits, which come in form of reduced labour supply and remittances, coupled with increased consumption (figures E2A, E2D, E2G, E6A, E6D and E6G). The gain in the mixed-urban household welfare, however, is more than offset by the loss incurred by the mixed-rural household, thus the welfare of mixed household as a whole is impacted negatively by the non-farming shock.

In Model 3, the mixed-rural household begins with a loss in welfare, but unlike in Model 2 where it returns gradually to steady state, it takes a non-monotonic path that crosses over to the positive side around quarter 3 and continues to climb to a peak around quarter 10, from where it declines gradually to the steady state. Thus, the presence of capital enables the mixed-rural household to enjoy positive welfare benefits from non-farming productivity shock, that it does not in the absence of capital. The effect of mobile money varies between Model 2 and Model 3. In Model 2, the welfare of the mixed-urban household increases by notably larger amount, while that of the mixed-rural household drops by less, because of a combination of higher labour income from non-farming industry and savings from the transaction fees for remittances. In Model 3, the welfare increase shifts up for the mixed-urban household, while shifting down for the mixed-rural household. As for the purely urban household the increase is subdued when there is mobile money, while for the purely rural household it increases by marginally less.

3.5.3.3 Manufacturing productivity shock

Response of remittances and non-farm goods

Manufacturing productivity shock increases the income of the urban households relative to that of the rural, and accordingly, remittances respond with an increase in both models (figures E3A and E7A). Notably, when mobile money is present, gross remittances increase by less, but the amount that arrives on the other end increases by more, showing that the amount recovered from transaction fees is mostly passed over to the mixed-rural household.

As for the purchase of non-farm goods, the value increases in both models and so does the fees paid. If the economy has mobile money, the value increases more, while the associated transaction fees increase by less. This reflects the fact that the purely urban household purchases more of those goods as they become cheaper, and that the proportion that gets lost as transaction fees becomes much smaller. The transmission of the shock to the rural becomes more efficient through both channels when mobile money is present.

In all productivity shocks, we see that the primary and secondary income channels reinforce each other to pass the benefits of mobile money to the rural. The response of remittances to any shock shifts up when mobile money is present and so does the response of primary income. This serves to show that the mechanism by which the disposable incomes of the rural increase may not be explained by remittances alone as suggested by most authors, but also by increase in direct purchase of rural produced goods, i.e. through the primary income channel (AW; Jack et al., 2013; Lenka and Bairwa, 2016; Mbiti and Weil, 2016; Morawczynski and Pickens, 2009; Munyegera and Matsumoto, 2016).

Response of production

The value of GDP responds with an increase to manufacturing productivity shock in both models, and the main driver of this response is manufactured goods. Non-farming industry also responds with an increased production, but the farming industry responds with a decline. The behaviour of rural production mirrors the increased demand for non-farm goods, induced by higher income of the purely urban household. Besides manufacturing, the response of other firms' production happens at very small scale (figures E3B, E3C, E7B and E7C). If the economy has mobile money, the value of farm goods produced drops by a notably larger magnitude, while that of non-farm goods responds with a larger increase on impact, as demand for these goods shifts up. Overall, the value of rural output responds with a weaker increase when mobile money is present, as the drop in farming offsets the increase in non-farming, while in the urban, output responds with a marginally stronger increase.

In Model 3 all firms respond to manufacturing productivity shock with increase in the value of output produced. The path and persistence of output responses is notably different between the two models. In Model 2 the values of all goods produced converge back to steady state from their initial response positions monotonically, but in Model 3, the paths of farm and non-farm goods are curved according to the path taken by the capital used in farming. Capital in farming responds to manufacturing productivity shock positively on impact and continues to increase gradually until it reaches a peak around quarter 24, and then converges to steady state gradually (Figure E7L). Investment responds to manufacturing shock positively because manufactured goods, that also play as capital goods, become cheaper. In Model 3, the response of the value produced is broadly similar to that of Model 2, but again the path taken by the output of the rural firms is curved and more persistent. Thus mobile money shifts the response of non-farm goods production up, mirrored by a downward shift in the response of farm goods. This reflects the relatively higher demand for non-farm goods induced by the reduction in transaction costs.

Response of labour supply

In Model 2 labour supply responds to manufacturing productivity shock by a decrease for all households except the mixed-urban. The purely urban household responds with a marked reduction, while the mixed-urban household keeps its labour supply close to its steady-state level, beginning on the negative side and then jumping to the positive region after two to four quarters, and thereafter converging steadily to the steady state. Both households staying in the rural reduce their labour supply, but the mixed-rural household reduces the most, because it receives more remittances. The purely rural household reduces its labour supply more when there is mobile money, partly due to stronger decline in the price of manufactured goods that makes its consumption basket cheaper (Figure E3D). Despite the decline in labour supply, all households, except the mixed-rural, experience increase in labour income because of rise in relative wages (Figure E3I). Model 3 exhibits similar behaviour as Model 2 with regard to household labour supply, but the path to steady state becomes curved and longer lasting on account of the behaviour of capital used by firms (figures E7D and E7I).

Response of consumption

In both models, all households experience increase in consumption due to manufacturing productivity shock. The purely urban household experiences the largest increase, while the mixed-urban household falls behind because it remits part of the gain (figures E3G and E7G). In the rural the increase of the mixed-rural household consumption exceeds that of the purely rural household markedly, reflecting the large remittances it receives.[43] In Model 2, the initial response in consumption is followed by gradual convergence to steady state for each household. In Model 3 though, the path to steady state from the initial response of consumption is curved for each household, but most notably for the purely rural and purely urban households.

[43] This happens even though the mixed-rural household labour income declines.

The presence of remittance receiving household in the rural raises the overall rural consumption gains from urban productivity shock, while the presence of mixed-urban household in the urban dampens the combined urban households' consumption gain from the shock. In other words, remittances strengthen the pass-through of urban shock to the rural. The consumption of the mixed household as a whole is impacted more strongly than the purely rural household. If the manufacturing shock occurs when the economy has mobile money, consumption increases by more for the mixed-rural household, while increasing by less for the mixed-urban household. This is a reflection of the fact that the mixed-urban household works less when mobile money is present (Figure E3D), and that the lower cost of remitting money translates the reduced gross amount remitted into larger net amount received in the rural. That is to say, the drop in gross remittances becomes more than offset by the amount recovered from transaction fees due to the presence of mobile money. As in the previous two shocks, the response of consumption becomes stronger in the rural when mobile money is present, while in the urban it does not show discernible difference. Interestingly, with mobile money, the response of consumption by the purely rural household shifts up in Model 3, contrasting with Model 2 where this household experience a marginal downward shift in consumption (figures E3G and E7G). This happens as the purely rural household responds to cheaper manufactured goods by consuming more (figures E3I, E7I), while other households invest part of the manufactured goods they buy.

Response of welfare

Turning to welfare, we see in figures E3H and E7H that in both models, manufacturing productivity shock raises the welfare of all households in the economy, with most of the gain going to the purely urban and the mixed-rural households. When mobile money is present, the purely rural and the mixed-urban household welfare increase by more, while that of the mixed-rural increases by less. The increase in the urban comes entirely from reduced labour supply, because consumption increases more for all rural households. The reallocation of welfare gains cancel out within the mixed household, leading to near neutral impact from the presence of mobile money. The main difference between the two models is that in Model 3 the response of welfare is much more persistent than in Model 2, again reflecting the ability of the households to save through capital acquisition.

3.5.4 Monetary policy issues

In this section we discuss the impulse responses of inflation and interest rate to productivity shocks. Next we discuss the response of selected endogenous variables to monetary policy shocks and finally, we carryout validation of the models against data and estimation of optimal monetary policy rules.

3.5.4.1 Response of inflation and interest rate to productivity shocks

For all positive productivity shocks the headline inflation responds with a decline, consistent with the fact that each shock increases supply of its own goods, while at the same time pulling the price of other goods down by drawing demand away from them. The response of inflation and interest rate to farming shock is largely similar between Model 1 and Model 2 (figures E1J and C1H). Interest rate jumps above its steady state level first before it drops below and then converges smoothly to its steady state level. The volatility of interest rate and that of urban labour supply discussed earlier, can be calmed down if the policy rule targets core inflation. This however, happens at the expense of increasing volatility in headline inflation (Figure E10A)—a behaviour also observed by AW. In Model 3, we observe similar behaviour, but the influence of non-farm goods price is relatively more subdued, thus the initial increase in interest rate observed under the farming shock, is not there. This is explained by the fact that, part of purely urban household demand, in Model 3, is diverted into capital goods, thus reducing the pressure imposed by this household on the price of rural produced goods. Inflation takes lower path in the mobile money scenarios of Model 2 and Model 3 as well, and so does the interest rate.

From non-farming shock, we observe similar behaviour in Model 2 and Model 3 as in Model 1, but again in Model 3 the responses are not as large as in the other two models (Figure E2J and H6J). As in the case of farming shock, mobile money scenario leans on the side of shifting the response of inflation and interest rate down, although the difference under this shock is much smaller. Manufacturing productivity shock also drives headline inflation down, primarily due to lower price of manufactured goods. In this case the prices of farm and non-farm goods also decline and accordingly, interest rate follows. Although the difference between baseline and mobile money scenarios is small, inflation appears to drop by less under the mobile money scenario than it does under the baseline scenario, as it did in Model 1 (figures C3H, E3J and

E7J). This again shows the increased influence of the state of rural economy on headline inflation under the mobile money scenario.

In Table 3.9, we use relative weights of the shocks in the variance of the selected policy variables, as an alternative way of assessing the effect of mobile money on the response of monetary policy to productivity shocks. We did the same for Model 1 in Table 2.8. We see that rural based shocks gain weight in the variance of the policy variables, when mobile money is present in all models as they did in Model 1. This implies that the policy design needs to pay more attention to the state of the rural economy, under the mobile money scenario, because it becomes more integrated into the national economy, under this scenario, compared to the baseline scenario. It is noteworthy that in Model 3, the weight of farming shock in the variance of interest rate is way larger than it is in the other two models. This is a manifestation of the indirect influence that return on capital in farming has on interest rate.[44] By allowing the mixed household to invest, we expose its behaviour to the stabilizing effects of monetary policy actions, effectively increasing the proportion of Ricardian households in the economy.

Table 3.9: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, interest rate rule[45]

Item	Farming shock	Non-farming shock	Manufacturing shock	Policy shock
Model 2				
Output	1.200	1.124	0.980	1.000
Inflation	1.161	1.070	0.935	1.016
Interest rate	1.000	1.065	0.958	1.024
Model 3				
Output	1.250	1.035	0.998	1.000
Inflation	1.231	1.041	0.986	1.017
Interest rate	1.375	1.057	0.987	1.020

3.5.4.2 Monetary policy shock

Applying expansionary policy shock under the interest rate rule (IRR) in Model 2 and Model 3, produces results that are broadly similar to those observed in Model 1 (figures E4C and

[44] In Model 1 and Model 2 the policy has to sync the change in the price of manufactured goods and wage in manufacturing only, but in Model 3 it has to do so for the return on capital as well. This means that a shock in farming, when this industry is using capital, demands more from policy response, than when it is not.
[45] Corresponding results under MSR are presented in Table 3C10.

E8C). GDP responds with an increase, driven mostly by manufacturing and to a less extent non-farming. Farming responds with a drop (figures E4B and E8B). The households living in the urban increase their total labour supply, but the mixed-urban household increases the most. By contrast, the households living in the rural respond with reduction in their labour supply, with the mixed-rural household reducing the most (Figure E4D). Thus, as it was in the case of manufacturing productivity shock, the increase in the manufacturing wages in Model 2 and Model 3 (Figure E4I) draws labour hours from the rural to the urban through the mixed household. Because of this, the decrease in rural labour supply due to expansionary monetary policy is relatively deeper in Model 2, where remittances are present, compared to Model 1. The mixed-rural household affords to reduce its labour supply more than the purely rural household, because it receives more remittances (Figure E4A), consistent with the findings by Bayangos and Jansen, (2011), and Hossain and Sunmoni, (2021).

If the policy shock occurs in the presence of mobile money, the optimal price of manufactured goods responds with a stronger increase, indicating a more efficient flow of the policy signal across the economy under this scenario. This resonates with the findings by Ndirangu and Nyamongo (2015), that there was improved effectiveness of monetary policy after mobile money was introduced in Kenya. Accordingly, the relative wage of the urban increases by more, which translates to stronger response in the urban purchasing power. This causes the response of demand for non-farm goods to be stronger and therefore production of farm goods drops by more (figures E4B and E8B). This way, mobile money increases the welfare benefits of the policy shock to the rural households.

While the responses of production in farming and non-farming in Model 2 converge to their respective steady state monotonically after the initial impact, in Model 3 they take curved paths, shaped by the mixed-urban household investment (figures E4B, E8B and E8J). The mixed-urban household investment and capital drop first, as production of farm goods decreases due to migration of rural labour into non-farming. They then increase gradually as the price of farm goods increases (figures E4I and E8I). The mixed-urban household capital turns positive around period 20 and keeps on increasing until it reaches a peak around period 50 and then converges to steady state smoothly. The response of most variables to policy shock in Model 3 is milder than in Model 2, which is consistent with the fact that the number of households that can optimize across time is larger in Model 3 compared to Model 2.

In sum, mobile money makes the production in all industries more responsive to policy shock. It also increases the welfare benefits of expansionary monetary policy for the rural households by intensifying the increase in income and consumption, and the reduction in household labour supply. Interestingly, in Model 2, the increase in urban labour supply due to policy shock is sufficiently large to turn the welfare response of the urban households negative (Figure E4H). In Model 3 though, the ability of the urban households to invest makes the response of their labour supply relatively less, such that they too receive positive welfare gain from policy shock (Figure E10C). The presence of remittances widens the gap between the response of rural and urban production, while narrowing the gap in the response of consumption. The presence of capital on the other hand, helps to distribute the welfare gains from policy shock more evenly across the rural and urban.

As observed in Model 1, inflation and interest rate become more sensitive to policy shock when the economy has mobile money compared to the baseline scenario. The policy shock increases demand across all sectors of the economy, but the extent to which rural demand impacts inflation, and therefore interest rate, becomes stronger under the mobile money scenario (Table 3.9).

Policy options

As observed in Model 1, most variables respond in qualitatively similar fashion under the MSR as in IRR. Figures E9A to E9D puts together a summary of impulse response functions, that manifest notable difference between the policy rules. These variables are the same as those selected in Model 1, namely those related to manufacturing and inflation. The responses reaffirm the observation made in Model 1, that IRR stabilizes the economy better than MSR.

Regarding headline versus core inflation targeting, in Model 2, the mean value of total welfare produced by headline inflation targeting is higher than that produced by core inflation targeting, similar to the results observed in Model 1. In Model 3 though, the results are opposite, i.e. core inflation targeting produces higher welfare than headline inflation targeting (Table E1). The difference in welfare between the two policy options remains very small in all models. Nonetheless, given that Model 3 has larger proportion of households with access to saving (40 per cent in Model 3 compared to 30 per cent and 33 per cent in Model 2 and Model 1, respectively), these findings are compatible with the observation made by Anand and Prasad

(2010) that, targeting core inflation becomes welfare maximizing as the proportion of rule-of-thumb consumers declines.

3.5.4.3 Model validation

Since we have developed three models in this work, it is pertinent at this stage, to validate them against data, with a view to finding out the extent to which their predictions match the data. In particular, we compare the second moments of selected endogenous variables, namely the standard deviation, correlation and autocorrelation of output, inflation and interest rate. The data used are quarterly GDP at constant price, consumer price index (CPI) headline inflation and interbank cash market interest rate from Tanzania for the period 2000 to 2022. The summary of the moments is presented in Table 3.10. The standard deviations produced by Model 3 are closest to those found in data. As for the cross correlations, the sign of correlation between output and inflation is the same, although all models produce much stronger correlation compared to data. Regarding interest rate, its correlation with output is negative for all models, but positive in data. However, if lagged by at least one period the sign of output correlation with interest rate in data becomes negative. This is partly explained by strong seasonality in output, which is also manifested in its coefficients of autocorrelation. Its first to third order autocorrelations are negative, but the fourth order is positive and very close to those produced by Model 3.

On the basis of these statistics, we see that the moments from Model 3 are the closest to those found in data. This conforms with the literature that associates migration, remittances and investment in the rural (Lee *et al.*, 2021; Oyvat, 2017; Tragger 1984). In addition, the share of GDP transacted by mobile money in Model 3 is 8 per cent, which is only one percentage point above the share of mobile money in transaction balances for Tanzania (Bank of Tanzania, 2022). This is in agreement with the finding by Mbiti and Weil (2016) that mobile money circulates faster than other forms of transaction balances, implying that it may support larger share in GDP transactions than its share in the transactions balances. Furthermore, the share of non-farm income to total rural income in Model 3 is 22 per cent, which is close to 24 per cent for Tanzania, reported by Nagler (2015) from the World Bank LSMS-ISA data. This share is 19 per cent and 17 per cent for Model 1 and Model 2, respectively. It deserves also to mention that, under the MSR framework, the implied income velocity of circulation in the baseline scenario of Model 3 is 2.2 and for the mobile money scenario it increases to 2.3. These values are close to the average of 2.5 for Kenya. We therefore proceed with estimation of optimal policy rule using Model 3.

Table 3.10: Selected second moments [a]

	Output	Inflation	Interest rate
Standard deviation			
Data	0.0465	0.0330	0.0369
Model 1, baseline	0.0123	0.0154	0.0181
Model 1, m-money	0.0123	0.0149	0.0175
Model 2, baseline	0.0120	0.0151	0.0182
Model 2, m-money	0.0130	0.0158	0.0187
Model 3, baseline	0.0441	0.0312	0.0301
Model 3, m-money	0.0450	0.0307	0.0296
Cross correlation with output [b]			
Data	1.0000	-0.0279	*-0.0113*
Model 1, baseline	1.0000	-0.9898	-0.9786
Model 1, m-money	1.0000	-0.9891	-0.9748
Model 2, baseline	1.0000	-0.9891	-0.9791
Model 2, m-money	1.0000	-0.9884	-0.9770
Model 3, baseline	1.0000	-0.9974	-0.9958
Model 3, m-money	1.0000	-0.9973	-0.9957
Coefficient of autocorrelation [c]			
Data	0.8720	0.9140	0.7490
Model 1, baseline	0.7561	0.8676	0.9395
Model 1, m-money	0.7463	0.8612	0.9369
Model 2, baseline	0.7591	0.8658	0.9366
Model 2, m-money	0.7504	0.8591	0.9338
Model 3, baseline	0.8794	0.9463	0.9745
Model 3, m-money	0.8770	0.9450	0.9738

[a] In this table, the rural to urban household ratio of Model 1 is adjusted from 2:1 to 1.5:1, to match it with the 6:4 ratio of the other two models. This adjustment is to make the three models more comparable.

b The correlation of output with interest is only negative from lag 1

c The order of autocorrelation is 1 for inflation and interest rate and 4 for output. Order 4 has been used for output because it is highly seasonal.

3.5.4.4 Estimation of optimal policy parameters

In this section we attempt to work out optimal monetary policy rule, defined as a rule that generates maximum aggregate welfare response from the positive productivity shocks under each of the payment scenarios. In particular, we estimate a combination of the parameters of the Taylor rule equations for IRR, that maximizes the aggregate welfare as presented in equation M77 in Table 3B2.[46]

Following the procedure used by Quint and Rabanal (2013), we limit the search range to $\rho_i \in (0,1)$; $\rho_\pi \in (1,10)$; and $\rho_y \in (0,1)$, in order to speed up the process of obtaining optimal coefficients. The estimations are made in the context of all three productivity shocks discussed in the previous sections. Tables 3.11a and 3.11b present the estimated optimal parameters for the baseline and the mobile money scenarios, of Model 3, alongside the calibrated parameters, together with cumulative welfare gain for each policy rule and payment scenario.

Table 3.11a: Optimal policy rule parameters

Policy rule	Payment scenario	ρ_i	$\frac{\rho_\pi}{1-\rho_i}$	$\frac{\rho_y}{1-\rho_i}$
Calibrated	Baseline and mobile money	0.700	6.667	3.333
Optimal	Baseline	0.226	1.467	0.010
	Mobile money	0.549	4.005	0.038

Table 3.11b: Comparison of welfare gain between the policy rules

	Cumulative welfare [a]					
	Baseline			Mobile money		
Shock in	Calibrated	Optimal	Change	Calibrated	Optimal	Change
Farming	4.564	4.784	4.82%	4.375	4.566	4.37%
Non-farming	1.416	1.633	15.32%	1.201	1.514	26.06%
Manufacturing	124.554	127.81	2.61%	126.843	130.156	2.61%

[a] The number of periods for cumulative welfare was chosen such that the observable persistence of the shock in all endogenous variables was exhausted.

The estimated optimal policy rule parameters suggest a relatively subdued monetary policy response under the baseline and a stronger response under the mobile money scenario. The optimal policy under the baseline scenario delivers positive deviation in headline inflation and interest rate, in response to farming productivity shock, which is opposite of what we have seen under the calibrated rule (Figure E5K). These divergent outcomes can be explained by looking at the way the response of consumption to farming shock flows through two categories of

[46] We choose to carry out estimation of optimal policy rule under the IRR, because the East African countries studied in this work have all adopted interest rate as their monetary policy operational target.

households, the rural basket households and the purely urban households, separately. The rural basket households consume farm and manufactured goods only, while the purely urban households consume all goods produced in the economy.

The farming productivity shock increases supply of farm goods; reduces their price relative to that of manufactured goods, driving rural basket households' demand towards farm goods and away from manufactured goods. This pulls the price of manufactured goods downwards. The decline in the price of manufactured goods coupled with the decline in the price of farm goods exert downward pressure on headline inflation. Therefore, the response of rural basket households' demand to farming shock, viewed in isolation, sums up to having deflationary effect.

From the purely urban household perspective, the outcome is different. The reduction of supply of the non-farm goods arising from a positive farming productivity shock increases the price of non-farm goods sufficiently to make the aggregate price of rural produced goods relatively higher, compared to the price of manufactured goods. This drives the purely urban households' demand towards manufactured goods, and away from rural produced goods, thus exerting upward pressure on the price of manufactured goods. This, coupled with the increase in the price of non-farm goods, sums up having inflationary effect. Depending on which one of the two demand forces dominates, the price of manufactured goods, and subsequently the headline inflation, may end up being lower or higher than their corresponding steady-state levels, following a farming productivity shock. If the rural basket households' demand effect dominates, the price of manufactured goods will decline and show up as decline in both core and headline inflation. If, on the other hand, the purely urban households' demand effect dominates, then the price of manufactured goods will go up and show up as an increase in both core and headline inflation.

The purely urban households' demand is the most directly affected by monetary policy and therefore, its effect on inflation depends on how aggressive the policy is. If this demand is left unchecked, it dominates and thus causes inflation to rise in response to farming productivity shock. The more the purely urban households' demand is constrained by policy the less influential it becomes, and the less inflationary the farming shock becomes, up to a point that it becomes deflationary. The estimated optimal policy rules are passive enough to allow the farming shock to be inflationary, while the calibrated rule is sufficiently aggressive to have deflationary outcomes. Since GDP responds with an increase to farming shock, these results show circumstances under which a positive supply side shock may become both growth inducing and inflationary and still be optimal.

The results also reveal a noteworthy difference between having capital and not having it in the model. For each shock, Model 3 yields substantially more stable headline inflation. This demonstrates the enhanced strength of monetary policy due to broader access to savings in Model 3 (figures E5K, E6K and E7K). The stability of headline inflation also improves noticeably, in the context of mobile money.

3.6 Conclusion

In this Chapter we have made two extensions to Model 1 that was developed in Chapter 2. In the first extension, we developed Model 2 by adding secondary income channel through which mobile money impacts the economy and in the second extension we developed Model 3 by adding capital to Model 2. The secondary income channel was added by including a third type of household, that has two members: one living and working in the rural and another, a migrant who lives and works in the urban. We refer to the household member in the rural as mixed-rural household and the one in the urban as mixed-urban household. The mixed-urban household uses the prevailing money transfer technology to make remittances to the mixed-rural household, with objective of equalizing their consumption. Since there is cost involved in sending remittances, the consumption of the mixed-rural household is less than the consumption of mixed-urban household by the amount taken away as money transfer fees. Mobile money plays the role of reducing the transaction fees and therefore brings the consumption of the mixed households closer. The setting of Model 2 establishes microfoundations for remittances, based on the altruistic motive and therefore constitutes a further extension of the AW model, which assumes an ad hoc remittance rule, also based on altruism. In Model 3 we relaxed the assumptions of the households in the urban by allowing them to own capital and rent it to specific firms. The mixed-urban household rents its capital to the farming industry, while the purely urban household rents its capital to manufacturing industry. As a producer of artisanal goods, the non-farming industry is assumed to employ labour only.

The steady state results of Model 2 and Model 3 revealed that GDP responds with an increase to introduction of mobile money, driven by the non-farming industry, as in Model 1. However, the secondary income channel, which is enabled by the presence of the mixed household, helps to broaden the base of steady state output growth by supplying more labour hours to the urban through the mixed household, thus boosting manufacturing output as well. Regarding incomes and consumption, the secondary income channel facilitates further redistribution in favour of the rural. Net remittances increase in both models when mobile money is introduced and accordingly, consumption increases more in the rural, while increasing less in the urban.

Regarding capital, we observed that its presence in Model 3 drives rural wages further up, at steady state. This increases the rural consumption and welfare gains from the introduction of mobile money even more. This happens because, when mobile money is introduced the supply of labour hours in the rural changes in favour of non-farming industry. It turns out that when the model has capital, farming retains a relatively larger amount of capital compared to labour. This condition demands higher increase in wages in order to equate the change in the value of labour with the change in the value of capital in farming.

As for the impulse response results we have observed that, the value of GDP responds with an increase to all productivity shocks as in Model 1, with manufacturing shock delivering the largest increase in GDP followed by non-farming and lastly farming. Mobile money makes the response of the value of output stronger for all shocks, but more so for those occurring in the rural. The presence of remitting household makes the response of output more volatile because it allows labour hours trade-off between the rural and the urban through the mixed household. With the mixed household, a positive productivity shock in farming draws labour hours not only from non-farming, but also from manufacturing, and likewise, a positive shock in manufacturing draws labour hours from the rural to the urban.

Contrary to its destabilizing effect on output, the secondary income channel facilitates transmission of income gains, arising from positive productivity shocks, from one sector to the other thus increasing stability of consumption and welfare. Mobile money enhances the response of rural households' consumption to all shocks, because the amount recovered from transaction fees goes into increasing both the primary and disposable incomes of the rural households.

The presence of capital in the model spreads the response of output to manufacturing shock more evenly across all industries. In Model 2, non-farming responds to positive manufacturing productivity shock with an increase, while farming responds with a decrease. In Model 3 though, the values of both non-farming and farming output respond to positive manufacturing productivity shock with increase because the shock lowers the price of manufactured goods, thus increasing investment in farming, leading to a positive outcome in the value of farming output. In addition, capital helps to distribute the welfare benefits of positive non-farming productivity shock across all households whereas in Model 2 the benefits are experienced by all, but the mixed-rural household. Capital allows the mixed household to earn more by increasing investment in the farming industry, where the price becomes higher when non-farming shock hits. Lastly, capital lengthens the persistence of the response of most variables to shocks, partly because it provides more households with means to spread their welfare across time. These results suggest that omission of capital can alter some important conclusions, contrary to the argument by some authors.

Turning to inflation and interest rate, we observed similar results for Model 2 and Model 3, as those observed in Model 1. All positive productivity shocks lead to a drop in headline inflation, and the policy rate is accordingly reduced in each one of them to bring inflation back to steady state. In the context of mobile money, the response of inflation to rural shocks become stronger and so does the response of interest rate. In the case of manufacturing shock, the response of both inflation and interest rate becomes marginally weaker, when the economy has mobile money. These findings reaffirm our conclusion in Model 1 that mobile money integrates the rural economy more into the national economy, which is compatible with the role it has played in increasing financial inclusion.

Meanwhile, output responds with an increase to expansionary monetary policy shock, driven mostly by manufacturing industry. Mobile money strengthens the impact of monetary policy shock across the economy, while redistributing its welfare benefits in favour of the rural sector. Capital helps to spreads the welfare benefits of the policy shock across all households, whereas without capital the urban households suffer a marginal welfare loss from the policy shock, particularly under the mobile money scenario. Regarding policy rules, we observed that whether the economy has mobile money or not, the IRR performs better than MSR in terms of stabilization of inflation and output, particularly manufacturing output. As for policy targets, two observations have been made. First, the response of manufacturing to farming shock becomes more stabilized if the policy target is core inflation, as opposed to headline inflation. Second, headline inflation targeting produces higher level of welfare than core inflation targeting in Model 2, as in Model 1. By contrast, in Model 3, core inflation targeting produces higher welfare than headline inflation. We associate this with the fact that Model 3 has more households responding to interest rates changes than the other two models, consistent with the observation made by Anand and Prasad (2010).

To validate our models against data, we compared a selection of second moments produced by the models with those found in data and found that, those of Model 3 matched those obtained from data better than those of the other two models. This is in agreement with the argument that migrant incomes support investment in the rural. We then estimated optimal policy rules for the baseline and mobile money scenarios using Model 3 and found that a policy rule that maximizes welfare in the presence of mobile money is one that is relatively more aggressive, compared to the one that maximizes welfare under the scenario without mobile money. This is in conformity with the observation that mobile money integrates the rural economy more into the national economy. It also implies that central banks need to revise their policy rules with expectation of prescribing stronger policy responses to inflation and output gaps, after the introduction of mobile money.

Given the structure of our model, it has been possible to identify circumstances under which a positive productivity shock can be both inflationary and welfare maximizing. By having two resource sharing industries in the rural, coupled with the confinement of non-farm goods consumption to the purely urban households, headline inflation responds with an increase to farming shock, when monetary policy is relatively subdued. For instance, the baseline optimal policy rule estimated in this work is sufficiently subdued to produce a combination of higher inflation, higher output and maximized welfare, in response to positive farming shock. A more aggressive policy rule, like the one calibrated in this work, produces lower inflation, and higher output and welfare in response to the same kind of shock.

Chapter 3 Tables

List of variables, parameters and programmed equations

Table 3A1: List of Model 2 variables

S/N	VARABLE	DESCRIPTION
1	C_t^r	Rural household total consumption
2	$C_{f,t}^r$	Rural household consumption of farm goods
3	$C_{m,t}^r$	Rural household consumption of manufactured goods
4	C_t^z	Urban household total consumption
5	$C_{l,t}^z$	Urban household consumption of rural produced goods
6	$C_{f,t}^z$	Urban household consumption of farm goods
7	$C_{a,t}^z$	Urban household consumption of non-farm goods
8	$C_{m,t}^z$	Urban household consumption of manufactured goods
9	N_t^r	Total labour in the rural
10	$N_{f,t}^r$	Labour in farming
11	$N_{a,t}^r$	Labour in non-farming
12	$N_{m,t}^z$	Labour in manufacturing
13	$\frac{P_{l,t}}{P_t}$	The consumer price of rural produced goods relative to aggregate price index
14	$\frac{P_{m,t}}{P_t}$	The price of manufactured goods relative to aggregate price index
15	$\frac{P_{a,t}^{\mathrm{z}}}{P_{a,t}}$	The consumer price of non-farm goods relative to their producer price
16	$\frac{P_{f,t}}{P_{l,t}}$	The price of farm goods relative to consumer price of rural produced goods
17	$\frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}}$	The consumer price of non-farm goods relative to consumer price of rural produced goods
18	$\frac{P_{f,t}}{P_t^{\mathrm{r}}}$	The price of farm goods relative to the price index of rural household consumer basket
19	$\frac{P_{m,t}}{P_t^{\mathrm{r}}}$	The aggregate price of manufactured goods relative to the price index of rural household consumer basket
20	$\frac{P_{m,t}^*}{P_{m,t}}$	The price chosen by manufacturing firm relative to the aggregate price of manufactured goods
21	$\frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}}$	The ratio of rural wage to the price index of the rural consumption basket
22	$\frac{W_t^{\mathrm{r}}}{P_{f,t}}$	The ratio of rural wage to the price of farm goods
23	$\frac{W_t^{\mathrm{r}}}{P_{a,t}}$	The ratio of rural wage to the price of non-farm goods

24	$\frac{W_t^z}{P_t}$	The ratio of urban wage to aggregate price index
25	$\frac{W_t^z}{P_{m,t}}$	The ratio of urban wage to aggregate price index
26	$Y_t,$	Total GDP
27	$Y_{f,t}^r,$	Farm goods produced
28	$Y_{a,t}^r$	Non-farm goods produced
29	$Y_{m,t}^z$	Manufactured goods produced
30	Π_t	Gross headline inflation
31	$\Pi_{m,t}$	Gross core inflation
32	R_t	Interest rate
33	$A_{f,t}$	Productivity in farming
34	$A_{a,t}$	Productivity in non-farming
35	$A_{m,t}$	Productivity in manufacturing
36	$A_{p,t}$	Policy shock
37	za_t	Numerator for the manufactured relative price equation
38	$zb_t,$	Denominator for the manufactured relative price equation
39	$MC_{m,t}^z$	Marginal cost in manufacturing
40	v_t^r	Rural household lifetime welfare
41	v_t^z	Urban household lifetime welfare
42	v_t	Aggregate lifetime welfare
43	$Y_{fp,t}^r$	Value of farm goods in aggregate price terms
44	$Y_{ap,t}^r$	Value of non-farm goods in aggregate price terms
45	$Y_{mp,t}^z$	Value of manufactured goods in aggregate price terms
46	$M_{s,t}$	Money supply, only applicable under MSR
47	$M_{h,t}$	Money demand, only applicable under MSR
48	$M_{g,t}$	Growth of money, gross, only applicable under MSR

Added for Model 2

45	C_t^{xr}	Mixed-rural household total consumption
46	$C_{f,t}^{xr}$	Mixed-rural household consumption of farm goods
47	$C_{m,t}^{xr}$	Mixed-rural household consumption of manufactured goods
48	F_t^{xz}	Gross mixed household remittance
49	S_t^{xz}	Fees for remittances
50	D_t^{xz}	Dividends for mixed-urban households
51	C_t^{xz}	Mixed-urban household total consumption
52	$C_{f,t}^{xz}$	Mixed-urban household consumption of farm goods
53	$C_{m,t}^{xz}$	Mixed-urban household consumption of manufactured goods
54	N_t^{xr}	Mixed-rural household labour supply
55	N_t^{xz}	Mixed-urban household labour supply

56	$\frac{P_t^r}{P_t}$	Price of rural basket relative to aggregate price index
57	$\frac{W_t^z}{P_t^r}$	Urban wage relative to aggregate price index
58	N_t^{zz}	Purely urban household labour supply
59	$C_{f,t}^x$	Mixed household consumption of farm goods
60	$C_{m,t}^x$	Mixed household consumption of manufactured goods
61	v_t^{xr}	Mixed-rural household lifetime welfare
62	v_t^{xz}	Mixed-urban household lifetime welfare
63	v_t^x	Mixed household lifetime welfare

Table 3A2: List of Model 2 and Model 3 parameters

Notation	Value	Description
β	0.9902	Discount factor
γ	0.3	Share of flexible price goods in the consumer basket
γ_z	0.5	Share of non-farm goods in the flexible price goods part of the urban household consumer basket.
γ_m	0.5	Proportion of urban firms that keep the prices they set unchanged next period.
η	10	Elasticity of substitution between flexible price goods and sticky price goods
η_m	10	Elasticity of substitution between intermediate goods in manufacturing firms
η_z	0.5	Elasticity of substitution between farm goods and non-farm goods, in the urban household consumer basket
λ	6	The index of number of households (size of labour force) in the rural sector
μ	0.3	Urban-rural payment transaction fees
$\overline{\Pi}$	1	Steady-state gross headline inflation
$\overline{\Pi}_m$	1	Steady-state gross core inflation
ρ_{af}	0.75	Persistence of productivity shock in farming industry
ρ_{aa}	0.75	Persistence of productivity shock in non-farming industry
ρ_{am}	0.95	Persistence of productivity shock in manufacturing
ρ_i	0.7	Weight of interest rate-smoothing term in the Taylor rule
ρ_π	2	Weight of inflation gap in the Taylor rule
ρ_y	1	Weight of output gap in the Taylor rule
σ	2	Inverse of the elasticity of intertemporal substitution (risk aversion factor)
ϕ	20	Scaling factor on the disutility from labour supplied
ψ	10	Inverse of the Frisch elasticity of labour supplied
υ	20	Marginal elasticity of demand for real money balances

Added for Model 2

α	5	The index of number of purely rural households
ς	3	The index of number of purely urban households
ϱ	4	The index of number of households (size of work force) in the urban

Added for Model 3

δ	0.025	Depreciation rate
ω_r	0.85	Elasticity of output with respect to labour in farming
ω_z	0.65	Elasticity of output with respect to labour in manufacturing

Table 3A3: List of Model 2 equations programmed in Dynare 4.3.3

Model equations	Number

Rural household consumption

Rural household total consumption (budget constraint)

$$C_t^{rr} = \frac{W_t^r}{P_t^r} N_t^{rr} \qquad \text{M1}$$

Rural demand for *f*arm goods

$$C_{f,t}^r = \gamma \left(\frac{P_t^r}{P_{f,t}} \right)^{\eta} C_t^r \qquad \text{M2}$$

Rural demand for urban *m*anufactured goods

$$C_{m,t}^r = (1-\gamma) \left(\frac{P_t^r}{P_{m,t}} \right)^{\eta} C_t^r \qquad \text{M3}$$

Mixed household consumption

Relation between the consumption of urban and rural members of mixed household

$$C_t^{xr} = \left(\frac{1}{(1-\mu)} \right)^{-\frac{1}{\sigma}} C_t^{xz} \qquad \text{M4}$$

Mixed-rural household consumption of farm goods

$$C_{f,t}^{xr} = \gamma \left(\frac{P_{f,t}}{P_t^r}\right)^{-\eta} C_t^{xr} \qquad \text{M5}$$

Mixed-rural household consumption of manufactured goods

$$C_{m,t}^{xr} = (1-\gamma) \left(\frac{P_{m,t}}{P_t^r}\right)^{-\eta} C_t^{xr} \qquad \text{M6}$$

Mixed-urban household real gross remittances to the mixed-rural household

$$F_t^{xz} = \left(\frac{1}{1-\mu}\right)\left(C_t^{xr} - \frac{W_t^r}{P_t^r} N_t^{xr}\right) \qquad \text{M7}$$

Transaction fees paid by the mixed-urban household to send transfers to the mixed-rural household

$$S_t^{xz} = \left(\frac{\mu}{1-\mu}\right)\left(C_t^{xr} - \frac{W_t^r}{P_t^r} N_t^{xr}\right) \qquad \text{M8}$$

Dividend earned by mixed-urban household

$$D_t^{xz} = \frac{1}{\varrho}\left(\frac{P_{m,t}}{P_t^r} Y_{m,t}^z - \varsigma \frac{W_t^z}{P_t^r} N_t^{zz} - \frac{W_t^z}{P_t^r} N_t^{xz}\right) \qquad \text{M9}$$

Consumption by mixed-urban household

$$C_t^{xz} = \frac{W_t^r}{P_t^r} N_t^{xz} + D_t^{xz} + S_t^{xz} - F_t^{xz} \qquad \text{M10}$$

Mixed-urban household consumption of farm goods

$$C_{f,t}^{xz} = \gamma \left(\frac{P_{f,t}}{P_t^r}\right)^{-\eta} C_t^{xz} \qquad \text{M11}$$

Mixed-urban household consumption of manufactured goods

$$C_{m,t}^{xz} = (1-\gamma) \left(\frac{P_{m,t}}{P_t^r}\right)^{-\eta} C_t^{xz} \qquad \text{M12}$$

Urban household consumption

Urban aggregate consumption, Euler equation

$$1 = \beta E_t \left[\left(\frac{C_{t+1}^{zz}}{C_t^{zz}} \right)^{-\sigma} \frac{R_t}{\Pi_{t+1}} \right] \qquad \text{M13}$$

Urban aggregate demand for flexible price goods

$$C_{l,t}^{z} = \gamma \left(\frac{P_{l,t}}{P_t} \right)^{-\eta} C_t^{zz} \qquad \text{M14}$$

Urban demand for *f*arm goods

$$C_{f,t}^{z} = \gamma_z \left(\frac{P_{f,t}}{P_{l,t}} \right)^{-\eta_z} C_{l,t}^{zz} \qquad \text{M15}$$

Urban demand for non-f*a*rm goods

$$C_{a,t}^{z} = (1 - \gamma_z) \left(\frac{P_{a,t}^{z}}{P_{l,t}} \right)^{-\eta_z} C_{l,t}^{z} \qquad \text{M16}$$

Urban household demand for *m*anufactured goods

$$C_{m,t}^{z} = (1 - \gamma) \left(\frac{P_{m,t}}{P_t} \right)^{-\eta} C_t^{zz} \qquad \text{M17}$$

Urban household money demand condition
Note: Equation (M17b) is only applicable under the money supply rule (MSR)

$$\frac{C_t^{z}}{m^{\upsilon}} = -\frac{1 - R_t}{R_t} \qquad \text{M17b}$$

Labour supplied

Rural labour supplied

$$\frac{W_t^{r}}{P_t^{r}} = \phi \frac{(N_t^{rr})^{\psi}}{(C_t^{rr})^{-\sigma}} \qquad \text{M18}$$

Labour supply by mixed-rural household

$$N_t^{xr} = \left(\frac{1}{\phi}\frac{W_t^r}{P_t^r}\right)^{\frac{1}{\psi}}(C_t^{xr})^{\frac{-\sigma}{\psi}} \qquad \text{M19}$$

Labour supply by mixed-urban household

$$N_t^{xz} = \left(\frac{1}{\phi}\frac{W_t^z}{P_t^r}\right)^{\frac{1}{\psi}}(C_t^{xz})^{\frac{-\sigma}{\psi}} \qquad \text{M20}$$

Labour supply to firm j by urban household

$$\frac{W_{m,t}^z}{P_t} = \phi\frac{\left(N_{m,j,t}^{zz}\right)^{\psi}}{(C_t^{zz})^{-\sigma}} \qquad \text{M21}$$

Production functions

Farming production function

$$Y_{f,t}^r = A_{f,t}N_{f,t}^r \qquad \text{M22}$$

Non-farm goods production function

$$Y_{a,t}^r = A_{a,t}N_{a,t}^r \qquad \text{M23}$$

Production function for manufactured goods

$$Y_{m,t}^z = A_{m,t}N_{m,t}^z \qquad \text{M24}$$

Demand for labour in farming firms

$$\frac{W_t^r}{P_{f,t}} = A_{f,t} \qquad \text{M25}$$

Demand for labour in non-farm firms

$$\frac{W_t^r}{P_{a,t}} = A_{a,t} \qquad \text{M26}$$

Demand for labour in manufacturing firms, real marginal cost

$$MC_t = \frac{W_t^z}{P_{m,t}}\frac{1}{A_{m,t}} \qquad \text{M27}$$

Demand for capital

Prices

Manufactured goods price setting

$$za_t = MC_t Y^z_{m,t} + (\gamma_m \beta)\left(\frac{C_{m,t+1}}{C_{m,t}}\right)^{-\sigma}\left(\frac{1}{\Pi_{m,t+1}}\right)^{-\eta_m} za_{t+1} \qquad \text{M28}$$

$$zb_t = Y^z_{m,t} + (\gamma_m \beta)\left(\frac{C_{m,t+1}}{C_{m,t}}\right)^{-\sigma}\left(\frac{1}{\Pi_{m,t+1}}\right)^{-\eta_m}\frac{1}{\Pi_{t+1}} zb_{t+1} \qquad \text{M29}$$

$$\frac{P^*_{m,t}}{P_t} = \left(\frac{\eta_m}{\eta_m - 1}\right)\frac{za_t}{zb_t} \qquad \text{M30}$$

Price index of rural consumption basket

$$1 = \gamma\left(\frac{P_{f,t}}{P^{\mathrm{r}}_t}\right)^{1-\eta} + (1-\gamma)\left(\frac{P_{m,t}}{P^{\mathrm{r}}_t}\right)^{1-\eta} \qquad \text{M31}$$

Price index of flexible price goods

$$1 = \gamma_z\left(\frac{P_{f,t}}{P_{l,t}}\right)^{1-\eta_z} + (1-\gamma_z)\left(\frac{P^{\mathrm{z}}_{a,t}}{P_{l,t}}\right)^{1-\eta_z} \qquad \text{M32}$$

Price index of manufactured goods

$$1 = \gamma_m\left(\frac{P_{m,t-1}}{P_{m,t}}\right)^{1-\eta_m} + (1-\gamma_m)\left(\frac{P^*_{m,t}}{P_{m,t}}\right)^{1-\eta_m} \qquad \text{M33}$$

Aggregate price index

$$1 = \gamma\left(\frac{P_{l,t}}{P_t}\right)^{1-\eta} + (1-\gamma)\left(\frac{P_{m,t}}{P_t}\right)^{1-\eta} \qquad \text{M34}$$

Relative price of the consumer price of non-farm goods to their producer price

$$\frac{P^{\mathrm{z}}_{a,t}}{P_{a,t}} = 1 + \mu \qquad \text{M35}$$

Non-farm goods price relationships

$$\frac{P_{a,t}^{\mathrm{z}}}{P_{a,t}} = \frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}} \frac{P_{l,t}}{P_{f,t}} \frac{P_{f,t}}{W_t^{\mathrm{r}}} \frac{W_t^{\mathrm{r}}}{P_{a,t}} \quad \text{M36}$$

Rural consumer price relationships

$$\frac{P_{m,t}}{P_t^{\mathrm{r}}} = \frac{P_{f,t}}{P_t^{\mathrm{r}}} \frac{P_{m,t}}{P_t} \frac{P_t}{P_{l,t}} \frac{P_{l,t}}{P_{f,t}} \quad \text{M37}$$

Rural consumer price index to aggregate consumer price index

$$\frac{P_t^r}{P_t} = \left(\frac{P_{f,t}}{P_t^r}\right)^{-1} \frac{P_{f,t}}{P_t} \quad \text{M38}$$

Relation between headline and core inflation

$$\Pi_t = \Pi_{m,t} \frac{P_{m,t-1}}{P_{t-1}} \left(\frac{P_{m,t}}{P_t}\right)^{-1} \quad \text{M39}$$

Price and wage ratios

Rural wage-price relationships

$$\frac{W_t^{\mathrm{r}}}{P_{f,t}} = \frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}} \frac{P_t^{\mathrm{r}}}{P_{f,t}} \quad \text{M40}$$

Mixed-urban wage rural price ratio

$$\frac{W_t^{\mathrm{z}}}{P_t^r} = \frac{W_t^{\mathrm{z}}}{P_{m,t}} \frac{P_{m,t}}{P_t^r} \quad \text{M41}$$

Urban wage-price relationships

$$\frac{W_t^{\mathrm{z}}}{P_{m,t}} = \frac{W_t^{\mathrm{z}}}{P_t} \frac{P_t}{P_{m,t}} \quad \text{M42}$$

Clearing equations

Labour from all households and firms in the rural adds up

$$N_{a,t}^r = \frac{1}{\lambda}(\alpha N_t^{rr} + N_t^{xr}) - N_{f,t}^r \quad \text{M43}$$

Urban labour from all households adds up

$$\varrho N_{m,t}^{z} = \varsigma N_{t}^{zz} + N_{t}^{xz} \qquad \text{M44}$$

Aggregation of mixed household consumption of farm goods

$$C_{f,t}^{x} = C_{f,t}^{xr} + C_{f,t}^{xz} \qquad \text{M45}$$

Consumption of farm goods equals production

$$\lambda Y_{f,t}^{r} = \alpha C_{f,t}^{r} + C_{f,t}^{x} + \varsigma C_{f,t}^{z} \qquad \text{M46}$$

Consumption of non-farm goods equals production

$$\lambda Y_{a,t}^{r} = \varsigma C_{a,t}^{z} \qquad \text{M47}$$

Aggregate consumption of manufactured goods by mixed household

$$C_{m,t}^{x} = C_{m,t}^{xr} + C_{m,t}^{xz} \qquad \text{M48}$$

Consumption of manufactured goods matches production

$$\varrho Y_{m,t}^{z} = \alpha C_{m,t}^{r} + C_{m,t}^{x} + \varsigma C_{m,t}^{z} \qquad \text{M49}$$

Output aggregation

Value of farm output

$$Y_{fp,t}^{r} = \frac{P_{f,t}}{P_{l,t}}\frac{P_{l,t}}{P_{t}}Y_{f,t}^{r} \qquad \text{M50}$$

Value of non-farm output

$$Y_{ap,t}^{r} = \frac{P_{a,t}^{z}}{P_{l,t}}\frac{P_{l,t}}{P_{t}}Y_{a,t}^{r} \qquad \text{M51}$$

Value of manufactured output

$$Y_{mp,t}^{z} = \frac{P_{m,t}}{P_{t}}Y_{m,t}^{z} \qquad \text{M52}$$

Aggregate output

$$Y_t = \lambda\left(Y^r_{fp,t} + Y^r_{ap,t}\right) + \varrho Y^z_{mp,t} \qquad \text{M53}$$

Equations M53 is used obtain Y_t, which is an input in the Taylor's rule equation number M67.

Monetary policy

Interest rate (Taylor rule) for flexible headline inflation targeting

Note: This equation replaces equation number (M54b) under the interest rate rule (IRR)

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_i \log\left(\frac{R_{t-1}}{\bar{R}}\right) + \rho_\pi \log\left(\frac{\Pi_t}{\overline{\Pi}}\right) + \rho_y \log\left(\frac{Y_t}{\bar{Y}}\right) \qquad \text{M54a}$$

Money supply rule for flexible headline inflation targeting

Note: This equation replaces equation number (M54a) under the MSR

$$\log\left(M_{g,t}\right) = \log(\bar{\Pi}) - m\rho_\pi \log\left(\frac{\Pi_t}{\overline{\Pi}}\right) + m\rho_y \log\left(\frac{Y_t}{\bar{Y}}\right) + \log\left(A_{pt}\right) \qquad \text{M54b}$$

Money supply

Note: This equation is only applicable under the MSR

$$M_{s,t} = M_{g,t} M_{s,t-1} \qquad \text{M54c}$$

Productivity

Farming productivity process

$$\log A_{f,t} = \rho_{af} \log A_{f,t-1} + \xi_{f,t} \qquad \text{M55}$$

Non-farm goods productivity process

$$\log A_{a,t} = \rho_{aa} \log A_{a,t-1} + \xi_{a,t} \qquad \text{M56}$$

Manufacturing productivity process

$$\log A_{m,t} = \rho_{am} \log A_{m,t-1} + \xi_{m,t} \qquad \text{M57}$$

Monetary policy shock process

$$\log\left(A_{p,t}\right) = \rho_{ap} \log\left(A_{p,t-1}\right) + \xi_{p,t} \qquad \text{M58}$$

Welfare

Expected lifetime welfare, rural household

$$v_t^{rr} = \frac{(C_t^{rr})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{rr})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{r} \qquad \text{M59}$$

Welfare of mixed household rural member

$$v_t^{xr} = \frac{(C_t^{xr})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{xr})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{xr} \qquad \text{M60}$$

Welfare of mixed household urban member

$$v_t^{xz} = \frac{(C_t^{xz})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{xz})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{xz} \qquad \text{M61}$$

Aggregate welfare for the mixed household

$$v_t^{x} = v_t^{xr} + v_t^{xz} \qquad \text{M62}$$

Expected lifetime welfare, urban household

$$v_t^{z} = \frac{(C_t^{z})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{zz})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{z} \qquad \text{M63}$$

Aggregate expected lifetime welfare for the whole economy

$$v_t = \alpha v_t^{r} + v_t^{x} + \varsigma v_t^{z} \qquad \text{M64}$$

Table 3A4: List of Model 2 steady state equations in recursive order

Steady-state equations

$$\Pi = 1$$

$$\Pi_m = 1$$

$$\frac{P_m^*}{P_m} = 1$$

$$A_f = 1$$

$$A_a = 1$$

$$A_m = 1$$

$$A_p = 1$$

$$\frac{P_a^z}{P_a} = 1 + \mu$$

$$R = \frac{\Pi}{\beta}$$

$$\frac{W^r}{P_f} = A_f$$

$$\frac{W^r}{P_a} = A_a$$

$$\frac{W^z}{P_m} = A_m\left(1 - \frac{1}{\eta_m}\right)$$

$$Y_a^r = A_a N_a^r$$

$$Y_f^r = A_f N_f^r$$

$$N^{zz} = \left(\frac{1}{\phi}\frac{W^z}{P}\right)^{\frac{1}{\psi}} (C^z)^{\frac{-\sigma}{\psi}}$$

$$C^{rr} = \left[\frac{1}{\phi}\left(\frac{W^r}{P^r}\right)^{1+\psi}\right]^{\frac{1}{\sigma+\psi}}$$

$$N^{rr} = \left(\frac{W^r}{P^r}\right)^{-1} C^{rr}$$

$$\frac{P_f}{P^r} = \left(\frac{W^r}{P_f}\right)^{-1}\frac{W^r}{P^r}$$

$$\frac{P_m}{P} = \left(\frac{W^z}{P_m}\right)^{-1}\frac{W^z}{P}$$

$$C_m^z = (1-\gamma)\left(\frac{P_m}{P}\right)^{-\eta} C^z$$

$$C_a^z = \frac{1}{\varsigma}\lambda Y_a^r$$

This equation is only applicable under the MSR

$$m = \left(\frac{(C^z)^{\frac{\sigma}{\upsilon}}}{\frac{1-R}{R}}\right)^{\frac{1}{\upsilon}}$$

$$\frac{P_l}{P} = \left(\frac{1}{\gamma}\left[1 - (1-\gamma)\left(\frac{P_m}{P}\right)^{1-\eta}\right]\right)^{\frac{1}{1-\eta}}$$

$$C_l^z = \gamma \left(\frac{P_l}{P}\right)^{-\eta} C^{zz}$$

$$C_f^r = \gamma \left(\frac{P^r}{P^f}\right)^{\eta} C^{rr}$$

$$\frac{P_m}{P^r} = \left[\left(\frac{1}{(1-\gamma)}\right)\left[1-\gamma\left(\frac{P_f}{P^r}\right)^{1-\eta}\right]\right]^{\frac{1}{1-\eta}}$$

$$\frac{W^z}{P^r} = \frac{W^z}{P_m}\frac{P_m}{P^r}$$

$$N^{xz} = \left(\frac{1}{\phi}\frac{W^z}{P^r}\right)^{\frac{1}{\psi}} (C^{xz})^{\frac{-\sigma}{\psi}}$$

$$C^{xr} = \left(\frac{1}{(1-\mu)}\right)^{-\frac{1}{\sigma}} C^{xz}$$

$$C_f^{xr} = \gamma \left(\frac{P_f}{P^r}\right)^{-\eta} C^{xr}$$

$$C_m^{xr} = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^{xr}$$

$$N^{xr} = \left(\frac{1}{\phi}\frac{W^r}{P^r}\right)^{\frac{1}{\psi}} (C^{xr})^{\frac{-\sigma}{\psi}}$$

$$F^{xz} = \left(\frac{1}{1-\mu}\right)\left(C^{xr} - \frac{W^r}{P^r} N^{xr}\right)$$

$$C_f^{xz} = \gamma \left(\frac{P_f}{P^r}\right)^{-\eta} C^{xz}$$

$$C_m^{xz} = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^{xz}$$

$$C_m^x = C_m^{xr} + C_m^{xz}$$

$$C_f^x = C_f^{xr} + C_f^{xz}$$

$$C_f^z = \frac{1}{\varsigma}\left(\lambda Y_f^r - \alpha C_f^r - C_f^{xr} - C_f^{xz}\right)$$

$$\frac{P_f}{P_l} = \left(\frac{1}{\gamma_z C_l^z} C_f^z\right)^{-\frac{1}{\eta_z}}$$

$$\frac{P_a^z}{P_l} = \left[\left(\frac{1}{(1-\gamma_z)}\right)\left[1-\gamma_z\left(\frac{P_f}{P_l}\right)^{1-\eta_z}\right]\right]^{\frac{1}{1-\eta_z}}$$

$$\frac{P_f}{P} = \frac{P_f}{P_l}\frac{P_l}{P}$$

$$\frac{P^r}{P} = \left(\frac{P_f}{P^r}\right)^{-1}\frac{P_f}{P}$$

$$\frac{W^r}{P} = \frac{W^r}{P^r}\left(\frac{P_m}{P^r}\right)^{-1}\frac{P_m}{P}$$

$$C_m^r = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^{rr}$$

$$N_m^z = \frac{1}{\varrho}(\varsigma N^{zz} + N^{xz})$$

$$Y_m^z = A_m N_m^z$$

$$D^{xz} = \frac{\left(\frac{P_m}{P^r}Y_m^z - \varsigma\frac{W^z}{P^r}N_m^{zz} - \frac{W^z}{P^r}N^{xz}\right)}{\varrho}$$

$$S^{xz} = \left(\frac{\mu}{1-\mu}\right)\left(C^{xr} - \frac{W^r}{P^r}N^{xr}\right)$$

$$MC_m^z = \frac{\mathrm{W}^z}{P_m}A_m$$

$$za = \frac{(MC)Y_m^z}{(1-\gamma_m\beta)}$$

$$zb = \frac{Y_m^z}{(1-(\gamma_m\beta))}$$

$$Y_{fp}^r = \frac{P_f}{P_l}\frac{P_l}{P}Y_f^r$$

$$Y_{ap}^r = \frac{P_a^z}{P_l}\frac{P_l}{P}Y_a^r$$

$$Y_{mp}^z = \frac{P_m}{P}Y_m^z$$

$$Y = \lambda\left(Y_{fp}^r + Y_{ap}^r\right) + \varrho Y_{mp}^z$$

$$v^{rr} = \left(\frac{(C^r)^{1-\sigma}}{1-\sigma} - \phi\frac{(N^{rr})^{1+\psi}}{1+\psi}\right)\Big/(1-\beta)$$

$$v^{zz} = \left(\frac{(C^z)^{1-\sigma}}{1-\sigma} - \phi\frac{(N^{zz})^{1+\psi}}{1+\psi}\right)\Big/(1-\beta)$$

$$v^{xr} = \left(\frac{(C^{xr})^{1-\sigma}}{1-\sigma} - \phi\frac{(N^{xr})^{1+\psi}}{1+\psi}\right)\Big/(1-\beta)$$

$$v^{xz} = \left(\frac{(C^{xz})^{1-\sigma}}{1-\sigma} - \phi\frac{(N^{xz})^{1+\psi}}{1+\psi}\right)\Big/(1-\beta)$$

$$v^x = v^{xr} + v^{xz}$$

$$v = \alpha v^{rr} + v^x + \varsigma v^{zz}$$

$$C_a^z = (1-\gamma_z)\left(\frac{P_a^z}{P_l}\right)^{-\eta_z} C_l^z \qquad \text{F1}$$

$$Y_m^z = \frac{1}{\varrho}(\alpha C_m^r + C_m^x + \varsigma C_m^z) \qquad \text{F2}$$

$$\frac{P_a^z}{P_a} = \frac{P_a^z}{P_l} \Big/ \left(\frac{P_f}{P_l}\frac{W^r}{P_f}\right)\frac{W^r}{P_a} \qquad \text{F3}$$

$$\frac{P_m}{P^r} = \frac{P_f}{P^r}\frac{P_m}{P}\left(\frac{P_l}{P}\frac{P_f}{P_l}\right)^{-1} \qquad \text{F4}$$

$$C^{xz} = \frac{W^z}{P^r}N^{xz} + D^{xz} + S^{xz} - F^{xz} \qquad \text{F5}$$

The last 5 equations are solved by the fsolve function.

Table 3B1: List of Model 3 variables

S/N	VARABLE	DESCRIPTION
1	C_t^r	Rural household total consumption
2	$C_{f,t}^r$	Rural household consumption of farm goods
3	$C_{m,t}^r$	Rural household consumption of manufactured goods
4	C_t^z	Urban household total consumption
5	$C_{l,t}^z$	Urban household consumption of rural produced goods
6	$C_{f,t}^z$	Urban household consumption of farm goods
7	$C_{a,t}^z$	Urban household consumption of non-farm goods
8	$C_{m,t}^z$	Urban household consumption of manufactured goods
9	N_t^r	Total labour in the rural
10	$N_{f,t}^r$	Labour in farming
11	$N_{a,t}^r$	Labour in non-farming
12	$N_{m,t}^z$	Labour in manufacturing
13	$\frac{P_{l,t}}{P_t}$	The consumer price of rural produced goods relative to aggregate price index
14	$\frac{P_{m,t}}{P_t}$	The price of manufactured goods relative to aggregate price index
15	$\frac{P_{a,t}^z}{P_{a,t}}$	The consumer price of non-farm goods relative to their producer price
16	$\frac{P_{f,t}}{P_{l,t}}$	The price of farm goods relative to consumer price of rural produced goods

17	$\frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}}$	The consumer price of non-farm goods relative to consumer price of rural produced goods
18	$\frac{P_{f,t}}{P_t^{\mathrm{r}}}$	The price of farm goods relative to the price index of rural household consumer basket
19	$\frac{P_{m,t}}{P_t^{\mathrm{r}}}$	The aggregate price of manufactured goods relative to the price index of rural household consumer basket
20	$\frac{P_{m,t}^{*}}{P_{m,t}}$	The price chosen by manufacturing firm relative to the aggregate price of manufactured goods
21	$\frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}}$	The ratio of rural wage to the price index of the rural consumption basket
22	$\frac{W_t^{\mathrm{r}}}{P_{f,t}}$	The ratio of rural wage to the price of farm goods
23	$\frac{W_t^{\mathrm{r}}}{P_{a,t}}$	The ratio of rural wage to the price of non-farm goods
24	$\frac{W_t^{\mathrm{z}}}{P_t}$	The ratio of urban wage to aggregate price index
25	$\frac{W_t^{\mathrm{z}}}{P_{m,t}}$	The ratio of urban wage to aggregate price index
26	$Y_t,$	Total GDP
27	$Y_{f,t}^r,$	Farm goods produced
28	$Y_{a,t}^r$	Non-farm goods produced
29	$Y_{m,t}^z$	Manufactured goods produced
30	Π_t	Gross headline inflation
31	$\Pi_{m,t}$	Gross core inflation
32	R_t	Interest rate
33	$A_{f,t}$	Productivity in farming
34	$A_{a,t}$	Productivity in non-farming
35	$A_{m,t}$	Productivity in manufacturing
36	$A_{p,t}$	Policy shock
36	za_t	Numerator for the manufactured relative price equation
37	$zb_t,$	Denominator for the manufactured relative price equation
38	$MC_{m,t}^z$	Marginal cost in manufacturing
39	v_t^r	Rural household lifetime welfare
40	v_t^z	Urban household lifetime welfare
41	v_t	Aggregate lifetime welfare
42	$Y_{fp,t}^r$	Value of farm goods in aggregate price terms
43	$Y_{ap,t}^r$	Value of non-farm goods in aggregate price terms
44	$Y_{mp,t}^z$	Value of manufactured goods in aggregate price terms
46	$M_{s,t}$	Money supply, only applicable under MSR
47	$M_{h,t}$	Money demand, only applicable under MSR
48	$M_{g,t}$	Growth of money, gross, only applicable under MSR

Added for Model 2

45	C_t^{xr}	Mixed-rural household total consumption
46	$C_{f,t}^{xr}$	Mixed-rural household consumption of farm goods
47	$C_{m,t}^{xr}$	Mixed-rural household consumption of manufactured goods
48	F_t^{xz}	Gross mixed household remittance
49	S_t^{xz}	Fees for remittances
50	D_t^{xz}	Dividends for mixed-urban households
51	C_t^{xz}	Mixed-urban household total consumption
52	$C_{f,t}^{xz}$	Mixed-urban household consumption of farm goods
53	$C_{m,t}^{xz}$	Mixed-urban household consumption of manufactured goods
54	N_t^{xr}	Mixed-rural household labour supply
55	N_t^{xz}	Mixed-urban household labour supply
56	$\frac{P_t^r}{P_t}$	Price of rural basket relative to aggregate price index
57	$\frac{W_t^z}{P_t^r}$	Urban wage relative to aggregate price index
58	N_t^{zz}	Purely urban household labour supply
59	$C_{f,t}^{x}$	Mixed household consumption of farm goods
60	$C_{m,t}^{x}$	Mixed household consumption of manufactured goods
61	v_t^{xr}	Mixed-rural household lifetime welfare
62	v_t^{xz}	Mixed-urban household lifetime welfare
63	v_t^{x}	Mixed household lifetime welfare

Added for Model 3

64	K_t^{xz}	Capital supplied by the mixed-urban household
65	K_t^{zz}	Capital supplied by the purely urban household
66	I_t^{xz}	Investment by the mixed-urban household
67	I_t^{zz}	Investment by the purely urban household
68	$\frac{R_{k,t}^r}{P_{f,t}}$	Ratio of return to capital in the rural to the price of farm goods
69	$\frac{R_{k,t}^z}{P_{m,t}}$	Ratio of return to capital in the urban to the price of manufactured goods
70	$\frac{R_{k,t+1}^r}{P_{t+1}^r}$	Ratio of return to capital the rural to the price index of rural basket
71	$\frac{R_{k,t+1}^z}{P_{t+1}}$	Ratio of return to capital the urban to aggregate price index
72	$K_{f,t}^{r}$	Capital in farming
73	$K_{m,t}^{z}$	Capital in manufacturing
74	v_t^{r}	Aggregate welfare in the rural
75	v_t^{z}	Aggregate welfare in the urban

Table 3B2: List of Model 3 equations programmed in Dynare 4.3.3

Model equations	Number
Rural household consumption	
Rural household total consumption (budget constraint)	
$$C_t^{rr} = \frac{W_t^r}{P_t^r} N_t^{rr}$$	M1
Rural demand for *f*arm goods	
$$C_{f,t}^r = \gamma \left(\frac{P_t^r}{P_{f,t}}\right)^{\eta} C_t^r$$	M2
Rural demand for urban *m*anufactured goods	
$$C_{m,t}^r = (1-\gamma) \left(\frac{P_t^r}{P_{m,t}}\right)^{\eta} C_t^r$$	M3
Mixed household consumption	
Relation between the consumption of urban and rural members of mixed household	
$$C_t^{xr} = \left(\frac{1}{(1-\mu)}\right)^{-\frac{1}{\sigma}} C_t^{xz}$$	M4
Mixed-rural household consumption of farm goods	
$$C_{f,t}^{xr} = \gamma \left(\frac{P_{f,t}}{P_t^r}\right)^{-\eta} C_t^{xr}$$	M5
Mixed-rural household consumption of manufactured goods	
$$C_{m,t}^{xr} = (1-\gamma) \left(\frac{P_{m,t}}{P_t^r}\right)^{-\eta} C_t^{xr}$$	M6

Mixed-urban household real gross remittances to the mixed-rural household

$$F_t^{xz} = \left(\frac{1}{1-\mu}\right)\left(C_t^{xr} - \frac{W_t^r}{P_t^r} N_t^{xr}\right) \qquad \text{M7}$$

Transaction fees paid by the mixed-urban household to send transfers to the mixed-rural household

$$S_t^{xz} = \left(\frac{\mu}{1-\mu}\right)\left(C_t^{xr} - \frac{W_t^r}{P_t^r} N_t^{xr}\right) \qquad \text{M8}$$

Dividend earned by mixed-urban household

$$D_t^{xz} = \left(\frac{P_t^r}{P_t}\right)^{-1}\left(\frac{P_{m,t}}{P_t} Y_{m,t}^z - \frac{W_t^z}{P_t} N_{m,t}^z - \frac{R_t^k}{P_t} K_{m,t}^z\right) \qquad \text{M9}$$

Consumption by mixed-urban household

$$C_t^{xz} = \frac{W_t^r}{P_t^r} N_t^{xz} + \frac{R_t^k}{P_t^r} K_{t-1}^{xz} + D_t^{xz} + S_t^{xz} - F_t^{xz} - I_t^{xz} \qquad \text{M10}$$

Mixed-urban household consumption of farm goods

$$C_{f,t}^{xz} = \gamma \left(\frac{P_{f,t}}{P_t^r}\right)^{-\eta} C_t^{xz} \qquad \text{M11}$$

Mixed-urban household consumption of manufactured goods

$$C_{m,t}^{xz} = (1-\gamma)\left(\frac{P_{m,t}}{P_t^r}\right)^{-\eta} C_t^{xz} \qquad \text{M12}$$

Urban household consumption

Urban aggregate consumption, Euler equation

$$1 = \beta E_t \left[\left(\frac{C_{t+1}^{zz}}{C_t^{zz}}\right)^{-\sigma} \frac{R_t}{\Pi_{t+1}}\right] \qquad \text{M13}$$

Urban aggregate demand for flexible price goods

$$C_{l,t}^{z} = \gamma \left(\frac{P_{l,t}}{P_t}\right)^{-\eta} C_t^{zz} \qquad \text{M14}$$

Urban demand for *f*arm goods

$$C_{f,t}^{z} = \gamma_z \left(\frac{P_{f,t}}{P_{l,t}}\right)^{-\eta_z} C_{l,t}^{z} \qquad \text{M15}$$

Urban demand for non-f*a*rm goods

$$C_{a,t}^{z} = (1-\gamma_z) \left(\frac{P_{a,t}^{z}}{P_{l,t}}\right)^{-\eta_z} C_{l,t}^{z} \qquad \text{M16}$$

Urban household demand for *m*anufactured goods

$$C_{m,t}^{z} = (1-\gamma) \left(\frac{P_{m,t}}{P_t}\right)^{-\eta} C_t^{zz} \qquad \text{M17}$$

Urban household money demand condition
Note: Equation (M17b) is only applicable under the money supply rule (MSR)

$$\frac{C_t^{z}}{m^{v}} = -\frac{1-R_t}{R_t} \qquad \text{M17b}$$

Capital accumulation

Mixed-urban household

$$K_t^{xz} = (1-\delta)K_{t-1}^{xz} + I_t^{xz} \qquad \text{M18}$$

Urban household

$$K_t^{zz} = (1-\delta)K_{t-1}^{zz} + I_t^{zz} \qquad \text{M19}$$

Labour supplied

Rural labour supplied

$$\frac{W_t^{r}}{P_t^{r}} = \phi \frac{(N_t^{rr})^{\psi}}{(C_t^{rr})^{-\sigma}} \qquad \text{M20}$$

Labour supply by mixed-rural household

$$N_t^{xr} = \left(\frac{1}{\phi}\frac{W_t^r}{P_t^r}\right)^{\frac{1}{\psi}} (C_t^{xr})^{\frac{-\sigma}{\psi}} \qquad \text{M21}$$

Labour supply by mixed-urban household

$$N_t^{xz} = \left(\frac{1}{\phi}\frac{W_t^z}{P_t^r}\right)^{\frac{1}{\psi}} (C_t^{xz})^{\frac{-\sigma}{\psi}} \qquad \text{M22}$$

Labour supply to firm j by urban household

$$\frac{W_t^z}{P_t} = \phi \frac{\left(N_{m,j,t}^{zz}\right)^{\psi}}{(C_t^{zz})^{-\sigma}} \qquad \text{M23}$$

Production functions

Farming production function

$$Y_{f,t}^r = A_{f,t}\left(N_{f,t}^r\right)^{\omega}\left(K_{f,t-1}^r\right)^{1-\omega} \qquad \text{M24}$$

Non-farm goods production function

$$Y_{a,t}^r = A_{a,t}N_{a,t}^r \qquad \text{M25}$$

Production function for manufactured goods

$$Y_{m,t}^z = A_{m,t}\left(N_{m,t}^z\right)^{\omega}\left(K_{m,t-1}^z\right)^{1-\omega} \qquad \text{M26}$$

Demand for labour in farming firms

$$\frac{W_t^r}{P_{f,t}} = \omega_r \frac{Y_{f,t}^r}{N_{f,t}^r} \qquad \text{M27}$$

Demand for labour in non-farm firms

$$\frac{W_t^r}{P_{a,t}} = A_{a,t} \qquad \text{M28}$$

Demand for labour in manufacturing firms, real marginal cost

$$MC_t = \left(\frac{1}{\omega_z}\right)\frac{W_t^z}{P_{m,t}}\frac{N_{m,t}^z}{Y_{m,t}^z} \qquad \text{M29}$$

Demand for capital

Farming firms

$$\frac{R_{k,t}^{r}}{P_{f,t}} = (1-\omega_r)\frac{Y_{f,t}^{r}}{K_{f,t-1}^{r}} \qquad \text{M30}$$

Manufacturing firms

$$\frac{R_{k,t}^{z}}{P_{m,t}} = (1-\omega_z)\frac{MC_t Y_{m,t}^{z}}{K_{m,t-1}^{z}} \qquad \text{M31}$$

Prices

Manufactured goods price setting

$$za_t = MC_t Y_{m,t}^{z} + (\gamma_m\beta)\left(\frac{C_{m,t+1}}{C_{m,t}}\right)^{-\sigma}\left(\frac{1}{\Pi_{m,t+1}}\right)^{-\eta_m} za_{t+1} \qquad \text{M32}$$

$$zb_t = Y_{m,t}^{z} + (\gamma_m\beta)\left(\frac{C_{m,t+1}}{C_{m,t}}\right)^{-\sigma}\left(\frac{1}{\Pi_{m,t+1}}\right)^{-\eta_m}\frac{1}{\Pi_{t+1}} zb_{t+1} \qquad \text{M33}$$

$$\frac{P_{m,t}^{*}}{P_t} = \left(\frac{\eta_m}{\eta_m-1}\right)\frac{za_t}{zb_t} \qquad \text{M34}$$

Price index of rural consumption basket

$$1 = \gamma\left(\frac{P_{f,t}}{P_t^{\mathrm{r}}}\right)^{1-\eta} + (1-\gamma)\left(\frac{P_{m,t}}{P_t^{\mathrm{r}}}\right)^{1-\eta} \qquad \text{M35}$$

Price index of flexible price goods

$$1 = \gamma_z\left(\frac{P_{f,t}}{P_{l,t}}\right)^{1-\eta_z} + (1-\gamma_z)\left(\frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}}\right)^{1-\eta_z} \qquad \text{M36}$$

Price index of manufactured goods

$$1 = \gamma_m\left(\frac{P_{m,t-1}}{P_{m,t}}\right)^{1-\eta_m} + (1-\gamma_m)\left(\frac{P_{m,t}^{*}}{P_{m,t}}\right)^{1-\eta_m} \qquad \text{M37}$$

Aggregate price index

$$1 = \gamma \left(\frac{P_{l,t}}{P_t}\right)^{1-\eta} + (1-\gamma)\left(\frac{P_{m,t}}{P_t}\right)^{1-\eta} \qquad \text{M38}$$

Relationship between headline and core inflation

$$\frac{P_t}{P_{t-1}} = \frac{P_{m,t}}{P_{m,t-1}} \frac{P_{m,t-1}}{P_{t-1}} \left(\frac{P_{m,t}}{P_t}\right)^{-1} \qquad \text{M39}$$

Relative price of the consumer price of non-farm goods to their producer price

$$\frac{P_{a,t}^{\mathrm{z}}}{P_{a,t}} = 1 + \mu \qquad \text{M40}$$

Non-farm goods price relationships

$$\frac{P_{a,t}^{\mathrm{z}}}{P_{a,t}} = \frac{P_{a,t}^{\mathrm{z}}}{P_{l,t}} \frac{P_{l,t}}{P_{f,t}} \frac{P_{f,t}}{W_t^{\mathrm{r}}} \frac{W_t^{\mathrm{r}}}{P_{a,t}} \qquad \text{M41}$$

Rural consumer price relationships

$$\frac{P_{m,t}}{P_t^{\mathrm{r}}} = \frac{P_{f,t}}{P_t^{\mathrm{r}}} \frac{P_{m,t}}{P_t} \frac{P_t}{P_{l,t}} \frac{P_{l,t}}{P_{f,t}} \qquad \text{M42}$$

Rural consumer price index to aggregate consumer price index

$$\frac{P_t^r}{P_t} = \left(\frac{P_{f,t}}{P_t^r}\right)^{-1} \frac{W^r}{P_t} \left(\frac{W^r}{P_{f,t}}\right)^{-1} \qquad \text{M43}$$

Price of farm goods to aggregate price index

$$\frac{P_{f,t}}{P_t} = \frac{P_{f,t}}{P_{l,t}} \frac{P_{l,t}}{P_t} \qquad \text{M44}$$

Price and wage ratios

Rural wage-price relationships

$$\frac{W_t^{\mathrm{r}}}{P_{f,t}} = \frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}}\frac{P_t^{\mathrm{r}}}{P_{f,t}} \qquad \text{M45}$$

Rural wage to aggregate price index

$$\frac{W_t^{\mathrm{r}}}{P_t} = \frac{W_t^{\mathrm{r}}}{P_t^{\mathrm{r}}}\left(\frac{P_{m,t}}{P_t^r}\right)^{-1}\frac{P_{m,t}}{P_t} \qquad \text{M46}$$

Urban wage rural basket price ratio

$$\frac{W_t^{\mathrm{z}}}{P_t^r} = \frac{W_t^{\mathrm{z}}}{P_{m,t}}\frac{P_{m,t}}{P_t^r} \qquad \text{M47}$$

Urban wage-price relationships

$$\frac{W_t^{\mathrm{z}}}{P_{m,t}} = \frac{W_t^{\mathrm{z}}}{P_t}\left(\frac{P_{m,t}}{P_t}\right)^{-1} \qquad \text{M48}$$

Conditions for investment

Condition for mixed-urban household investment

$$1 = \beta\frac{P_t^r}{P_{m,t}}\left(\frac{C_{t+1}^{xz}}{C_t^{xz}}\right)^{-\sigma}\left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}^r} + \frac{R_{k,t+1}^r}{P_{t+1}^r}\right] \qquad \text{M49}$$

No arbitrage condition for the purely urban household

$$R_t\frac{P_{m,t}}{P_t} = \beta\Pi_{t+1}\left[(1-\delta)\frac{P_{m,t+1}}{P_{t+1}} + \frac{R_{k,t+1}^z}{P_{t+1}}\right] \qquad \text{M50}$$

Return on capital to price ratios

Aggregate price index

$$\frac{R_{k,t}^r}{P_t^{\mathrm{r}}} = \frac{R_{k,t}^r}{P_{f,t}}\frac{P_{f,t}}{P_t^{\mathrm{r}}} \qquad \text{M51}$$

$$\frac{R_{k,t}^z}{P_{m,t}} = \left(\frac{P_{m,t}}{P_t}\right)^{-1}\frac{R_{k,t}^z}{P_t} \qquad \text{M52}$$

Clearing equations

Labour from all households and firms in the rural adds up

$$N_{a,t}^{r} = \frac{1}{\lambda}(aN_t^{rr} + N_t^{xr}) - N_{f,t}^{r} \qquad \text{M53}$$

Urban labour from all households adds up

$$\varrho N_{m,t}^{z} = \varsigma N_t^{zz} + N_t^{xz} \qquad \text{M54}$$

Capital in the rural

$$K_t^{xz} = \lambda K_{f,t}^{r} \qquad \text{M55}$$

Capital in the urban

$$K_t^{zz} = \frac{\varrho}{\varsigma} K_{m,t}^{z} \qquad \text{M56}$$

Aggregation of mixed household consumption of farm goods

$$C_{f,t}^{x} = C_{f,t}^{xr} + C_{f,t}^{xz} \qquad \text{M57}$$

Consumption of farm goods equals production

$$\lambda Y_{f,t}^{r} = \alpha C_{f,t}^{r} + C_{f,t}^{x} + \varsigma C_{f,t}^{z} \qquad \text{M58}$$

Consumption of non-farm goods equals production

$$\lambda Y_{a,t}^{r} = \varsigma C_{a,t}^{z} \qquad \text{M59}$$

Aggregate consumption of manufactured goods by mixed household

$$C_{m,t}^{x} = C_{m,t}^{xr} + C_{m,t}^{xz} \qquad \text{M60}$$

Consumption of manufactured goods matches production

$$\varrho Y_{m,t}^{z} = \alpha C_{m,t}^{r} + C_{m,t}^{x} + I_t^{xz} + \varsigma\left(C_{m,t}^{z} + I_t^{zz}\right) \qquad \text{M61}$$

Output aggregation

Value of farm output

$$Y_{fp,t}^{r} = \frac{P_{f,t}}{P_{l,t}} \frac{P_{l,t}}{P_t} Y_{f,t}^{r} \tag{M62}$$

Value of non-farm output

$$Y_{ap,t}^{r} = \frac{P_{a,t}^{z}}{P_{l,t}} \frac{P_{l,t}}{P_t} Y_{a,t}^{r} \tag{M63}$$

Value of manufactured output

$$Y_{mp,t}^{z} = \frac{P_{m,t}}{P_t} Y_{m,t}^{z} \tag{M64}$$

Aggregate output

$$Y_t = \lambda\left(Y_{fp,t}^{r} + Y_{ap,t}^{r}\right) + \varrho Y_{mp,t}^{z} \tag{M65}$$

Equations M66 is used obtain Y_t, which is an input in the Taylor's rule equation number M67.

Monetary policy

Interest rate (Taylor rule) for flexible headline inflation targeting
Note: This equation replaces equation number (M66b) under the interest rate rule (IRR)

$$\log\left(\frac{R_t}{\bar{R}}\right) = \rho_i \log\left(\frac{R_{t-1}}{\bar{R}}\right) + \rho_\pi \log\left(\frac{\Pi_t}{\bar{\bar{\Pi}}}\right) + \rho_y \log\left(\frac{Y_t}{\bar{\bar{Y}}}\right) \tag{M66a}$$

Money supply rule for flexible headline inflation targeting
Note: This equation replaces equation number (M66a) under the MSR

$$\log\left(M_{g,t}\right) = \log(\bar{\Pi}) - m\rho_\pi \log\left(\frac{\Pi_t}{\bar{\bar{\Pi}}}\right) + m\rho_y \log\left(\frac{Y_t}{\bar{\bar{Y}}}\right) + \log\left(A_{pt}\right) \tag{M66b}$$

Money supply
Note: This equation is only applicable under the MSR

$$M_{s,t} = M_{g,t} M_{s,t-1} \tag{M66c}$$

Productivity

Farming productivity process

$$\log A_{f,t} = \rho_{af} \log A_{f,t-1} + \xi_{f,t} \qquad \text{M67}$$

Non-farm goods productivity process

$$\log A_{a,t} = \rho_{aa} \log A_{a,t-1} + \xi_{a,t} \qquad \text{M68}$$

Manufacturing productivity process

$$\log A_{m,t} = \rho_{am} \log A_{m,t-1} + \xi_{m,t} \qquad \text{M69}$$

Monetary policy shock process

$$\log(A_{p,t}) = \rho_{ap} \log(A_{p,t-1}) + \xi_{p,t} \qquad \text{M70}$$

Welfare

Expected lifetime welfare, rural household

$$v_t^{rr} = \frac{(C_t^{rr})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{rr})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{rr} \qquad \text{M71}$$

Welfare of mixed household rural member

$$v_t^{xr} = \frac{(C_t^{xr})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{xr})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{xr} \qquad \text{M72}$$

Welfare of mixed household urban member

$$v_t^{xz} = \frac{(C_t^{xz})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{xz})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{xz} \qquad \text{M73}$$

Expected lifetime welfare, urban household

$$v_t^{zz} = \frac{(C_t^{zz})^{1-\sigma}}{1-\sigma} - \phi \frac{(N_t^{zz})^{1+\psi}}{1+\psi} + \beta v_{t+1}^{zz} \qquad \text{M74}$$

Rural welfare

$$v_t^{r} = \alpha v_t^{rr} + v_t^{xr} \qquad \text{M75}$$

Urban welfare

$$v_t^z = v_t^{xz} + \varsigma v_t^{zz} \quad \text{M76}$$

Mixed-household welfare

$$v_t^x = v_t^{xr} + v_t^{xz} \quad \text{M77}$$

Aggregate expected lifetime welfare for the whole economy

$$v_t = \alpha v_t^{rr} + v_t^x + \varsigma v_t^z \quad \text{M78}$$

Table 3B3: List of Model 3 steady state equations in recursive order

Steady-state equations
$\Pi = 1$
$\Pi_m = 1$
$\frac{P_m^*}{P_m} = 1$
$A_f = 1$
$A_a = 1$
$A_m = 1$
$A_p = 1$
$\frac{P_a^z}{P_a} = 1 + \mu$
$R = \frac{\Pi}{\beta}$
$\frac{R_k^z}{P_m} = \frac{R}{\beta\Pi} - 1 + \delta$
$N^{zz} = \left(\frac{1}{\phi(C^{zz})^\sigma}\frac{W^z}{P}\right)^{\frac{1}{\psi}}$
$C^{rr} = \left[\frac{1}{\phi}\left(\frac{W^r}{P^r}\right)^{1+\psi}\right]^{\frac{1}{\sigma+\psi}}$
$Y_f^r = A_f\left(N_f^r\right)^{\omega_r}\left(K_f^r\right)^{1-\omega_r}$
$\frac{W^r}{P_f} = \omega_r \frac{Y_f^r}{N_f^r}$
$Y_a^r = A_a N_a^r$

$$N^{rr} = \left(\frac{W^r}{P^r}\right)^{-1} C^{rr}$$

$$\frac{P_f}{P^r} = \left(\frac{W^r}{P_f}\right)^{-1} \frac{W^r}{P^r}$$

$$\frac{P_m}{P} = \left(\frac{W^z}{P_m}\right)^{-1} \frac{W^z}{P}$$

$$C_m^z = (1-\gamma)\left(\frac{P_m}{P}\right)^{-\eta} C^{zz}$$

$$C_a^z = \frac{1}{\varsigma} \lambda Y_a^r$$

Only applicable under the MSR

$$m = \left(\frac{(C^z)^{\frac{\sigma}{\upsilon}}}{\frac{1-R}{R}}\right)^{\frac{1}{\upsilon}}$$

$$C_f^r = \gamma \left(\frac{P_f}{P^r}\right)^{-\eta} C^{rr}$$

$$C^{xr} = \left(\frac{1}{(1-\mu)\zeta}\right)^{-\frac{1}{\sigma}} C^{xz}$$

$$C_f^{xr} = \gamma \left(\frac{P_f}{P^r}\right)^{-\eta} C^{xr}$$

$$\frac{P_l}{P} = \left(\frac{1}{\gamma}\left[1-(1-\gamma)\left(\frac{P_m}{P}\right)^{1-\eta}\right]\right)^{\frac{1}{1-\eta}}$$

$$C_l^z = \gamma \left(\frac{P_l}{P}\right)^{-\eta} C^{zz}$$

$$\frac{P_m}{P^r} = \left[\left(\frac{1}{(1-\gamma)}\right)\left[1-\gamma\left(\frac{P_f}{P^r}\right)^{1-\eta}\right]\right]^{\frac{1}{1-\eta}}$$

$$C_m^{xr} = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^{xr}$$

$$\frac{W^z}{P^r} = \frac{W^z}{P_m}\frac{P_m}{P^r}$$

$$N^{xz} = \left(\frac{1}{\phi}\frac{W^z}{P^r}\right)^{\frac{1}{\psi}} (C^{xz})^{\frac{-\sigma}{\psi}}$$

$$N_m^z = \frac{1}{\varrho}(\varsigma N^{zz} + N^{xz})$$

$$Y_m^z = A_m (N_m^z)^{\omega_z} (K_m^z)^{1-\omega_z}$$

$$N^{xr} = \left(\frac{1}{\phi}\frac{W^r}{P^r}\right)^{\frac{1}{\psi}} (C^{xr})^{\frac{-\sigma}{\psi}}$$

$$F^{xz} = \left(\frac{1}{1-\mu}\right)\left(C^{xr} - \frac{W^r}{P^r}N^{xr}\right)$$

$$S^{xz} = \left(\frac{\mu}{1-\mu}\right)\left(C^{xr} - \frac{W^r}{P^r}N^{xr}\right)$$

$$C_f^{xz} = \gamma\left(\frac{P_f}{P^r}\right)^{-\eta} C^{xz}$$

$$C_m^{xz} = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^{xz}$$

$$C_m^x = C_m^{xr} + C_m^{xz}$$

$$C_f^x = C_f^{xr} + C_f^{xz}$$

$$C_f^z = \frac{1}{\varsigma}\left(\lambda Y_f^r - \alpha C_f^r - C_f^{xr} - C_f^{xz}\right)$$

$$\frac{P_f}{P_l} = \left(\frac{1}{\gamma_z C_l^z} C_f^z\right)^{-\frac{1}{\eta_z}}$$

$$\frac{P_a^z}{P_l} = \left[\left(\frac{1}{(1-\gamma_z)}\right)\left[1 - \gamma_z\left(\frac{P_f}{P_l}\right)^{1-\eta_z}\right]\right]^{\frac{1}{1-\eta_z}}$$

$$\frac{P_f}{P} = \frac{P_f}{P_l}\frac{P_l}{P_t}$$

$$\frac{W^r}{P} = \frac{W^r}{P^r}\frac{P_m}{P}\left(\frac{P_m}{P^r}\right)^{-1}$$

$$\frac{P^r}{P} = \left(\frac{P_f}{P^r}\frac{W^r}{P_f}\right)^{-1}\frac{W^r}{P}$$

$$C_m^r = (1-\gamma)\left(\frac{P_m}{P^r}\right)^{-\eta} C^{rr}$$

$$MC = \left(\frac{1}{\omega_z}\right)\frac{\mathrm{W}^z}{P_m}\frac{N_m^z}{Y_m^z}$$

$$Y_{fp}^r = \frac{P_f}{P_l}\frac{P_l}{P}Y_f^r$$

$$Y_{ap}^r = \frac{P_a^z}{P_l}\frac{P_l}{P}Y_a^r$$

$$Y_{mp}^z = \frac{P_m}{P}Y_m^z$$

$$Y = \lambda\left(Y_{fp}^r + Y_{ap}^r\right) + \varrho Y_{mp}^z$$

$$\frac{W^r}{P_a} = A_a$$

$$\frac{R_k^r}{P_f} = (1-\omega_r)\frac{Y_f^r}{K_f^r}$$

$$K^{xz} = \lambda K_f^r$$

$$K^{zz} = \frac{\varrho}{\varsigma} K_m^z$$

$$I_t^{xz} = \delta K^{xz}$$

$$I_t^{zz} = \delta K^{zz}$$

$$\frac{R_k^z}{P} = \frac{R_k^z}{P_m}\frac{P_m}{P}$$

$$\frac{R_k^r}{P^r} = \frac{R_k^r}{P_f}\frac{P_f}{P^r}$$

$$D^{xz} = \left(\frac{P^r}{P}\right)^{-1}\left(\frac{P_m}{P}Y_m^z - \frac{W^z}{P}N_m^z - \frac{R_k^z}{P}K_m^z\right)$$

$$C^{xz} = \frac{W^z}{P^r}N^{xz} + \frac{R_k^r}{P^r}K^{xz} + D^{xz} + S^{xz} - F^{xz} - \frac{P_m}{P_r}I^{xz} \qquad \text{F1}$$

$$C_{a,t}^z = (1-\gamma_z)\left(\frac{P_{a,t}^z}{P_{l,t}}\right)^{-\eta_z} C_{l,t}^z \qquad \text{F2}$$

$$\frac{R_k^z}{P_m} = (1-\omega_z)\frac{MCY_m^z}{K_m^z} \qquad \text{F3}$$

$$\frac{P_a^z}{P_a} = \frac{P_a^z}{P_l}\Big/\left(\frac{P_f}{P_l}\frac{W^r}{P_f}\right)\frac{W^r}{P_a} \qquad \text{F4}$$

$$\frac{P_m}{P^r} = \frac{P_f}{P^r}\frac{P_m}{P}\left(\frac{P_l}{P}\frac{P_f}{P_l}\right)^{-1} \qquad \text{F5}$$

$$\frac{R_k^r}{P^r} = \frac{P_m}{P^r}\frac{1}{\beta} - 1 + \delta \qquad \text{F6}$$

$$N_a^r = \frac{1}{\lambda}(\alpha N^{rr} + N^{xr}) - N_f^r \qquad \text{F7}$$

$$Y_m^z = \frac{1}{\varrho}(\alpha C_m^r + C_m^x + I^{xz} + \varsigma(C_m^z + I^{zz})\,) \qquad \text{F8}$$

$$MC = \left(1 - \frac{1}{\eta_m}\right)A_m \qquad \text{F9}$$

The last 9 equations are solved by the fsolve function.

Result tables

Table 3C1: Production by all firms

	Model 2		Model 3	
Item	Baseline	M-money	Baseline	M-money
Constant steady state prices				
GDP	4.8921	4.9081	8.2098	8.2645
Rural total	2.6603	2.6328	3.1400	3.1037
Farming	2.3228	2.2130	2.6221	2.4663
Non-farming	0.3375	0.4198	0.5180	0.6375
Manufacturing	2.2318	2.2754	5.0698	5.1608
Current consumer price				
GDP	4.9934	5.2203	8.3652	8.6596
Rural total	2.7615	2.8675	3.2954	3.3865
Farming	2.3228	2.3913	2.6221	2.6583
Non-farming	0.4387	0.4762	0.6733	0.7283
Manufacturing	2.2318	2.3527	5.0698	5.2730
Current factor cost				
GDP	4.8921	5.1976	8.2098	8.6249
Rural total	2.6603	2.8449	3.1400	3.3519
Non-farming	0.3375	0.4536	0.5180	0.6936
Ratio GDP at consumer price to GDP at factor cost	1.0207	1.0044	1.0189	1.0040

Table 3C2: Generation of primary income by firm

	Model 2		Model 3	
Item	Baseline	M-money	Baseline	M-money
GDP income side, adjusted	0.4993	0.5220	0.8365	0.8660
GDP income side	0.4892	0.5198	0.8210	0.8625
Rural firms	0.4434	0.4741	0.5233	0.5586
Paid to labour	0.4434	0.4741	0.4578	0.4922
Farm goods	0.3871	0.3986	0.3715	0.3766
Non-farm goods	0.0562	0.0756	0.0863	0.1156
Paid to capital			0.0656	0.0665
Farm goods			0.0656	0.0665
Non-farm goods				
Urban firms	0.5580	0.5882	1.2675	1.3183
Manufacturing paid to labour	0.5022	0.5294	0.7415	0.7712
Manufacturing paid to capital			0.3992	0.4153
Manufacturing dividends	0.0558	0.0588	0.1268	0.1318

Table 3C3: Labour and capital demanded by firms

	Model 2		Model 3	
Item	Baseline	M-money	Baseline	M-money
Labour				
Farming labour quantity	0.4950	0.4716	0.4384	0.4085
Farming labour value	0.3871	0.3986	0.3715	0.3766
Non-farming labour quantity	0.0719	0.0895	0.1019	0.1254
Non-farming labour value	0.0562	0.0756	0.0863	0.1156
Rural wage	0.7821	0.8451	0.8474	0.9220
Manufacturing labour quantity	0.5214	0.5315	0.4320	0.4397
Manufacturing labour value	0.5022	0.5294	0.7415	0.7712
Urban wage	0.9632	0.9959	1.7165	1.7538
Capital				
Rented to farming			1.8278	1.8136
Farming rental price			0.0359	0.0366
Farming capital rental value			0.0656	0.0665
Rented to manufacturing			8.6536	8.8091
Manufacturing rental price			0.0461	0.0471
Manufacturing capital rental value			0.3992	0.4153

Table 3C4: Labour supply by the households

Item	Model 2		Model 3	
	Baseline	M-money	Baseline	M-money
Rural				
Purely rural households quantity	0.5687	0.5666	0.5595	0.5555
Mixed-rural household quantity	0.5582	0.5335	0.4442	0.4257
Purely rural households value	0.4447	0.4788	0.4741	0.5121
Mixed-rural household value	0.4365	0.4509	0.3764	0.3925
Urban				
Mixed-urban household quantity	0.5312	0.5540	0.4990	0.5185
Purely urban household quantity	0.5181	0.5240	0.4096	0.4135
Mixed-urban household value	0.5117	0.5518	0.8565	0.9093
Purely urban household value	0.4990	0.5219	0.7031	0.7251
Selected aggregations				
Rural quantity weighted average	0.5669	0.5611	0.5403	0.5338
Urban quantity weighted average	0.5214	0.5315	0.4320	0.4397
Rural value weighted average	0.4434	0.4741	0.4578	0.4922
Urban value weighted average	0.5022	0.5294	0.7415	0.7712
Mixed household quantity	0.5634	0.5501	0.5018	0.4906
Mixed household value	0.4406	0.4648	0.4252	0.4523

Table 3C5: Household consumption - quantities and values by good type

Item	Model 2		Model 3	
	Baseline	M-money	Baseline	M-money
Farm goods quantity				
Purely rural households	0.3415	0.3159	0.3139	0.2830
Mixed-rural households	0.3511	0.3457	0.4437	0.4219
Mixed-urban households	0.4197	0.3546	0.5303	0.4329
Purely urban households	0.1640	0.1833	0.2384	0.2649
Non-farm goods quantity				
Purely urban households	0.1438	0.1789	0.2038	0.2508
Manufactured goods quantity				
Purely rural households	0.1660	0.1914	0.5099	0.5378
Mixed-rural households	0.1708	0.2095	0.2155	0.2539
Mixed-urban households	0.2041	0.2149	0.3047	0.3785
Purely urban households	0.5885	0.5883	0.3642	0.3884
Farm goods value				
Purely rural households	0.2670	0.2669	0.2526	0.2455
Mixed-rural households	0.2746	0.2921	0.3570	0.3660
Mixed-urban households	0.3282	0.2997	0.4267	0.3755
Purely urban households	0.1283	0.1549	0.1918	0.2298
Non-farm goods value				
Purely urban households cp [a]	0.1462	0.1587	0.2244	0.2428
Purely urban households tp [b]	0.1125	0.1512	0.1727	0.2312
Manufactured goods value				
Purely rural households	0.1777	0.2118	0.2215	0.2666
Mixed-rural households	0.1827	0.2318	0.3131	0.3975
Mixed-urban households	0.2184	0.2378	0.3743	0.4078
Purely urban households	0.6299	0.6510	1.1485	1.1696
Selected aggregates value by good				
Rural total	2.6811	2.9179	3.0405	3.3241
Rural farm goods	1.6098	1.6268	1.6198	1.5934
Rural manufactured goods	1.0713	1.2911	1.4207	1.7307
Urban total	3.2597	3.4315	5.4953	5.7098
Urban farm goods	0.7130	0.7645	1.0022	1.0648
Non-farm goods	0.4387	0.4762	0.6733	0.7283
Urban manufactured goods	2.1080	2.1908	3.8197	3.9167
Selected aggregates value by household				
Rural total	2.6811	2.9179	3.0405	3.3241
Purely rural households	0.4447	0.4788	0.4741	0.5121
Mixed-rural households	0.4574	0.5239	0.6702	0.7634
Urban total	3.2597	3.4315	5.4953	5.7098
Mixed-urban households	0.5466	0.5375	0.8010	0.7833
Purely urban households	0.9043	0.9646	1.5648	1.6422

[a] cp stands for consumer price
[b] tp stands for factor cost

Table 3C6: Selected aggregation of consumption by good, household and sector

	Model 2		Model 3	
Item	Baseline	M-money	Baseline	M-money
Selected aggregates value by good				
Rural total	2.6811	2.9179	3.0405	3.3241
Rural farm goods	1.6098	1.6268	1.6198	1.5934
Rural manufactured goods	1.0713	1.2911	1.4207	1.7307
Urban total	2.2110	2.2797	3.9982	4.0902
Urban farm goods	0.7130	0.7645	1.0022	1.0648
Non-farm goods	0.3375	0.4536	0.5180	0.6936
Urban manufactured goods	1.1606	1.0617	2.4780	2.3317
Selected aggregate values by household				
Rural average	0.4469	0.4863	0.5068	0.5540
Purely rural households	0.4447	0.4788	0.4741	0.5121
Mixed-rural households	0.4574	0.5239	0.6702	0.7634
Urban average	0.5528	0.5699	3.9982	4.0902
Mixed-urban households	0.5466	0.5375	0.8010	0.7833
Purely urban households	0.5548	0.5807	1.0657	1.1023
Mixed household average	0.5020	0.5307	0.7356	0.7734
Households of rural origin average	0.4611	0.4936	0.5488	0.5868

Table 3C7: Household expenditures

	Model 2		Model 3	
Item	Baseline	M-money	Baseline	M-money
Purely rural household consumption	0.4447	0.4788	0.4741	0.5121
Mixed-rural household consumption	0.4574	0.5239	0.6702	0.7634
Mixed-urban household				
Consumption	0.5466	0.5375	0.8010	0.7833
Investment			0.2818	0.2857
Net transfer	0.0208	0.0730	0.2938	0.3710
Transaction fees for remittance	*0.0089*	*0.0038*	*0.1259*	*0.0195*
Purely urban household				
Consumption	0.5548	0.5807	1.0657	1.1023
Investment			0.2964	0.3083
Transaction fees for non-farm goods	*0.0337*	*0.0076*	*0.0518*	*0.0116*
Selected aggregation				
Mixed household	0.5020	0.5307	0.7356	0.7733

Table 3C8: Household welfare

Item	Model 2		Model 3	
	Baseline	M-money	Baseline	M-money
Aggregate welfare	-2435.66	-2418.96	-1877.96	-1844.92
Rural welfare	-265.16	-257.97	-235.16	-226.91
Purely rural	-266.78	-262.86	-249.93	-242.87
Mixed-rural	-257.07	-233.52	-161.30	-147.09
Urban welfare	-211.17	-217.79	-116.75	-120.87
Mixed-urban	-214.28	-235.37	-149.97	-163.91
Purely urban	-210.13	-211.93	-105.67	-106.52
Selected aggregation				
Mixed household	-235.67	-234.44	-155.63	-155.50

Table 3C9: Relative prices, wages and return on capital

Item	Model 2		Model 3	
	Baseline	M-money	Baseline	M-money
Prices				
Rural household basket	0.9302	0.9867	0.9289	0.9752
Rural produced goods	0.8956	0.8661	0.9473	0.9170
Farm goods	0.7821	0.8451	0.8047	0.8673
Non-farm goods	1.0167	0.8873	1.1016	0.9681
Manufactured goods	1.0702	1.1066	1.0277	1.0501
Urban household basket	1.0000	1.0000	1.0000	1.0000
Wages per unit of labour				
Rural households	0.7821	0.8451	0.8474	0.9220
Urban households	0.9632	0.9959	1.7165	1.7538
Return per unit of capital				
Mixed-urban households			0.0359	0.0366
Urban household			0.0461	0.0471

Table 3C10: The weight of shock in the variance of selected endogenous variables, ratio of mobile money to baseline scenario, money supply rule

Item	Farming	Non-farming	Manufacturing	Policy shock
Model 2				
Output	1.195	1.127	0.980	0.987
Inflation	1.158	1.070	0.935	1.014
Interest	2.000	1.052	0.963	1.028
Money	2.000	1.052	0.967	1.029
Model 3				
Output	1.255	1.038	0.998	1.048
Inflation	1.233	1.044	0.984	1.015
Interest	1.400	1.035	0.988	1.023
Money	1.200	1.054	0.989	1.023

Chapter 4

Mobile money and the income velocity of circulation: the case of East African countries

4.1 Introduction

4.1.1 Objectives and choice of countries to study

In this Chapter, we use 22 years of quarterly time series data, covering the period 2000 to 2021, from Tanzania, Kenya and Uganda, to empirically seek an answer to the question: has the rise of mobile money in these countries impacted the monetary policy variables? In particular, we seek to find out whether mobile money has increased the income velocity of circulation in a statistically significant way.[47] Studies have shown that the income velocity of circulation exhibits a downward trend as economies grow from low to high income and that financial innovation can cause a permanent upward shift in the velocity of money circulation (Adil *et al*., 2020; Friedman, 1959; Mele and Stefanski, 2019; Ochs and Rush, 1983). It has also been argued that mobile money is a form of financial innovation that has occurred at a rate that exceeds the ordinary pace of financial innovations in the countries where it has flourished.[48] This would imply that mobile money may have caused a shift in the income velocity of circulation in excess of that warranted by the ordinary pace of financial innovations.[49] Occurrence of an upward shift in velocity will require relatively lower levels of money supply in order to maintain desired levels of output and price. This, as noted by Driscoll and Lahiri (1983), may also have a bearing on the amount of resources that can be raised through money creation and, therefore, have government budgetary implications. Given its key role in the monetary policy framework, understanding how velocity has been affected by mobile money

[47] Income velocity of circulation refers to the ratio of GDP to the quantity of money supply. It measures the number of times a unit of money is used over a period of time, usually one year. Income velocity differs from transactions velocity in that, the latter includes all transactions in the economy—final and intermediate—while the former is made up of final transactions only.
[48] The rise of mobile communication and mobile money has been described as revolutionary (Demombynes and Thegeya, 2012; Kendall, and Voorhies, 2014; Mawejje and Lakuma, 2019; Mbiti and Weil, 2016).
[49] As stated by Thornton (1983), velocity does not need to be constant for the monetary policy authorities to perform their duty well. Rather its growth needs to be stable and therefore predictable. If the known growth is driven out of its path by a certain development, policy authorities need to know, so that they make adjustment to their policy actions in the right direction, magnitude and time. The ordinary (and known) pace of financial innovation in developing economies is, for convenience, assumed to be the rate at which the financial industry in these economies absorb advanced financial instruments, processes and institutions that already exist in more advanced countries.

will provide valuable input to macroeconomic policy design. Other factors that have been identified as causing permanent change in velocity include changes in the institutions and industrial structure of the economy (Bordo and Jonung, 1981). The findings of this Chapter will also help to assess whether statistics from these countries support the predictions of the model developed in the preceding chapters that mobile money would, by reducing payment friction, allow shocks to be transmitted more efficiently across sectors.

We have chosen Tanzania, Kenya and Uganda for this study because they are among the countries with the longest and most widespread presence of mobile money. Mobile money was introduced in Kenya in 2007, in Tanzania in 2008 and in Uganda in 2009 (Di Castri and Gidvani, 2014; Mawejje and Lakuma, 2019) (Figure F1). Chironga *et al*. (2017) put these countries in the mature market group in 2016, defined as countries where mobile money accounts exceeded 1,000 per 1,000 adults (Figure H8).[50] According to G20 Financial Inclusion Indicators data, these have been the leading countries with highest number of mobile money transactions per 100 thousand adults. These countries also share similar economic regimes and a history of cooperation, partly because they have since the 1990s engaged in a process of economic integration under the revived East African Community (EAC), which involves harmonization of key macroeconomic performance indicators, instruments and policies towards the anticipated East Africa Monetary Union (EAMU). They emerged from their colonial past in the early 1960s as members of EAC, which later collapsed in 1977 and then was revived in the mid-1990s (Figure H6).[51] According to Financial Inclusion Insight (2021) data, 72 per cent of adult Kenyans had mobile money account ownership, while for Tanzania, it was 55 per cent and for Uganda, 43 per cent. The World Bank Global Findex Database (2017) shows that these countries were among the top 10 countries with the highest mobile money accounts in the world in 2017 (Figure F2). We therefore consider these countries suitable to provide a good case study, with regard to the impact of mobile money on monetary policy.

[50] The excess of accounts over adult population is caused by the fact that some customers hold more than one account to circumvent interoperability limitations, and inclusion of some dormant accounts.
[51] The Treaty for Re-establishment of the EAC was signed among Tanzania, Kenya and Uganda in 1999. Ten years later, in 2009, Burundi and Rwanda joined the community and afterward, South Sudan joined in 2016. More recently the Democratic Republic of Congo joined the Community in March 2022 (Figure H6). In the meantime, the East African Customs Union became operational in 2005 and the Common Market Protocol entered into force in 2010 (East African Community, 2022).

4.1.2 Financial developments in the countries studied

While mobile money may be considered to have revolutionized development of financial services in the countries where it has thrived (figures H5 and H7), other financial developments have been an integral part of economic development among the countries studied in this work (Mbiti and Weil, 2016; Mattern and McKay, 2018). In Tanzania, the period studied was preceded by financial liberalization that gave rise to a notable improvement in a number of financial sector indicators. Reforms were carried out in the legal and regulatory frameworks, which coupled with innovations in digital finance, facilitated greater outreach of financial services through the introduction of new financial products such as bank cards and biometric readers (Balele *et al*., 2018). This period also saw a remarkable expansion of the banking infrastructure—bank branches, bank agents, automatic teller machines (ATMs) and point of sale (POS) terminals. Uganda also experienced similar developments in the financial services space, with the introduction of ATMs, debit and credit cards, development of electronic banking products and mobile money services (Nampewo and Opolot, 2016). Table F1 gives a snapshot of selected indicators of financial development in Tanzania, Kenya and Uganda in 2020. These indicators show that, while Kenya is far more developed in terms of having substantially smaller ratio of people per bank branch, there are twice as many people per mobile money agent in Kenya and Uganda compared to Tanzania. Figure F3 shows the increasing credit to GDP ratio for all countries. However, in Kenya and Tanzania, it seems to have peaked around 2015 and then declined towards 2021, but remained noticeably higher historically. During this period, the total bank assets to GDP ratio rose from 7 to 18 per cent in Tanzania, and similar development was observed in Uganda, where it grew from 8 to 19 per cent, and Kenya from 30 to 47 per cent (Figure F4).

The rise of mobile money, though, has been the most remarkable financial development to have occurred in the countries studied. Unsurprisingly, it has raised interest among researchers seeking to understand its impact in various social-economic aspects. Of the various areas of impact of mobile money, the one that has received the most attention is financial inclusion, understandably because of the enormous outreach of formal financial services that has been made possible by mobile money (Abiona and Koppensteiner, 2020; Ahmad *et al*. 2020; Ondiege 2015). Mobile money has brought hope that the seemingly insurmountable problem of delivering formal financial services to the unbankable poor might have found a solution, and achievements in this area have been dramatic. For example, in Tanzania, mobile money and related innovations like mobile banking and digital finance, have been credited with a sharp increase in access to formal financial services, from 16 per cent in 2009 to 65 per cent in 2017. Similarly, access to formal financial services in Kenya rose from 27 per cent in 2006 to 83 per cent in 2019, and Uganda from 28 per cent in 2006 to 58 per cent in 2018 (FinScope Tanzania, 2017; FinScope Uganda, 2018; Kenya National Bureau of Statistics, 2019).

In the area of macroeconomic policy, empirical studies about how mobile money may have affected or may affect monetary policy variables are gradually building up, but the authors seem to be unsettled about the indicators they use to represent mobile money and financial innovation in general. Historically, the literature about the impact of financial developments on velocity has been motivated by two observations. First is the fact that the income velocity of circulation gets slower as economies develop and per capita income/wealth grows. Second is the tendency of traditional models, that rely on real income and interest rate, to under-predict the income velocity of circulation, first observed in the US in early 1970s (Arrau *et al*., 1995; Bilyk, 2006; Goldfeld *et al*. 1976; Judd and Scadding, 1982; Labán, 1992; Lieberman, 1977; Lown *et al*. 1999; Orphanides, 2010). A number of views have been put forward to explain the first observation including the process of monetization driven by structural transformation towards monetized exchange as economies grow, money being a luxury good that becomes ever more demanded by wealthier people, and insufficiency of other investment options as people become wealthier (Driscoll and Lahiri, 1983; Friedman and Schwartz, 1983; Syrotian, 2012). Bordo and Jonung (1987) associate the second observation with financial innovation, in the sense of a progressive increase of close substitutes of money and better cash management techniques that make transaction balances more efficient, hence reducing their demand. Another factor pointed out by Goldstone (1991) is increase in proximity among economic agents, brought about by developments such as urbanization, that raises the density of transactions, thus speeding up the velocity of money circulation *ceteris paribus*.

Choosing suitable indicators for each of these developments is an important exercise for empirical results to be consistent with economic theory. Time trend has been used by some authors like Arrau *et al*. (1995) and Ndirangu and Nyamongo (2015) to represent financial innovation, which, in our view, has for some countries generated results that are inconsistent with effects that would be expected from financial innovation.[52] On account of this, we proceed by dedicating the first part of Section 2 to discussion of financial developments in general, with a view to shedding light on the interpretation of the results found in literature and inform the choice of indicators to be used in the empirical analysis that follows later. This is followed, in the same section, by discussion of literature on financial innovation, mobile money and monetary policy. In Section 3, we discuss the theoretical framework and empirical methodology used in the estimations, and then Section 4 deals with estimations and results. Finally, in Section 5, we make our conclusions.

4.2 Financial developments and the literature on financial innovation, mobile money and monetary policy

4.2.1 Financial developments

Financial development is a broad term that includes, among others, financial innovation. It entails the size, liquidity, access and efficiency of financial services (Sahay *et al*. 2015). Occurrence of financial development is manifested in changes that take place in financial indicators such as the ratio of bank credit to GDP, the proportion of financially included people and the ratio of financial assets to total assets in the economy. Financial innovation is a particular type of financial developments that relates to introduction of new financial products, or new processes in supplying existing financial products, or new financial institutions (Adil *et al*., 2020; Dabrowski, 2017; Lewis and Mizen, 2000). This differs from other forms of financial developments such as monetization and commercialization, that may occur without new financial products, processes and or institutions. Monetization refers to the process of enlargement of the value of transactions carried out using money relative to total GDP, that occurs mainly due to secular decline of the share of agricultural value added in total GDP, as economies develop (Chandavarkar, 1977).

Based on the nature of their outcomes, financial developments can be viewed in the following four main categories: i) developments that incentivize the uptake of formal financial services; ii) developments that increase outreach of the existing formal financial services; iii)

[52] Some authors like Cho and Miles (2007) and Adil *et al*. (2020) refer to financial innovation as including both monetization and introduction of new financial instruments, processes and institutions. In this work we consider them to be separate because monetization is a phenomenon that does not need new financial instruments, processes and institutions to occur. Besides, representing them as one phenomenon impairs the clarity of findings and their interpretation.

developments that reduce transactions costs, and; iv) developments that enlarge the aggregate size of monetized activities in the economy. Each one of these developments can be caused by: changes in legal and regulatory framework; improvement of existing products or introduction of new ones; improvement of the existing processes or introduction of new ones; and improvement of existing institutions or introduction of new ones. Developments like monetization and commercialization may also be an outcome of changes in the behaviour of agents that in turn lead to changes in the extent to which they use formal financial services. We briefly discuss each of the four categories of financial developments below, with a view to identifying suitable indicators for each.

The first category of financial developments is developments that incentivize uptake of formal financial services. These developments increase the spectrum of income and social groups participating in formal financial services. Examples of financial developments falling under this category include the reduction of minimum balances for bank deposit accounts and the minimum bid values for treasury securities. In Tanzania, for instance, the minimum investment threshold for direct placement of government securities in the primary market was reduced from Tanzanian shillings (TZS) 50 million to TZS 5 million (a decrease from USD 42,000 to USD 4,200) in 2005/06, with a view to increasing participation in the government securities market. This move was credited with an increase in participation by 27 per cent in the treasury bills market and 11 per cent in the treasury bond market in 2006/07 (Bank of Tanzania, 2007). Such developments allow investors in the lower-income groups to acquire formal financial assets or to participate in formal financial services. People can also be incentivized to take up formal financial services by reduction of documentary requirements and/or bureaucratic processes involved.

Other forms of disincentives to access are those causing certain social groups to be excluded on the basis of their beliefs and/or customs. The introduction of Islamic banking is one example of financial development that may open certain financial services to a particular social group. The result of developments that incentivize uptake is increase in the outreach of financial services in terms of the array of income and social groups included. These developments can be captured by financial intermediation indicators, such as: the ratio of bank credit held by the private sector to GDP, the ratio of bank credit held by the private sector to deposits, the ratio of private sector bank deposits to GDP, and the ratio of the financial assets of the whole economy to the wealth of the whole economy (Cinquegrana, 2010; Kessy *et al*., 2017; Mohan, 2006). These indicators are also referred to as financial deepening indicators (Alrabadi, 2016; Nnenna, 2012; Ndebbio, 2004). Other indicators of this category of financial development are the proportion of the formally banked population, the proportion of the population receiving remittances, the number of formally banked micro-enterprises, the number of cashless transactions, the number of mobile accounts, the number of mobile transactions, the number of active bank accounts, and the average cost of opening and maintaining a bank account.

The implication of this type of financial development on income velocity of circulation depends on the initial status of agents and transactions, and the type of new financial services to which they are admitted. If the agents were initially using money and then they got admitted to more efficient alternatives of money, the expected outcome is acceleration of the income velocity of circulation. Likewise, if these developments lead to higher levels of financial intermediation among those already using money, an increase in velocity will be expected. The reason for this is that money in form of demand deposits has higher turn-over rate than currency outside banks (Mbiti and Weil, 2016). Otherwise, and especially for developing economies where the scope for monetization is high, if by making access to financial services easier, large number of non-monetary transactions are migrated from subsistence and batter into the monetized economy, then the monetized part of the economy may increase and slow down velocity. Slowdown in velocity may also occur if higher levels of intermediation result in faster growth in the aggregate value of monetized activities due to increased access to intermediated credit.[53]

The second category of financial developments is developments that increase the outreach of existing financial services. This category of financial developments leads to an increase in the number of agents participating in formal financial services within similar income and/or social groups. It corresponds to financial broadening, also referred to as financial widening (Jenik *et al*. 2017; G20 Financial Inclusion Indicators). Some of the indicators used for this type of financial development are the density of points of financial service relative to population, such as bank branches, bank agents, ATMs, and POS terminals (Alih, 2018; Attanasio *et al*., 2002; Fischer, 2007; Lippi and Secchi, 2009; Nagayasu, 2012; Sichei and Kamau, 2012). The density can also be measured in terms of the average distance to the nearest point of financial service. For mobile money, the percentage of population with active mobile money accounts, the

[53] Since non-monetized activities have no access to intermediated credit, an increase in credit will generally cause faster growth in monetized activities relative to non-monetized activities.

average distance to the nearest mobile money agent and the number of mobile money transactions can serve as indicators of outreach. It is pertinent to note at this point that the number of mobile money accounts is considered here as one of suitable indicators of outreach because, unlike other forms of money, almost each mobile money account has a corresponding mobile phone, which functions as an electronic wallet.[54] A mobile money account, therefore, provides the account holder with capabilities to execute transactions without relying on another structure like ATM and POS terminals. In this case, the mobile phone itself becomes a point of financial service (Hughes and Lonie, 2007).

The implications of the second category of financial developments on income velocity of circulation are broadly similar to those of the first category. If the expansion of outreach of existing services reduce transaction costs to those already using money, the expected outcome is an increase in income velocity of circulation. Similar outcome is expected if these developments lead to higher levels of financial intermediation for those already using money. However, if the spread of the existing formal financial service access points results in agents migrating some of their transactions from subsistence and batter to money based, then the result will be an increase in the monetized part of the economy and hence, exert downward pressure on velocity.

The third category of financial developments is developments leading to the reduction of transaction costs. These may include removal of certain steps in the delivery of financial services, mostly in form of process automation. Such developments often include introduction of new instruments with features that allow automation of corresponding financial processes, or using existing infrastructure like the internet and the mobile network, as a platform for provision of financial services. For instance, the introduction of bank cards and POS terminals enabled self-initiated electronic funds transfers to be carried out, hence reducing transaction costs in that respect. Internet banking and mobile money arose out of innovations that made use of the internet and mobile phone networks for financial services, respectively. Indicators of this type of financial development include the volume and value of transactions going

[54] Surveys have reported some cases of SIM card swapping by mobile money account holders meaning that it is possible for the number of mobile money accounts to exceed the number of mobile phones, albeit by small amount (Hughes and Lonie, 2007). The motivation for SIM card swapping include avoidance of interoperability costs when transactions are made across different network providers and the sheer presence of few mobile money account holders that have no mobile phone of their own. Reasons for not having a phone of their own may include phone breakdown or inability to afford one (Munyegera and Matsumoto, 2016).

through the improved channels of transactions such as internet banking, electronic funds transfers and mobile money. Reduction of transaction costs increases the efficiency with which money balances are used, and thus leads to reduction in demand for real money balances, since these balances are held at an opportunity cost. The reduction in real money balances is mirrored by an increase in the income velocity of circulation (Mele and Stefanski, 2019).

The last category of financial developments is developments that lead to enlargement of the aggregate size of monetized activities. These developments occur mostly as economies develop from low to high income due to structural transformation associated with economic growth and therefore they tend to be long-term. Low-income countries tend to have larger rural, informal and non-monetized agricultural activity that progressively get absorbed into the monetized economy as the economies grow (Chandavarkar, 1977). This takes place due to migration of workers from agricultural activity into non-agricultural activities as agriculture becomes more productive and growth in other activities outpaces that of agriculture, hence causing a negative relationship between economic growth and income velocity of circulation, *ceteris paribus* (Driscoll and Lahiri, 1983; Mele and Stefanski, 2019). In addition to structural transformation, Driscoll and Lahiri, (1983) found that, in some developing economies, the marginal propensity to demand for money is higher in the non-agricultural sector than in the agricultural sector. Among EU economies also, it has been found by Dreger and Wolters (2009) that there is negative long-run relationship between wealth and velocity of money. These findings align with the claim by Friedman (1959) that the stock of money generally rises over long periods of time at a rate that exceeds the rate of increase in money income, that has repeatedly been confirmed as a stylized fact (Figure H1).

The enlargement of the aggregate size of monetized activity can also be driven by commercialization of economic activity. Commercialization is defined as the extent to which economic activities are directed towards market and profit maximization. Products of commercialized activity are both salable and market dependent (Chandavarkar, 1977). For example, a small farmer who grows food crop, using household labour, can keep substantial part of the output for their household consumption, making this household largely subsistent, and therefore non-monetized. If this farmer changes from production of food crop to production of a cash crop like cotton, then they must sell their crop and buy their needs from the market. The second type of activity is dependent on money-based (market) exchange so it is monetized. If this farmer becomes profit-oriented, their output will be determined by profitability, and thus make it a commercialized activity. Note that, by growing cash crop the farmer becomes reliant on money without causing change to the industrial structure of the economy. A progressive push towards monetization can also come from households' increasing demand for larger share of market goods in their consumption, due to such factors as exposure, the perpetual entrance of new non-agricultural consumer products into the market and urbanization. Since productivity, specialization, exposure, urbanization and the attendant market interactions increase as economies grow, commercialization becomes an integral part of economic growth, hence contributing to the secular decline in the income velocity of circulation (Goldstone, 1991). This increase in demand for money arising from structural transformation and commercialization is henceforth referred to as monetization in this work. The process of monetization can be viewed as taking place smoothly over time; therefore, a time trend variable can be used to represent it. Another suitable variable is the ratio of monetary GDP to total GDP, also referred to as monetization ratio.[55] Like deterministic trend, the ratio of monetary GDP to total GDP increases as economies develop. Income velocity of circulation is therefore, expected to be inversely related with trend and the share of monetary GDP in total GDP, in developing economies.

It deserves to mention at this point that while we have tried to allocate indicators to different categories of financial developments, some of them may not be strictly confined to one category. For instance, an increase in the ratio of private sector credit to GDP may be caused by financial deepening, which we have associated with the first category. At the same time, such an increase may be caused by financial broadening, which we have associated with the second category. Likewise, increase in the outreach of existing financial services may reduce transaction costs just as improvements in the existing products, processes and institutions, and admission of new economic and social groups into formal financial services may reduce transaction costs. In that respect therefore, the indicators of the first, second and third category may overlap, and for the most part, they are expected to be positively related with income velocity of circulation. To close this sub-section, we identify the place of mobile money as a form of financial development.

[55] In most developing countries, total GDP is made up of monetary and non-monetary GDP. The non-monetary GDP is, in turn, made up of imputed value added of products that are consumed without being brought to the market. Non-monetary products include products of subsistence activities, payment in kind and batter trade, which are mostly found in the farming, hunting and forestry industries. The share of these industries in total value added tends to shrink with growth.

Mobile money is a form of financial innovation that cuts across the first three categories discussed above. It has lowered the entry threshold into formal financial services, expanded the outreach of financial services across each income and/or social group, and reduced transaction costs by among others, increasing speed and transparency. Like most modern financial innovations, mobile money is a product of digital technologies. It falls among the types of financial developments that fit the historical motivation behind the search for the missing variable, in explaining the increase in income velocity of circulation, not covered by traditional models, (Arrau et al., 1995; Bilyk, 2006; Goldfeld et al. 1976; Judd and Scadding, 1982; Labán, 1992; Lieberman, 1977; Lown et al. 1999; Orphanides, 2010). By removing the barriers of distance and time to transactions, mobile money can also be viewed as having brought the transacting parties closer, in sparsely populated countries, reinforcing its effect on velocity of money circulation. An indicator drawn directly from mobile money statistics, such as the number of mobile money transactions can therefore be used in empirical analysis to represent elements of the first three categories of financial developments, with expectations that it will speed up the income velocity of circulation.

Having looked at various financial developments and their expected relationship with the income velocity of circulation, we now turn to a survey of literature about the impact of mobile money and financial innovation in general, on monetary policy variables.

4.2.2 Literature on financial innovation, mobile money and monetary policy

Since mobile money is a form of financial innovation, this sub-section includes discussion of studies on mobile money and monetary policy, as well as more general studies that cover financial innovation and monetary policy. It focuses on both velocity of money circulation and demand for money because these are concepts that mirror each other.

Literature about the empirical impact of mobile money on monetary policy variables in East Africa has focused on four interrelated areas, namely money multiplier, income velocity of circulation, demand for money and monetary transmission mechanism. Most of the existing studies have been carried out without sufficient mobile money statistics, hence inference about the impact of mobile money has been drawn implicitly, from a broader context of financial innovation indicators. For example, Ndirangu and Nyamongo (2015), employed trend as a proxy for financial innovation to study its impact on money multiplier, income velocity of circulation and demand for money in Kenya. They used autoregressive distributed lag and vector error correction approach, and found a negative relationship between financial innovation and income velocity of the extended broad money supply (M3) circulation. They tested the stability of the money multiplier, income velocity of circulation and money demand and found evidence of instability in velocity in the period 2009 to 2010 and in money multiplier and demand for money after 2007. They suggested that this instability could be attributed to financial innovations, the most prominent of which was the coming of mobile money in Kenya. They also investigated whether financial innovations had impacted the monetary policy transmission by carrying out impulse response analysis and found improved effectiveness of monetary policy on GDP, compared to previous studies, which they suggested could be linked to the introduction of mobile money as well. Since the secular decline in the income velocity of circulation is a stylized fact, finding a negative relationship between time trend and velocity is compatible with expectations, if trend is taken to represent monetization. Monetization, as we have seen earlier, occurs mostly due to the changing structure of the economy, and not due to financial innovation, in the sense of introduction of new financial products, processes and institutions.[56]

A similar study was carried out by Nampewo and Opolot (2016) for Uganda, but their interest was confined to finding the impact of financial innovations on the income velocity of circulation. They used two generic proxies of financial innovation, namely the ratio of currency in circulation to broad money (M2) and the ratio of time deposits to demand deposits.[57] They applied autoregressive distributed lag approach and found that financial innovations were having negative effects on income velocity of circulation in the short-run and positive effects in the long-run. This finding conforms with the fact that as economies grow, financial intermediation grows faster, implying that the ratio of currency in circulation to M2 for a developing economy will tend to fall with time—a trend observed among the East African countries as well (Figure G3). This translates to a positive long-run relationship between the ratio of currency in circulation to M2 and the income velocity of circulation. Therefore, the

[56] Other authors also have used time trend as a proxy for financial innovation and interpreted it as a measure of monetization when its coefficient came out negative, e.g. Cho and Miles (2007) and Adil *et al*. (2020).
[57] These indicators were also used as proxies of financial innovation by Akinlo, (2012), and Bordo and Jonung (1987). Table H1 provides a list of indicators that have been used to represent financial developments.

observed positive long-run relationship between the ratio of currency in circulation to M2 and income velocity of circulation in Uganda represents correlation that occurs due to monetization, rather than financial innovation defined as introduction of new financial products, processes and institutions. This correlation occurs for independent reasons.

Mbiti and Weil (2016) measured the velocity of mobile money (M-Pesa) in Kenya more directly as the total value of person-to-person transfers (per unit of time) divided by the average outstanding balance of mobile money. They found that there was a significant upward trend in the transaction velocity of mobile money, but concluded that mobile money velocity had no significant implications for the conduct of monetary policy in Kenya, partly because mobile money balances accounted for less than one per cent of narrow money.[58] In addition, Weil *et al*. (2012) found that, while velocity of mobile money exceeded that of currency and kept rising in Kenya, it was not as high as that of demand deposits observed in other countries. It is arguable from these findings though that, as the share of mobile money in transaction balances grows over time, its higher velocity may affect the overall income velocity of circulation in a significant way, a view also shared by Popovska-Kamnar (2014).

Other studies on East Africa have approached the impact of mobile money from inflation point of view. Simpasa and Gurara (2012) observed that there was an upturn in the income velocity of circulation in Tanzania, Kenya and Uganda from around 2009, which they attributed to the rise of mobile money in the region. They also concluded that increase in velocity contributed to the observed high inflation in the East African region around that time. Aron *et al.* (2015), on the other hand, found no sufficient evidence to support the claim that mobile money was inflationary in Uganda.

Outside East Africa, Orekoya (2017) estimated the impact of mobile money on monetary policy in Nigeria, employing structural VAR methodology and using mobile money payments to represent mobile money. The author concluded that it had no statistically significant effect on monetary policy. More recently, Wiafe *et al*., (2022) used similar methodology and the value of mobile money transactions as mobile money indicator in their study on monetary policy

[58] They calculated outstanding value of mobile money balance to be Kenyan shillings (KES) 3.3 billion in August 2008, while the average stock of currency over the period January– June 2008 was KES 85.2 billion and demand deposits KES 393 billion.

effectiveness in the advent of mobile money in Ghana. They observed that monetary policy responded to mobile money shock with an increase in short-term interest rate, which would be in conformity with the argument that mobile money increases velocity, to which the monetary policy authorities react by taking tighter policy stance. The contrast between Nigeria and Ghana is consistent with the fact that Nigeria had much less mobile money presence compared to Ghana. According to World Bank Global Findex Database (2017), 39 per cent of Ghanaian adults had mobile money account in 2017, whereas the figure for Nigeria was only 6 per cent.

It deserves to mention here that, while we argue that the negative long-run relationship found between time trend and velocity in Kenya and the positive relationship found between the ratio of currency to broad money and velocity in Uganda explains monetization better than financial innovation, time trend might be justified as an indicator of financial innovation in economies where monetization is minimal or non-existent. Lieberman (1977) utilized time trend to represent financial innovation in the estimation of US demand for money, and found that it had inverse relationship with demand for money, compatible with the argument that financial innovation was reducing demand for money, and therefore causing over-prediction among traditional money demand models. Arrau *et al*. (1995) applied time trend as a measure of financial innovation in the estimation of demand for money for nine countries. They employed cointegration methodology and found significant negative relationship between time trend and demand for money in five countries. Interestingly, in all countries where the variables were found to be cointegrated, and the relationship between time trend and demand for money both negative and significant, agriculture accounted for less than 8 per cent of GDP, except India.[59] Two of the remaining four countries, Morocco and Nigeria, where cointegration was not found, had agriculture accounting for a larger share of GDP, 13 and 25 per cent, respectively, in 1995 (World Bank Group, 2022). The five countries where cointegration and significance of time trend was found were Argentina, Brazil, India, Israel and Korea Republic.

Recently, Adil *et al*. (2020) studied the impact of financial innovation on demand for money in India using the ARDL approach to cointegration. They tried both time trend and institutional variables as proxies for financial innovation. The institutional variables that they used were

[59] The seven countries were Argentina where the share of agriculture in total GDP in 1995 was 5 per cent, Brazil (5 per cent) Chile (7 per cent), India (24 per cent), Israel (2 per cent), Korea Republic (5 per cent) and Mexico (4 per cent) (World Bank Group, 2022).

certificates of deposits and commercial papers. Unlike Arrau *et al*. (1995), they found positive relationship between trend and demand for money, which they attributed to monetization process, and suggested that this process was unleashed by the financial liberalization that took place in early 1990s in India. As for certificates of deposits and commercial papers they were both found to have inverse long-run relationship with demand for money, in line with the argument that financial innovation increases the income velocity of circulation. Compared with the findings by Arrau *et al*. (1995) on India, the findings by Adil *et al*. (2020) postulate that, even in countries where the share of agricultural output is still high like India, the secular decline in velocity may exhibit cyclical behaviour.[60] The authors draw their conclusion by emphasizing the importance of using instrument specific indicators.

4.2.3 Summary and limitations of the existing literature

The literature we have discussed above can be grouped according to the geographical region and time period covered; whether it specifically focused on mobile money or financial innovation and the proxies used. All studies that covered the East African region were carried out for periods that partially had mobile money. Two of them used generic indicators of financial innovations namely, the time trend, the ratio of currency to M2 and the ratio of time deposits to demand deposit balances. Although they drew none of their proxies from mobile money, they made conclusions that associated their findings with mobile money. As we have seen, these indicators may not correctly represent the effects of mobile money—or even financial innovation, in general. The study by Mbiti and Weil (2016) measured the velocity of mobile money directly and then compared it with the velocity of other forms of money, concluding that velocity of mobile money, though increasing, had not significant impact on monetary policy.

Elsewhere in Africa, the studies on Ghana and Nigeria, covered the periods that also partially had mobile money and sought to find out the impact of mobile money on monetary policy by utilizing mobile money transactions data as proxy for mobile money. The findings for Ghana were in conformity with the argument that mobile money would drive the income velocity of circulation up, while for Nigeria mobile money was not found to have statistically significant

[60] The study by Arrau *et al*. (1995) was carried out when the share of agriculture in India exceeded 20 per cent and yet their findings were consistent with an income velocity of circulation that was increasing with time. The estimations by Adil *et al*. (2020) were based on a period that the share of agriculture in India had fallen to between 20 and 18 per cent and yet their findings suggested that velocity was decreasing with time.

effect on monetary policy. Outside Africa, the study on India, was carried out for a period with similar characteristics as the preceding ones, but focused on financial innovation in general and utilized trend as a generic indicator of financial innovation, as well as institutional indicators i.e. certificates of deposits and commercial papers. They concluded that trend represented the monetization effect, while the other indicators captured the effect of financial innovation. They then emphasized the importance of using institutional indicators in order to obtain more robust and consistent results about the impact of financial innovation on monetary policy. The rest of studies were carried out before the advent of mobile money and employed trend as a proxy for financial innovation, concluding that financial innovation had a lasting upward effect on velocity.[61]

We identify two major limitations in the existing literature. First, is the over reliance of generic indicators of financial innovations, to draw inference about the impact of mobile money and financial innovation in general, on monetary policy. Second, while literature abounds in studies that have found noticeable impact of mobile money on financial inclusion, the same cannot be said about its impact on monetary policy. This seems to be caused by relatively small amounts of money involved in mobile money transactions compared to total volume of money-based transactions. To illustrate, while 63 per cent of Tanzanian adults had mobile money account in 2017, the total mobile money account balances accounted for only 4 per cent of total money supply (FinScope Tanzania, 2017; Bank of Tanzania, 2021).[62] This is also reflected in the average value of mobile money transactions as, for instance, noted by Jack and Suri (2011) that the average mobile money transaction in Kenya was about one per cent of the average cheque transaction and half of the average ATM transaction. Since the indicators of financial inclusion are primarily focused on the number of people participating in formal financial services, irrespective of the amounts of money involved, it may not be surprising that the impact of mobile money in the area of financial inclusion has been so visible. Monetary policy on the other hand, is impacted more by changes in the aggregate amount of money involved, than changes in the number of participating agents. It is possible therefore, that at the time when the studies discussed above were carried out, the weight of mobile money in total monetary aggregates was too small to have caused noticeable impact on the monetary aggregates, which

[61] Considering that reduction of demand for money implies an increase in the velocity of money circulation *ceteris paribus*.
[62] The comparison used here is that of 2017 because that was the year that the FinScope survey was carried out.

may as well explain the failure of those studies to utilize indicators drawn directly from mobile money statistics.[63]

In the current work we have advantage of having a much longer sample period, from 2000 to 2021, with larger coverage of mobile money presence. We have a period of 88 quarters, 28 of which the countries studied had no mobile money and 51 of which they had mobile money.[64] We also have indicators directly associated with mobile money such as: the number of mobile money accounts, the number of mobile money transactions and the value of mobile money transactions, that we can use to represent mobile money better, than the generic financial innovation indicators. In this work we are going to employ indicators drawn directly from mobile money statistics and therefore, hope to produce results that are consistent and more robust compared to those of the earlier studies. In addition, by studying the three East African countries as a group, we hope to be able to unveil insightful cross-country findings.

4.3 Theoretical framework and empirical methodology

To understand the impact of mobile money on velocity of money circulation, we begin by discussing the definition of the velocity, followed by the relevant analytical framework.

4.3.1 Velocity of money circulation

There are two definitions of velocity of money circulation, namely transactions velocity and income velocity. In Fisher's equation of exchange, the transactions velocity of money is defined as:

$$V^T = \frac{PT}{M}, \tag{4.1}$$

where V^T stands for transactions velocity of circulation, P for price level, T for the quantity of all goods and services transacted and M is the quantity of money.

The income velocity of circulation, on the other hand, is measured as:

$$V^Y = \frac{PY}{M}, \tag{4.2}$$

[63] Coverage of mobile money data in Mbiti and Weil (2016) is up to 2008, only a year after its establishment; in Ndirangu and Nyamongo (2015) data coverage is up to 2012; and in Weil *et al*. (2012) data coverage was up to April 2011.
[64] The period without mobile money for all countries in this sample is 2000Q1 to 2006Q4 (28 quarters) and the period with mobile money is 2009Q2 to 2021Q4 (51 quarters).

where V^Y stands for income velocity of circulation, P is price level (GDP deflator in this case) and Y is aggregate real value added—GDP. The difference between these two measures of velocity is that the transactions velocity covers transactions of all goods—final and intermediate—while the income velocity covers the real value of final goods only. Agents hold money for purchase of all kinds of goods and services, meaning that transactions velocity measures the purpose for which agents choose to hold money better, but such data is not available for empirical analysis. For this reason, it has become a common practice to use income velocity of circulation in empirical studies, instead of transactions velocity (Syrotian, 2012), which we adopt in this study and drop the superscript henceforth, to represent income velocity of circulation with notation V.

The relationship depicted in equation number (4.2) underlies the quantity theory of money, that in its basic form, takes price level as a product of quantity of money supplied, on assumption that velocity and output are fixed in the short-run. Recognizing the role that money can play in smoothing out the cyclical output fluctuations, the theory is relaxed by relegating the money-price relationship to the long-run. Taking compounded growth rates we can draw equation number (4.3) from equation number (4.2)

$$\dot{P} = \dot{M} + \left(\dot{V} - \dot{Y}\right), \tag{4.3}$$

where the dotted variables represent the compounded growth rate of the corresponding variables defined earlier. Equation number (4.3) underscores the importance central banks need to put on the behaviour of velocity in their pursuit of price stability. It says that the relationship between the growth rate of money and inflation rate mirrors the difference between the growth rates of velocity and real output (Thornton, 1983). As we have seen earlier, monetization and financial innovation have been found to have permanent effect on velocity. Since these factors are dynamic in the long-run, ability to predict how and when they affect velocity becomes crucial to monetary policy design. Other factors such as opportunity cost of holding money and inflation expectations affect velocity in the short-run.

4.3.2 Monetization, financial innovation and the income velocity of circulation

The theoretical foundation of the behaviour of income velocity of circulation with respect to financial innovation and structural transformation for this work, is built on the model used by Arrau *et al*. (1995) to analyze household utility problem, with money in the budget constraint. In this model, a representative household seeks to maximize the following utility function:

$$\sum_{t=0}^{\infty} \beta^t u(C_t), \tag{4.4}$$

where C_t is the only perishable good consumed, β is the discount factor, and $u(\cdot)$ is a concave utility function. To capture the effect of structural transformation on demand for money we assume that each unit of consumption is made up of two parts, namely market goods, C_t^m, which are bought using money, and subsistence goods, C_t^s, that are acquired without using money, either because they are produced by the household itself, or because they are acquired through batter exchange.

$$C_t = C_t^m + C_t^s \tag{4.5}$$

We assume that C_t^s forms a proportion s_t of the total consumption basket

$$C_t^s = s_t C_t, \tag{4.6}$$

where $s_t \in (0,1)$ relates negatively with the degree of monetization of the economy, which in turn is positively related to the level of economic development. Thus, for a representative household in a developed economy, the parameter s_t, is smaller than that of a representative household for a developing economy. The value of market goods in the consumption basket is the remaining part

$$C_t^m = (1 - s_t) C_t. \tag{4.7}$$

We henceforth refer to the share of market goods in the consumption basket, $(1 - s_t)$, as the existing degree of monetization.

The household must spend H units of consumption good for each unit of market good bought, where H is, with lower case letters representing real variables, defined as:

$$H(m_t, (1 - s_t)c_t, a_t) = \frac{1}{[(1 - s_t)c_t]^{1-\phi}} h\left(\frac{m_t}{[(1 - s_t)c_t]^{\phi}}, a_t\right), \tag{4.8}$$

where m_t represents real money balances, a_t represents the existing transaction technology and $\phi \in [0,1]$ represents the degree of economies of scale in transactions.

H is decreasing in m and increasing in $(1 - s)c$ and a. The more money balances the household has, the less transaction costs it incurs, because more money permits it to spend less time transacting. Purchase of more market goods increases the time spent in transactions hence increasing H. The degree of economies of scale in transactions ϕ, is set such that H declines with increase in consumption of market goods when $\phi < 1$, and remains constant when $\phi =$

1, irrespective of amount of consumption, implying constant returns to transactions scale. Note that the way consumption of market goods is expressed in equation (4.8) imply that an increase in H can be caused by increase in the degree of monetization $(1-s)$ or the total amount of household consumption. The transaction technology a, can be interpreted as the amount of resources spent in shopping activities associated with money-based transactions such that, a positive financial innovation leads to a decline in a, meaning reduction in the cost of money-based transactions. In this setting, financial innovation makes money balances more productive in delivering the transactions service to the household. Since s is smaller in a developed economy than in a developing economy, a representative household in a more developed economy demands higher proportion of money per unit of consumption, than that of a less developed economy.

The household has access to interest-bearing bonds, b_t, that pay nominal return i_t at the end of period $t+1$. With these assumptions, the budget constraint can be expressed in real terms as equation number (4.9), with all flows and stocks measured at the end of each period:

$$\begin{aligned} b_t + m_t + (1-s_t)c_t + H(m_t,(1-s_t)c_t,a_t)c_t \\ = b_{t-1}(1+r_{t-1}) + \frac{m_{t-1}}{(1+\pi_{t-1})} + y_t, \end{aligned} \tag{4.9}$$

where π_t stands for inflation rate, y_t is household income and, r_t is the real interest rate defined by the Fisher parity equation:

$$r_t = \frac{1+i_t}{1+\pi_t} - 1. \tag{4.10}$$

Applying λ_t as Lagrange multiplier for equation number (4.9), and maximizing with respect to b_t yields:

$$\frac{\lambda_t}{\lambda_{t+1}} = 1 + r_t. \tag{4.11}$$

Maximizing with respect to m_t yields:

$$h_1\left(\frac{m_t}{[(1-s_t)c_t]^{\phi}}, a_t\right) = \frac{\lambda_{t+1}}{\lambda_t}\frac{1}{(1+\pi_t)} - 1. \tag{4.12}$$

Substituting (4.11) in (4.12) we obtain:

$$h_1\left(\frac{m_t}{[(1-s_t)c_t]^{\phi}}, a_t\right) = \frac{1-(1+r_t)(1+\pi_t)}{(1+r_t)(1+\pi_t)} \tag{4.13}$$

From (4.10), the nominal interest rate can be expressed as:

$$1 + i_t = (1 + r_t)(1 + \pi_t) \tag{4.14}$$

Substituting (4.14) in (4.13) results in:

$$h_1\left(\frac{m_t}{[(1 - s_t)c_t]^{\phi}}, a_t\right) = -\frac{i_t}{1 + i_t} \tag{4.15}$$

Equation number (4.15) presents the relationship between money held by household, the opportunity cost of holding money, and consumption. It is an expanded version of equation number (2.19) designed to capture the effects of monetization and financial innovation on the household demand for money. It states that, the consumer allocates resources to money until the marginal cost of the last unit of money becomes equal to the marginal benefit related with the reduction of the cost of money-based transactions in the current period.

This formulation yields a variant of the classical Cagan's money demand function:

$$\log(m_t) = \phi \log(c_t) + \log(1 - s_t) - \alpha \frac{i_t}{1 + i_t} + \log(a_t) \tag{4.16}$$

where ϕ is the elasticity of consumption and α is semi-elasticity of the interest rate. In this derivation, consumption becomes the appropriate scale variable because it represents household demand for money. If the government and firms are brought into the model, the use of aggregate scale variable like GDP, gross national income (GNI) and gross national disposable income (GNDI), becomes appropriate.

From equation (4.16) we can specify the equation to be estimated as:

$$\log(m_t) = \beta_0 + \beta_1 \log(y_t) + \beta_2 \log(r_t) + \beta_3 \log(1 - s_t) + \beta_3 \log(a_t) + v_t \tag{4.17}$$

where y_t represents a scale variable, r_t is a measure of the opportunity cost of holding money, $(1 - s_t)$ is a measure of monetization, a_t is a measure of financial innovation and v_t is the error term introduced to put the equation in regression form.

Demand for real money balances is therefore, a function of income, opportunity cost of holding money, degree of monetization and financial innovation.

$$\frac{M_t}{P_t} = f(y_t, r_t, s_t, a_t) \tag{4.18}$$

In nominal terms we can present equation number (4.18) as:

$$M_t = P_t f(y_t, r_t, s_t, a_t) \tag{4.19}$$

Applying (4.19) in (4.2), we can express income velocity of circulation as

$$V_t = \frac{y_t}{f(y_t, r_t, s_t, a_t)}. \tag{4.20}$$

From equations number (4.17) and (4.20), the equation of velocity to be estimated becomes:

$$\log(V_t) = \psi_0 + \psi_1 \log(y_t) + \psi_2 \log(r_t) + \psi_3 \log(1 - s_t) + \psi_4 \log(a_t) + v_t \tag{4.21}$$

where $\psi_1 = 1 - \beta_1,\ \psi_2 = -\beta_2,\ \psi_3 = -\beta_3,\ \psi_4 = -\beta_4$.

The signs of the coefficients will be determined empirically, but based on economic theory we would expect β_2 to be positive because the higher the opportunity cost of holding money the less the money that is demanded and the faster the income velocity. We also expect the sign of β_3 to be negative if time trend or the ratio of monetary GDP to total GDP is used as a proxy for $(1 - s)$ and positive if the ratio of currency to broad money is used. As for β_4 we expect it to bear positive sign. The sign of ψ will depend on the size of β_1. Theoretically β_1, stands for the income elasticity of demand for money.[65]

4.3.3 Empirical methodology

Since most macroeconomic time series are not stationary, inference about long-run relationship between income velocity of circulation and its determinants—real income, opportunity cost of holding money and financial development—can only be made, if these variables are cointegrated. The existence of a cointegrating vector among the variables in empirical estimation implies that, the error term produced by the ordinary least squares (OLS) method is stationary, and the corresponding parameters represent consistent estimates. The cointegration approach has been used to estimate long-run relationships in demand for money and income velocity of circulation, by a number of researchers including Adil *et al*. (2020), Arrau *et al*. (1995), Johansen and Juselius (1990), Siklos (1993), Ndirangu and Nyamongo (2015), and Nampewo and Opolot (2016).

There are three cointegration techniques that have been mostly used in the estimation of demand for money and income velocity of circulation functions. These are the Engle and Granger (1987) residual-based approach; the Johansen and Juselius (1990) maximum likelihood-based approach; and the Pesaran *et al*. (2001) ARDL bounds test approach. The first two approaches require the variables in the estimated equation to be of the same order of

[65] The coefficients of equation (4.21) bear signs that are opposite of the corresponding coefficients in equation (4.17).

integration, a condition that is often hard to fulfil in empirical analysis. The ARDL bounds test approach, on the other hand, is credited with three main advantages over alternative methods. First, it allows series that are stationary in levels I(0) to be used in one equation with series that are integrated of the first order I(1), and therefore it is less restrictive. Second, it performs better in small samples, and third, it enables estimation of short-run dynamic adjustment and the long-run dynamic relationship, thus avoiding the problems associated with omitted variables and serial correlation (Adil *et al*., 2020; Lee, 2021; Özer and Karagöl, 2018; Samreth, 2008; Sharma and Syarifuddin, 2019; Siddiki, 2000).

For the reasons given above, we adopt the ARDL bounds test approach, to assess the impact of mobile money, by estimating an income velocity of money equation, to find out whether there is a stable long-run relationship among the variables involved. The functional form of the model to be estimated is:

$$\ln V = f(\ln Y, \ln R, \ln S, \ln A), \qquad (4.22)$$

Three variables will be tried to represent the opportunity cost of holding money, R, namely the interest rate on Treasury bills, expected inflation, and depreciation of the national currency against the US dollar. The ARDL equation for this model is specified as:

$$\begin{aligned}\Delta \ln V_t = {} & \alpha_0 + \alpha_1 \ln V_{t-1} + \alpha_2 \ln Y_{t-1} + \alpha_3 \ln R_{t-1} + \alpha_4 \ln S_{t-1} + \alpha_5 \ln A_{t-1} \\ & + \sum_{i=1}^{n} \theta_{1i}\, \Delta \ln V_{t-i} + \sum_{i=0}^{n} \theta_{2i}\, \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \theta_{3i}\, \Delta \ln R_{t-i} \\ & + \sum_{i=0}^{n} \theta_{4i}\, \Delta \ln S_{t-i} + \sum_{i=0}^{n} \theta_{5i}\, \Delta \ln A_{t-i} + \varepsilon_t^1\end{aligned} \qquad (4.23)$$

Equation number (4.23) is in the traditional form of error correction equation with one alteration, that is, the traditional error correction term EC_{t-1} is presented in form of the levels equation:

$$EC_{t-1} = -\alpha_0 + \alpha_1 \ln V_{t-1} - \alpha_2 \ln Y_{t-1} - \alpha_3 \ln R_{t-1} - \alpha_4 \ln S_{t-1} - \alpha_5 \ln A_{t-1}, \qquad (4.24)$$

and for this reason, equation number (4.23) is also referred to as unrestricted or unconstrained ECM.[66] The error term of the levels equation, which is the error correction term EC_{t-1}, is primarily made up of the short-run dynamics that can be presented as:

[66] The terms in equation (4.24) have been explicitly assigned their appropriate algebraic signs.

$$EC_{t-1} = \Delta\ln V_t - \left[\sum_{i=1}^{n} \theta_{1i}\,\Delta\ln V_{t-i} + \sum_{i=0}^{n} \theta_{2i}\,\Delta\ln Y_{t-i} + \sum_{i=0}^{n} \theta_{3i}\,\Delta\ln R_{t-i} + \sum_{i=0}^{n} \theta_{4i}\,\Delta\ln S_{t-i} + \sum_{i=0}^{n} \theta_{5i}\,\Delta\ln A_{t-i} + \varepsilon_t\right] \tag{4.25}$$

The short-run dynamics are represented by coefficients θ_{1i}, θ_{2i}, θ_{3i}, θ_{4i} and θ_{5i}, while the long-run relationships are represented by α_1, α_2, α_3, α_4 and α_5. The bounds test uses calculated F-statistic to establish the joint significance of the lagged independent variables in levels. The presence of cointegration between the variables of interest is examined by testing the null hypothesis that the long-run coefficients are jointly equal to zero, that is:

$H0$: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0,$

meaning that the variables are not cointegrated. The null hypothesis is rejected if any of the long-run coefficients is different from zero, or all of them are different from zero.

$H1$: $\alpha_1 \neq 0,\ \alpha_2 \neq 0,\ \alpha_3 \neq 0,\ \alpha_4 \neq 0,\ \alpha_5 \neq 0,$

meaning that, the null is not true.

In this test, two sets of critical values are provided: one computed with the assumption that all variables in the ARDL model are I(0), meaning that cointegration is irrelevant, and another with the assumption that the variables are I(1). The null hypothesis of no cointegration is rejected if the computed F-statistic falls above the upper bound critical value. Otherwise, if the F-statistic falls below the lower bound critical value, the null hypothesis cannot be rejected. In this case, only the short-run relationship can be estimated. If the F-statistic falls between the upper and lower bound critical values, the results are considered to be inconclusive. The distribution of this F-statistic is not standard, regardless of the order of integration of the series involved. The critical values for this test are found in Pesaran *et al*. (2001), (Lee, 2021; Nkoro and Uko, 2016; Samreth, 2008).

The long-run relationship between these variables in levels can be drawn from equation number (4.23) as:

$$\ln V_t = \psi_0 + \psi_1 \ln Y_t + \psi_2 \ln R_t + \psi_3 \ln S_t + \psi_4 \ln A_t + \varepsilon_t^2, \tag{4.26}$$

where

$$\psi_0 = \frac{\alpha_0}{\alpha_1}, \qquad \psi_1 = \frac{\alpha_2}{\alpha_1}, \qquad \psi_2 = \frac{\alpha_3}{\alpha_1}, \qquad \psi_3 = \frac{\alpha_4}{\alpha_1}, \qquad \psi_4 = \frac{\alpha_5}{\alpha_1}.$$

If cointegration is established, the error term, ε_t^2, in equation (4.26) will be stationary and the estimated parameters $\psi_0, \psi_1, \psi_2, \psi_3$ and ψ_4 will provide consistent estimates. The error correction equation is then specified as:

$$\begin{aligned} \Delta\ln V_t = {} & \sum_{i=1}^{m} \gamma_{1i}\, \Delta\ln V_{t-i} + \sum_{i=0}^{n} \gamma_{2i}\, \Delta\ln Y_{t-i} + \sum_{i=0}^{n} \gamma_{3i}\, \Delta\ln R_{t-i} \\ & + \sum_{i=0}^{n} \gamma_{4i}\, \Delta\ln S_{t-i} + \sum_{i=0}^{n} \gamma_{5i}\, \Delta\ln A_{t-i} + \lambda EC_{t-1} + \nu_t, \end{aligned} \tag{4.27}$$

where $EC_t = \varepsilon_t^2$ is the error correction term, and $\lambda \in [-1,0)$ represents the speed at which the previous period error, is corrected in the current period, towards the long-run equilibrium. This representation is credited for allowing both economic theory and data information to be applied in empirical estimation (Hassler and Wolters, 2006).

4.4 Estimations and results

4.4.1 Estimations

4.4.1.1 Data sources and characteristics

The variables utilized in the estimations were: the income velocity of circulation, measured as a ratio of GDP to broad money (M2VA); the scale variable, real GDP (RGDP); the opportunity cost of holding money variables; and the financial development variables. The broad money variable used was M2, which includes currency, demand deposits and time deposits all denominated in national currency. The opportunity cost series considered were: the CPI inflation (INFA); two measures of interest on government securities, namely 91-treasury bills rate (BILO) and the weighted average treasury bill rate (WAYA); and depreciation of the national currency against the US dollar (EXCAG). The depreciation of the national currency was considered as one of the opportunity cost variables because residents in these countries also hold deposits in foreign currency. Each one of the opportunity cost variables was expected to affect velocity positively.

The third group of variables constitutes our variables of interest, that is the financial development variables. Here we made attempts with four different variables, namely a time trend (ATREND), the ratio of currency to broad money (CCM2), the number of mobile money transactions (TRAS), and a mobile money dummy (MDUM). The time trend was included as a proxy to control for the monetization process, and therefore was expected to have an inverse relationship with the income velocity of circulation. While we would have preferred to use the ratio of monetary GDP to total GDP as a measure of monetization, it was not possible because such data could not be obtained on quarterly frequency. The ratio of currency to broad money served as an indirect measure of financial innovation and therefore was expected to affect velocity negatively. While negative relationship was the primary expectation, it deserves also to be mentioned that an opposite sign could be found, but this would be consistent with interpreting the ratio of currency to broad money as an indicator of monetization, which when it declines it implies and increase in the degree of monetization. The number of mobile money transaction was selected among the existing mobile money statistics, to represent mobile money, and it was expected to have positive relationship with velocity.[67] A mobile money dummy that was set with values of zero before mobile money and one after mobile money, served similar purpose as mobile money transactions and therefore, was expected to have positive effect on velocity.

For all countries, the real GDP and CPI series were obtained in different base years. They were then spliced to turn them to continuous series of roughly similar base year, for the entire sample period. The base year for Tanzania for both GDP and CPI was set to 2015, while that of Kenya was 2009 for GDP and December 2009 for CPI, and that of Uganda was 2016/17 for both GDP and CPI.

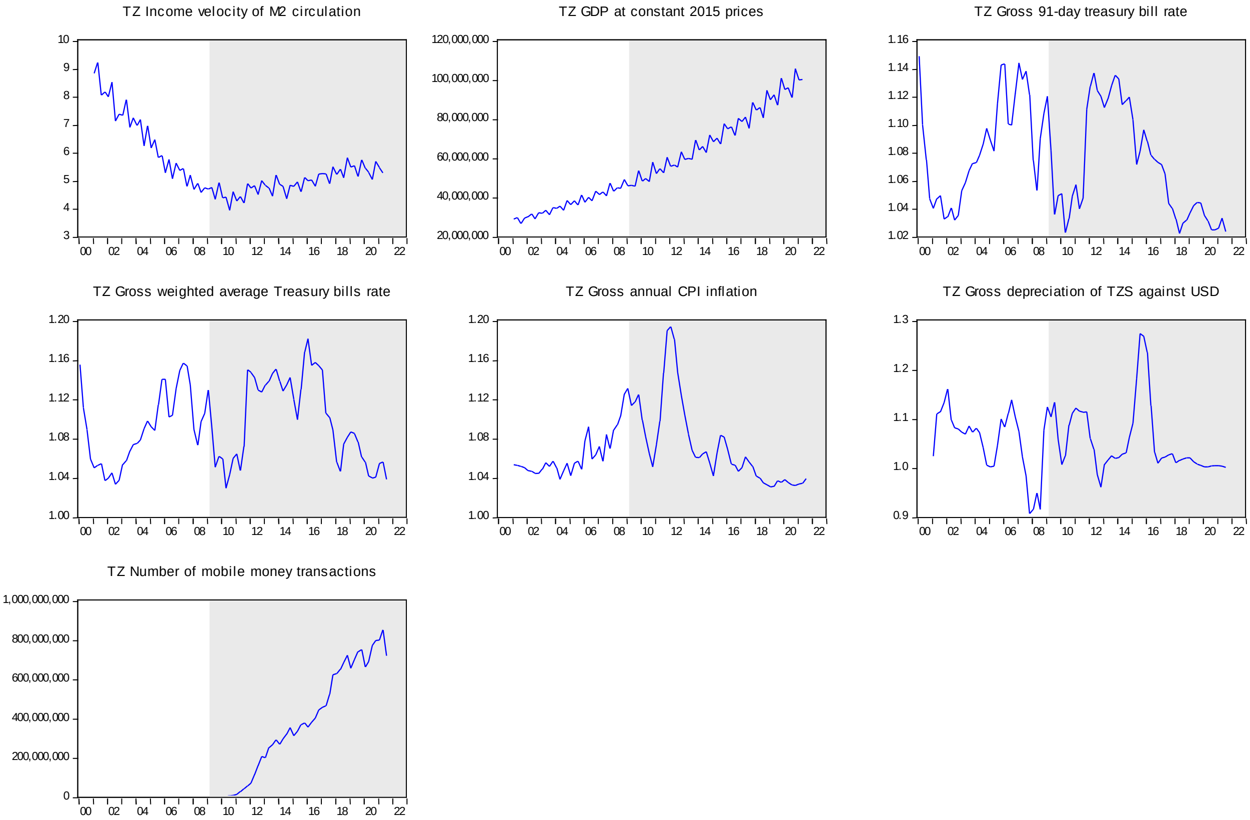
Tanzania data

All series for Tanzania were obtained from the Bank of Tanzania. The Tanzania series used in this work are presented graphically in Figure 4.1 and their corresponding statistical descriptions in log form in Table 4A1. The income velocity of circulation manifests a downward trend up to 2008, which seems to mark a turning point after which a gradual upward trend follows. Real GDP has been on a steady increase throughout the period, while inflation experienced two major peaks—one in 2007 to 2008, and another in 2011 to 2012. Both episodes of high inflation were associated with global increase in the price of oil and food grains (Bank of Tanzania, 2008 and 2012) (figures H2 to H4).

[67] Other variables that could be used to represent mobile money were the value of mobile money transactions, the number of mobile money accounts and the number of mobile money agents.

As a first step in the ARDL bounds test approach to cointegration, we applied augmented Dickey-Fuller (ADF) and Phillip-Peron (PP) unit root tests to all series and found that all Tanzania series were integrated of first order, i.e. the null hypothesis of unit root in each of the series utilized in these estimations could not be rejected when the series were tested in levels, but could be rejected at 1 per cent significance level, in their first difference form. The results of unit root tests for Tanzania series are summarized in Table 4.1.

Figure 4.1: Variables for Tanzania



The unshaded area is the period without mobile money, and the shaded area is the period with mobile money (2009Q1 onwards).

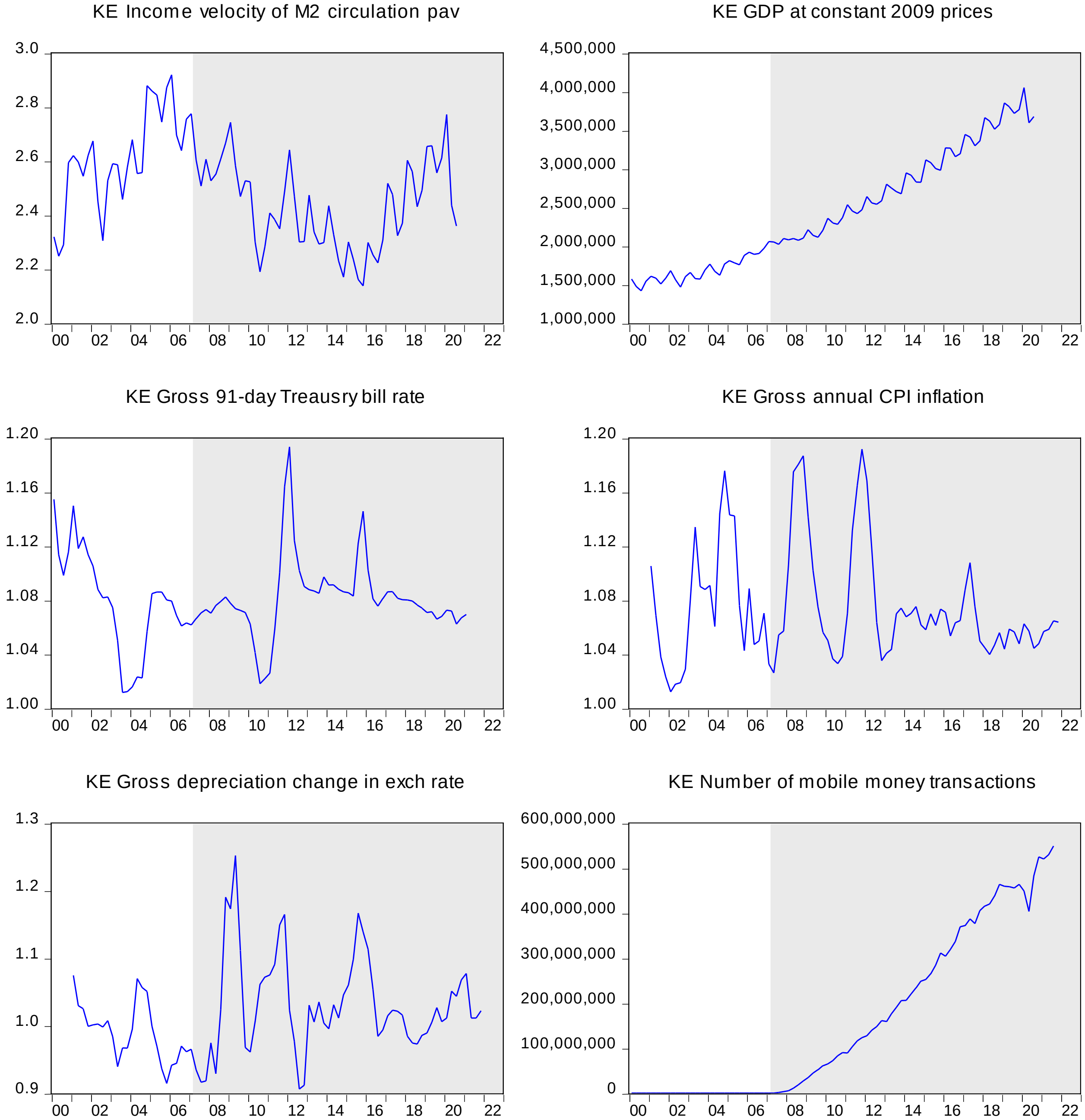
Table 4.1: Unit root test, Tanzania variables

	ADF		PP		Order of integration
	Levels	First difference	Levels	First difference	
log(tm2va)	-2.498	-2.989	-2.748	-18.086	I(1)
Probability	0.120	0.040	0.071	0.000	
log(trgdp)	-1.074	-38.238	-0.424	-49.750	I(1)
Probability	0.722	0.000	0.899	0.000	
log(tbilo)	-1.746	-8.357	-2.659	-9.921	I(1)
Probability	0.405	0.000	0.085	0.000	
log(twaya)	-1.914	-7.918	-2.598	-7.167	I(1)
Probability	0.324	0.000	0.097	0.000	
log(tinfa)	-2.602	-6.375	-2.258	-6.437	I(1)
Probability	0.097	0.000	0.188	0.000	
log(texcag)	-2.887	-7.301	-3.449	-6.809	I(1)
Probability	0.051	0.000	0.012	0.000	
log(ttras)	-0.807	-8.728	-0.819	-8.728	I(1)
Probability	0.812	0.000	0.808	0.000	

Kenya data

The data for Kenya were obtained from the Central Bank of Kenya and the Kenya National Bureau of Statistics websites. Similar definitions as those used for Tanzania data were used for the corresponding variables of the Kenya data. Kenya GDP manifests strong upward trend for the entire period like that of Tanzania, and the episodes of high inflation observed in Tanzania also appear in Kenya, albeit with different amplitude. The first episode of high inflation that lasted up to 2009 was the one that Simpasa and Gurara (2012) associated with financial innovation, particularly the advent of mobile money, but we have also seen that this was a time of high price of oil and grains (figures H2 to H4). The income velocity of circulation in Kenya is more cyclic, for the period covered, but is much smaller—about half that of Tanzania—and has less variability (Table 4A4). It begins with upward trend up to 2007 and then turns to downward trend that persists up to 2015, after which an upward trend resume up to 2021. The 91-treasury bills rate, inflation and depreciation of Kenyan shilling were found to be stationary in their levels, while the income velocity of circulation, real GDP and mobile money transactions were found to be integrated of first order. The Kenya variables are presented visually in Figure 4.2, and their unit root test results are presented in Table 4.2. Descriptive statistics for Kenya variables are shown in Table 4A2.

Figure 4.2: Variables for Kenya



The unshaded area is the period without mobile money, and the shaded area is the period with mobile money.

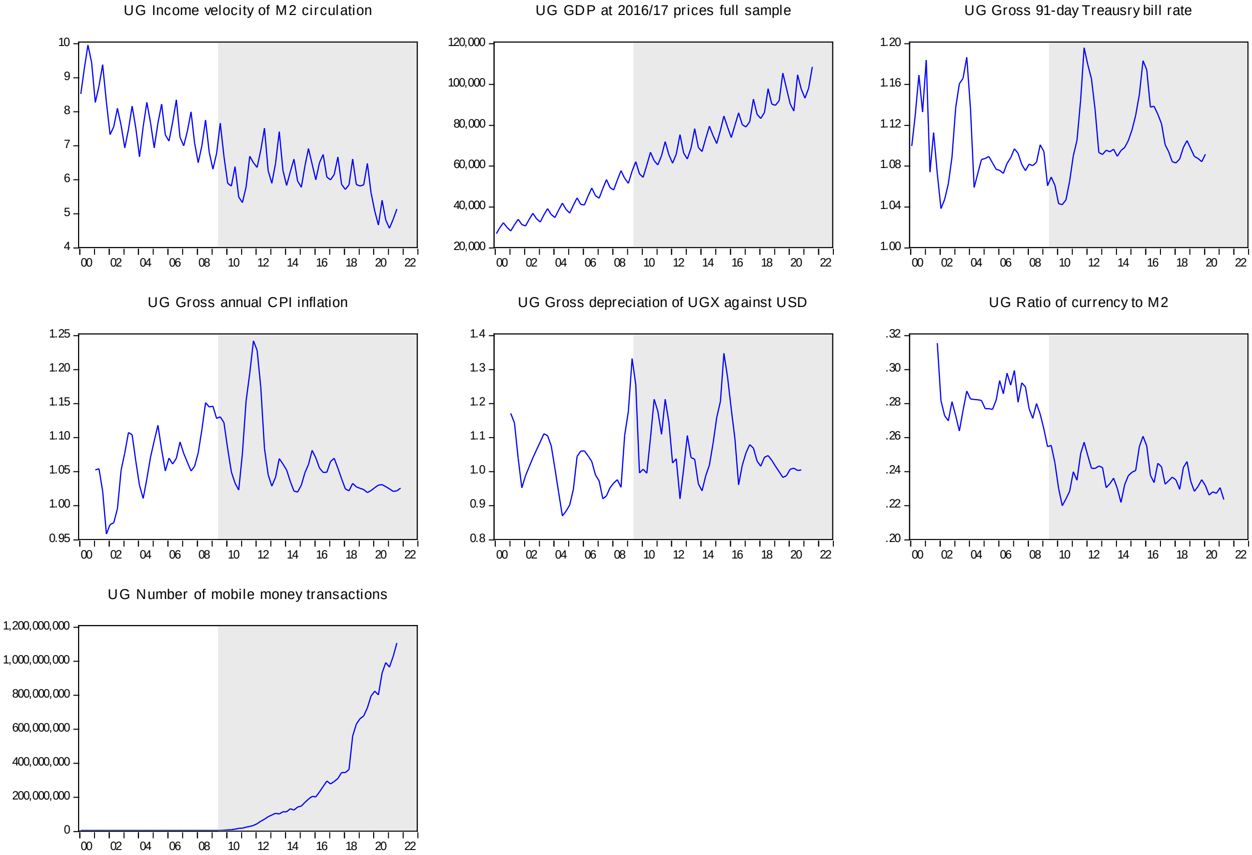
Table 4.2: Unit root test, Kenya variables

	ADF		PP		Order
	Levels	First difference	Levels	First difference	of integration
log(km2va)	-1.758	-3.081	-3.512	-10.815	I(1)
Probability	0.398	0.032	0.000	0.000	
log(krgdp)	-0.111	-4.433	0.027	-16.890	I(1)
Probability	0.944	0.001	0.958	0.000	
log(kbilo)	-4.099	-6.629	-3.653	-6.349	I(0)
Probability	0.002	0.000	0.007	0.000	
log(kinfa)	-4.586	-5.556	-3.801	-6.938	I(0)
Probability	0.000	0.000	0.004	0.000	
log(kexcag)	-4.523	-8.023	-3.805	-7.372	I(0)
Probability	0.000	0.000	0.004	0.000	
log(ktras)	-1.251	-6.718	-1.192	-6.710	I(1)
Probability	0.649	0.000	0.675	0.000	

Uganda data

The data for Uganda were obtained from the Bank of Uganda and the Uganda Bureau of Statistics websites. Similar definitions as those used for corresponding Tanzania data were used for the Uganda data. Unlike the other two countries, the income velocity of circulation in Uganda manifests a perpetual downward trend, but has closer properties with that of Tanzania in terms of size, range and variability (Table 4A4). The strong upward trend in GDP observed in Tanzania and Kenya is also manifested by Uganda GDP and the historical peaks in inflation are replicated in Uganda as well. The Uganda 91-treasury bills rate and inflation were found to be stationary in their levels, while the income velocity of circulation, real GDP, depreciation of the Ugandan shilling and mobile money transactions were found to be integrated of order one. The variables are presented visually in Figure 4.3, and unit root test results in Table 4.3. The descriptive statistics of the Uganda data in log form are presented in Table 4A3.

Figure 4.3: Variables for Uganda



The unshaded area is the period without mobile money, and the shaded area is the period with mobile money.

Having found that each of the series to be used was either I(0) or I(1), and that none of them was integrated of a higher order, we then proceeded to specify an unrestricted ARDL model, and then used the Akaike Information Criterion (AIC) to select lag structure, where the model with the lowest AIC value is selected for each equation estimated (Table 4A5 and figures G1A to G1C). Our sample allowed us to begin with 4 lags in the dependent and independent variables for each equation.[68]

[68] In the lag length selection, we begin with maximum lag-length and drop insignificant ones to improve precision of estimations (Ajaz, *et al*., 2016).

Table 4.3: Unit root test, Uganda variables

	ADF		PP		Order
	Levels	First difference	Levels	First difference	of integration
log(um2va)	-0.703	-5.243	-3.508	-17.218	I(1)
Probability	0.840	0.000	0.000	0.000	
log(urgdp)	-2.417	-4.654	-1.203	-14.936	I(1)
Probability	0.140	0.000	0.670	0.000	
log(ubilo)	-4.217	-5.653	-3.632	-8.904	I(0)
Probability	0.001	0.000	0.007	0.000	
log(uwaya)					
Probability					
log(uinfa)	-4.954	-8.978	-2.345	-5.090	I(0)
Probability	0.000	0.000	0.161	0.000	
log(uexcag)	-2.681	-3.165	-3.772	-6.823	I(1)
Probability	0.083	0.026	0.005	0.000	
log(uccm2a)	-2.266	-8.921	-2.254	-9.640	I(1)
Probability	0.186	0.000	0.189	0.000	
log(utras3)	-0.700	-8.394	-0.763	-8.407	I(1)
Probability	0.841	0.000	0.824	0.000	

4.4.2 Results

A variety of specifications in ARDL form, each including the scale variable, a measure of the opportunity cost of holding money, and measures of financial development were estimated using OLS.[69] A selection of the results was then picked and reported in tables 4.4a and 4.4b. These results were selected on the basis of the following criteria. First, for each selected model, the variables were found to be cointegrated, meaning that the coefficients of the long-run equation were jointly significant, i.e. we were able to reject the null hypothesis of no cointegration. This is indicated by the calculated F-statistic, that was found to be higher than its corresponding upper bound critical value under the ARDL bounds test, for each equation. Second, the coefficient of the error correction (EC) term, lagged one period, was found to be significant and lying between zero and negative one. This is a condition for the model to always converge to its long-run equilibrium. Third, the LM test of serial correlation in the residuals

[69] Quarterly seasonal dummies were taken into consideration.

was also carried out for each equation and in each one of them, the null hypothesis of the residuals not having serial correlation could not be rejected.[70] Fourth, the EC term, was computed separately as a residual from the long-run equation in levels, and subjected to unit root test and found to be stationary. The ADF test statistic and the corresponding probability for the EC term in each equation are also presented in tables 4.4a and 4.4b (detailed presentation of the error correction equations are in tables 4B1 to 4D2). Lastly, parameter stability tests were carried out and showed that the parameter estimates for each equation were stable at 5 per cent significance level, except that of the first Kenya full sample equation which showed marginal instability towards the end of the period, as indicated by the CUSUM graphs in figures G2A, G2B and G2C.[71]

The equations reported in Table 4.4a represent estimations for the full sample from 2000 to 2021, while those reported in Table 4.4b were estimated for the period that mobile money (m-money) was present, i.e. 2007Q1 onwards for Kenya, 2009 onwards for Tanzania and 2009Q2 onwards for Uganda.

4.4.2.1 Tanzania

In the results for Tanzania, the long-run coefficients of real GDP were found to be positive and significant for each estimated equation. They were also around 2 for all equations. The measures of opportunity cost of holding money that came out with significant long-run impact on the income velocity were the 91-day treasury bills rate and the weighted average treasury bills rate, and their elasticities were found to lie between 0.6 and 0.8. Inflation and depreciation did not appear as significant long-run determinants of velocity at all. Trend in all reported equations had significant long-run effect on velocity and the values of its coefficients were within a close range of -1.9. Mobile money transactions came out as a statistically significant long-run determinant of velocity, but economically weak. When a dummy was utilized to represent mobile money, it too came out as a statistically significant long-run determinant of velocity in the third equation for Tanzania (Table 4.4a), without affecting much, the estimated coefficients on the rest of variables, with improvement on the economic significance. All estimated long-run parameters were significantly different from zero at significance levels of

[70] The Breusch-Pagan-Godfrey heteroscedasticity test was also carried out on the residuals for each equation and all, except two equations for Uganda, were found to be homoscedastic.
[71] The CUSUM and CUSUMQ tests developed by Brown *et al*. (1975).

less than 5 per cent. As for the short-run dynamics, only real GDP and trend were found to have significant coefficients, with the former being positive and the latter negative. The error correction form of the full sample equations showed that the speed with which short-run errors are adjusted towards long-run equilibrium ranged from 34 per cent in the third equation to 41 per cent in the second equation (Table 4B1).

Table 4.4a: Estimation results of long-run velocity equations for the period 2000 to 2021
Dependent variable is income velocity of circulation

Variable/term	Tanzania			Kenya		Uganda	
Constant	-21.220	-21.375	-22.268	-30.139	-60.687	13.896	9.320
Probability	0.000	0.000	0.000	0.003	0.006	0.000	0.000
Real GDP	2.015	2.036	2.073	3.727	6.688	-0.432	-0.257
Probability	0.000	0.000	0.000	0.001	0.002	0.046	0.014
91-day tbill rate	0.695		0.828	0.416	0.987		
Probability	0.022		0.016	*0.444*	*0.177*		
Average tbill rate		0.763					
Probability		0.001					
Inflation					4.324	2.334	
Probability					0.090	0.029	
Depreciation							0.490
Probability							0.069
Trend	-1.913	-1.959	-1.896	-3.913	-6.399		
Probability	0.000	0.000	0.000	0.002	0.001		
Currency to M2 ratio						3.683	1.156
Probability						0.004	0.011
M-money trans.	0.007	0.007		0.007		0.044	
Probability	0.019	0.010		*0.231*		0.020	
M-money dummy			0.105		0.224		0.176
Probability			0.046		0.098		0.064
Error correction (-1)	-0.362	-0.405	-0.339	-0.198	-0.154	-0.110	-0.207
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Upper b. crit. value	4.842	4.842	4.842	*3.718*	4.620	4.842	4.842
F-statistic	6.864	8.050	6.478	4.156	7.332	18.539	12.864
Residual Breusch-Godfrey Serial correlation LM test							
F-statistic	1.008	1.008	1.068	1.482	1.333	1.163	0.904
Probability	0.410	0.410	0.380	0.220	0.271	0.319	0.410
Residual Breusch-Pagan-Godfrey heteroscedasticity test							
F-statistic	1.466	1.602	1.381	1.320	1.121	2.365	0.783
Probability	0.178	0.132	0.214	0.214	0.356	*0.016*	0.666
Unit root test of the error correction term							
ADF t-statistic	-3.825	-3.818	-4.375	-8.295	-3.537	-4.924	-4.444
Probability	0.004	0.004	0.004	0.000	0.010	0.000	0.001

Table 4.4b: Estimation results of long-run velocity equations for the mobile money period
Dependent variable is income velocity of circulation

Variable/term	Tanzania	Kenya		Uganda
Constant	1.917	-99.138	-103.980	13.183
Probability	0.043	0.000	0.044	0.000
Real GDP	0.232	11.492	11.094	-0.815
Probability	0.001	0.000	0.047	0.015
91-day tbill rate		1.076		1.603
Probability		0.070		0.015
Inflation			4.197	
Probability			0.061	
Depreciation	0.067			
Probability	*0.677*			
Trend		-14.444	-12.964	
Probability		0.001	0.073	
M-money trans.	0.029	0.492	0.640	0.084
Probability	0.016	0.000	0.068	0.000
Error correction (-1)	-0.397	-0.233	-0.140	-0.449
Probability	0.000	0.000	0.000	0.000
Upper b. crit. value	5.328	4.947	4.947	5.544
F-statistic	10.887	11.645	6.613	25.568
Residual Breusch-Godfrey Serial correlation LM test				
F-statistic	0.207	0.206	2.073	0.430
Probability	0.814	0.815	0.142	0.654
Residual Breusch-Pagan-Godfrey heteroscedasticity test				
F-statistic	0.646	0.748	0.797	3.289
Probability	0.799	0.741	0.695	*0.004*
Unit root test of the error correction term				
ADF t-statistic	-3.454	-6.237	-3.248	-3.494
Probability	0.014	0.000	0.087	0.013

One equation was selected for the mobile money sub-period for Tanzania (Table 4.4b), in which the coefficient of trend was not significant, while that of mobile money transactions remained statistically significant with positive sign, but again, economically weak. The estimated coefficient of the opportunity cost of holding money—depreciation of the Tanzanian shilling—bore a positive sign as expected, but was not statistically significant. The error correction form of the estimated equation for the mobile money sub-sample showed that, in the short-run, the income velocity of circulation was impacted positively by real GDP and mobile money transactions, and negatively by depreciation of the shilling against the USD (Table 4B2).

4.4.2.2 Kenya

In the estimations for Kenya, two equations met the criteria to be reported in Table 4.4a, when the estimations were made on the full sample. In both equations, the long-run coefficients of real GDP were found to be positive and significant at 1 per cent significance level, while out of the various measures of opportunity cost tried, only inflation came out as having positive long-run coefficient at 10 per cent level of significance (the second equation for Kenya in Table 4.4a). In both equations trend manifested a significant negative long-run relationship with velocity, while the long-run coefficient of mobile money transactions was positive as expected, but was not statistically significant. The mobile money dummy on the other hand, was found to have positive long-run coefficient at 10 per cent significance level, in the second equation for Kenya. When the estimations were made for the mobile money sub-period alone, real GDP and trend remained significant long-run explanatory variables of velocity with similar signs as those found in the full sample estimations, but their corresponding coefficients were substantially larger. In the mobile money sub-period the mobile money transactions emerged with significant positive elasticity in Kenya and likewise, the significance of treasury bills rate and inflation improved.

In the short-run, time trend was found to have negative relationship with velocity for all Kenya equations, while mobile money transactions were found to have negative relationship in the first equation of the full sample, and positive relationship in the mobile money sub-period equations (tables 4C1 and 4C2). In the equations where inflation was found to be significant determinant of velocity, the speed of adjustment was slower than in the rest of equations (comparison of the first equations for Kenya in Tables 4.4a and 4.4b with corresponding second equations in those tables).

4.4.2.3 Uganda

As for Uganda, two equations met the criteria under the full sample estimations. The scale variable real GDP was found to have statistically significant negative long-run relationship with velocity. Among the opportunity cost variables, inflation and depreciation were found to have significant positive long-run effect on velocity, in the first and second full sample equations, respectively. Unlike Tanzania and Kenya, trend did not appear as a significant predictor of velocity in Uganda. Instead, the ratio of currency in circulation to M2 came out with significant positive effect on velocity, which is in agreement with the findings of the study carried out by Nampewo and Opolot (2016). As we argued earlier, we interpret this positive relationship between the ratio of currency in circulation and velocity as a reflection of the monetization, rather than financial innovation. Whether mobile money was represented by a dummy or the number of mobile money transactions, the results were a positive long-run relationship with velocity, with strong statistical significance and relatively larger coefficients than those of Tanzania, but that of mobile money transactions was still economically weak. Carrying out estimation for the mobile money sub-period alone, gave qualitatively similar result for real GDP, but on the opportunity cost side, only the 91-treasury bills rate came out as a significant determinant of velocity as opposed to inflation and exchange rate depreciation in the full sample equations. As for the financial development variables, the mobile money transactions appeared to have significant positive relationship with velocity, while no significant relationship was found for trend and the ratio of currency in circulation to M2.

In the short-run, mobile money transactions, and the mobile money dummy appeared to have significant negative affect on velocity under the full sample estimates, but when the mobile money sub-period alone was considered, the short-run relationship between mobile money transaction and velocity became positive. The speed of adjustment of short-term errors to long-run was found to be much faster in the mobile money sub-period (45 per cent compared to 20 per cent and 11 per cent in the full sample estimations) (tables 4D1 and 4D2).

4.4.2.4 Comparison across countries

The results obtained in these estimations suggest that mobile money has affected the income velocity of circulation positively in the three countries studied. These findings had stronger statistical significance for Tanzania and Uganda, where the coefficients of mobile money transactions were significant at 5 per cent significance level for the full sample, whereas for Kenya, only the mobile money dummy was significant at 10 per cent significance level. The coefficients of mobile money transactions for Tanzania and Uganda were, however, economically weak (Table 4.4a). On the other hand, the coefficients of the dummy variable suggest that the presence of mobile money was associated with income velocity that was (other things being equal) 11 per cent, 17 per cent and 22 per cent higher, in Tanzania, Uganda and Kenya, respectively. When the mobile-money sub-period was considered in isolation, the significance of mobile money relationship with income velocity of circulation in Kenya became stronger (Table 4.4b). These findings also align with the prediction of higher velocity under the mobile money scenario of Model 3 (MSR case).

In all estimated equations, where trend came out as a significant long-run predictor of velocity, the sign of its coefficient was negative, agreeing with the argument made earlier, that for a developing economies where the scope for monetization is high, trend represents monetization better than financial innovation and therefore, should be expected to manifest negative relationship.[72] This was the case for all estimated equations for Tanzania and Kenya. In the case of Uganda, trend was not found to have significant relationship with velocity in any of the equations reported. Instead, a positive long-run relationship was found between the ratio of currency to broad money and the income velocity of circulation, which we also interpret as indication of the effect of monetization. It is noteworthy that much as inclusion of time trend helped to produce cointegrated relationships among the variables modelled, its presence also diminished the economic meaning of the coefficient of real income. In the equations that cointegration was found without inclusion of time trend, i.e. all equations for Uganda and the mobile money sub-sample equation for Tanzania, the coefficients of real income implied positive income elasticity of demand for money, but where trend was included the implied income elasticity was negative. This points to a possibility that the aggregate real income may not be the best scale variable to use in these estimations or time trend does not capture the monetization process well.

For the variables representing opportunity cost of holding money, the signs of the estimated coefficients were in conformity with expectations for all countries. Treasury bills rate came out as a significant explanatory variable of velocity in all countries studied, while inflation was significant in Kenya and Uganda, and depreciation of local currency in Uganda only.

Our findings conform with those of Sichei and Kamau (2011) that monetary balances were consistently below equilibrium in Kenya from 2007, which could imply that the Central Bank of Kenya was supplying money below what appeared to be historically optimal, as a reaction to what turned out to be excess money supply in the presence of mobile money—a sign of increasing velocity of money. Similar behaviour was also reported by Kessy *et al*. (2017) for Tanzania, where the Bank of Tanzania, was observed to run reserve-money growths that were

[72] The ratio of agricultural value added to GDP for the three countries studied exceeded 20 per cent, and their per capita GDP was less than US$ 2,000 in 2020, compared with the countries studied by Arrau *et al*. (1995) where all except India and Nigeria had per capita GDP exceeding US$ 3,000 (World Bank Group, 2022), suggesting that the monetization content of development process among the countries in this study, could be argued to be stronger.

below targets set within its policy framework, a phenomenon interpreted as a response of the central bank to faster than anticipated growth in velocity of money circulation.

In the light of the findings by Arrau *et al*. (1995) and Adil *et al*. (2020) about India, it is arguable that, although major financial innovations like mobile money may cause an up-turn in the income velocity of circulation, such an up-turn will eventually be overcome by the monetization force that dominates the long-run behaviour of velocity among developing economies. Judging by the position of money and per capita income among the countries studied in this Chapter (Figure H1), velocity is bound to stay on an overall declining trend for a long time. The challenge for policy authorities is to identify the turning points in the velocity cycles, or moments of acceleration and slowdown, and make the requisite policy adjustments. Occurrence of major changes in the financial sector like financial liberalization, which Adil *et al*. (2020) associated with resumption of downward velocity trend in India in the 1990s, and financial innovation such as the onset of mobile money, may help to identify the turning points.

The fact that monetization and financial innovation cause permanent changes in the income velocity of circulation is a matter of concern to policy authorities for reasons that include the ability of governments in developing economies to raise seigniorage resources safely, when the velocity is declining. The cyclical behaviour of velocity, however, means that the space for raising seigniorage resources is also cyclical and therefore it is important to know when it is safe and when it is not. It is worth mentioning that, the circumstances that lead to upturn in velocity may also come with opportunities for increasing government revenue collection. For instance, while the use of mobile money has sped up velocity, it has also opened opportunities for reduction of administrative costs and increasing efficiency in revenue collection. Governments therefore need to embrace this opportunity, to recover the loss in seigniorage, and boost revenue even more.

This behaviour also points to the importance of pursuing interest rate targeting monetary policy as opposed to money supply targeting. Under interest rate targeting regime, an increase in velocity will show up as a decline in the interest rate at the prevailing money supply, and therefore, the central bank will be prompted to action to restore the interest rate by reducing money supply. Such a framework will therefore enable the central bank to realign its policy actions with the new level of velocity in a timely fashion. Under a money supply regime, on the other hand, the feedback about the change in velocity will not automatically show up in the central bank's operational target and thus the corrective action may be delayed.[73]

While our estimations align with the view that financial innovation speeds up velocity, we are cognizant of the shortcomings of time series approach to establishment of causal relationship among variables. This has seen an increase in the use of experimental and quasi experimental design approach to identification of causal effect (Batista and Vicente, 2021; Lee *et al*., 2021). Applying experimental design approach to our research question though, would pose some challenges. For instance, one way that this could be done is by carrying out surveys on randomly sampled households from our economies of interest. The baseline condition for the sampled households would be non-participation in mobile money, while living within the reach of both mobile phone signal and mobile money agents. The baseline holding of transaction balances relative to their budget would have to be established. The next step would be to split the households into control and treatment groups and apply mobile money to the treatment group. The groups would then need to be visited over time, in rounds of surveys, to measure the outcome in terms of their holding of transaction balances relative to their budgets. Our expectation in this experiment would be to see a declining ratio of transactions balances relative to household budget, as the treatment households become active in mobile money usage. Setting such an experiment for the current research however, may not be easy for a number of reasons. First, currently mobile money usage in the countries of interest is widespread, so it might be challenging to find non-participating households that share similar characteristics with the participating ones. That is, finding households in similar environment and with similar abilities to participate, but not participating. Second, this approach requires observation over a period of time to produce reliable results, thus it would not fit within the timeframe of the current research. Third, factors such as opportunity cost of holding money do not fall within the control of the researcher, and thus administering targeted treatment for such factors may not be possible. The fact that the estimates of the parameters for the mobile money dummy came out positive and significant for all countries, serve to show the effect of mobile money on velocity has indeed been positive, similar to that of other financial innovations.

[73] In the DSGE setting, the policy rule receives full information about deviations of the targeted variables from their steady state levels, which helps to explain the similarity observed between IIR and MSR results. However, in reality, actual data on inflation and output becomes available to the policy maker with a lag. Determination of a change in velocity by comparing actual money growth and values of the targeted variables is therefore likely to come with a delay.

4.5 Conclusion

The objective of this chapter was to find out whether the rise of mobile money in Tanzania, Kenya and Uganda has increased the income velocity of circulation in these countries, in a statistically significant way. This objective would also serve as an empirical test of the predictions of the models developed in the previous chapters that shocks would be transmitted more efficiently across the economy in the presence of mobile money. We employed ARDL bounds test approach to cointegration, to estimate equations of income velocity of circulation for these countries for the period 2000 to 2021, with real GDP as a scale variable; treasury bills rate, inflation and depreciation of the national currency against the US dollar as measures of opportunity cost of holding money; and financial development variables. Under the financial developments variables, we considered the argument that in developing countries, the income velocity of circulation tends to experience secular slowdown due to the gradual increase in the monetization of economic activity. On account of this argument, we controlled for monetization by using time trend as a proxy, on assumption that structural transformation takes place smoothly over time as the economies grow, leading to a smooth decline in the income velocity of circulation. This is compatible with the arguments made by Chandavarkar (1977), Driscoll and Lahiri (1983) and Mele and Stefanski (2019). The variables utilized to represent mobile money were the volume of mobile money transactions and mobile money dummy. As most other financial innovation variables, mobile money was expected to speed up velocity, on account of the efficiency gains it brings to transaction balances. By the virtue of being electronic, mobile money was also expected to speed up velocity by promoting higher density of exchanges among transacting parties, because it makes the distance and time restraints among its users irrelevant.

The results show that, mobile money has statistically significant positive impact on the income velocity of circulation, in all three countries, albeit at different degrees. The coefficients of mobile money transactions are however, economically weak for Tanzania and Uganda. As for the monetization proxy, we found significant negative relationship between time trend and velocity in Tanzania and Kenya, while for Uganda we found significant positive relationship between the ratio of currency to broad money supply and the income velocity of circulation, consistent with expectations. While the measures of opportunity cost of holding money that were found to be significant differed across the countries, they all bore coefficients with positive sign as expected. The findings about the impact of mobile money on velocity in these countries are also compatible with the predictions of the models developed in the preceding chapters.

Our results agree with the conclusions made by Mele and Stefanski (2019) that the costs of bad monetary policy are disproportionately higher in richer economies than in poorer ones, because the slowdown in velocity among developing economies tends to offset, what would for a developed economy be considered excess in money growth. In the same vein, they agree with the conclusions made by Driscoll and Lahiri (1983) that governments of developing countries could raise resources for development investment through non-inflationary monetary expansion. Our results however, show that in periods of major financial innovations like the rise of mobile money, the policy authorities in developing economies need to be mindful of speeding up consequences that such innovations may have on velocity and include this information in the policy design, to avoid higher than desired inflation. In other words, a model that ignores mobile money in countries where it has flourished, like the ones studied in this chapter, will tend to under predict velocity and potentially produce inflationary policy advice. This would be the case in the occurrence of all major financial innovations, like the rise of mobile money. The results obtained in this chapter also underscore the relative advantage of price based monetary policy over quantity based one, because in a price based policy framework a change in velocity will automatically show up in the central bank's operational target and thus prompt timely action, whereas in the quantity based framework the feedback will not show up in the operational target.

This work contributes to the existing literature it two major areas. First, it employs explicit measure of financial innovation, i.e. the number of mobile money transactions, to study its impact on income velocity of circulation, whereas the existing literature has for the most part used indirect measures of financial innovation, particularly time trend, the ratio of currency in circulation to broad money and the ratio of time deposits to demand deposits as proxies for financial innovation (Arrau *et al.*, 1995; Bordo and Jonung, 1987; Lieberman, 1977). Similar indirect measures were also utilized in the existing studies about the impact of mobile money on monetary policy variables (Nampewo and Opolot 2016; Ndirangu and Nyamongo, 2015). While the use of such indirect measures of financial innovation is understandable, given the paucity of explicit measures in time series form, it carries a risk of producing less precise or inconsistent results. Second, we argue that, while using time trend as an indirect measure of financial innovation may produce consistent results for economies where monetization is non-existent or negligible, for instance as it was used by Lieberman (1977) for US, if utilized for developing economies where the scope for monetization is still high, the results may be misleading. The general consensus in the literature is that financial innovation leads to increase in velocity of circulation, a mirror image of decline in demand for money. In an economy where monetization is substantial, velocity will tend to slow down with time as the structure of the economy changes, which implies a negative relationship between time trend and velocity in developing countries, contrary to positive relationship that would be consistent, if time trend represented financial innovation adequately. It is vital therefore, for studies of developing countries to take into account both the effects of financial innovation and monetization in the estimation of income velocity of circulation.

Chapter 4 Result tables

Table 4A1: Tanzania data descriptive statistics

	LOG(TM2VA)	LOG(TRGDP)	LOG(TBILO)	LOG(TWAYA)	LOG(TINFA)	LOG(TEXCAG)	LOG(TTRAS)
Mean	1.692	17.800	0.072	0.090	0.066	0.051	11.430
Median	1.646	17.805	0.070	0.086	0.054	0.034	16.720
Maximum	2.221	18.475	0.135	0.167	0.177	0.242	20.561
Minimum	1.370	17.097	0.022	0.029	0.030	-0.098	0.000
Std. Dev.	0.192	0.385	0.035	0.038	0.033	0.064	9.354
Skewness	1.016	0.001	0.261	0.148	1.544	0.488	-0.362
Kurtosis	3.265	1.832	1.692	1.707	5.129	4.034	1.219
Jarque-Bera	14.350	4.658	6.779	6.010	48.045	6.905	12.638
Probability	0.001	0.097	0.034	0.050	0.000	0.032	0.002
Sum	138.778	1459.633	5.897	7.371	5.430	4.219	937.287
Sum Sq. Dev.	2.981	11.980	0.099	0.114	0.089	0.327	7087.149
Observations	82	82	82	82	82	82	82

TM2VA stands for income velocity of M2, TRGDP is real GDP, TBILO is gross 91-days treasury bills rate, TWAYA is gross weighted average rate yield for all treasury bills, TINFA is gross CPI inflation, TEXCAG is gross depreciation of TZS against the USD and TTRAS is mobile money transactions.

Table 4A2: Kenya data descriptive statistics

	LOG(KM2VA)	LOG(KRGDP)	LOG(KBILO)	LOG(KINFA)	LOG(KEXCAG)	LOG(KTRAS)
Mean	0.915	14.690	0.076	0.073	0.016	12.884
Median	0.926	14.677	0.076	0.062	0.006	18.310
Maximum	1.072	15.215	0.177	0.176	0.225	19.998
Minimum	0.760	14.202	0.012	0.012	-0.099	0.000
Std. Dev.	0.075	0.292	0.029	0.040	0.066	8.711
Skewness	-0.045	0.060	0.383	1.052	0.773	-0.764
Kurtosis	2.312	1.761	4.999	3.322	3.665	1.669
Jarque-Bera	1.585	5.100	15.088	14.910	9.332	13.524
Probability	0.453	0.078	0.001	0.001	0.009	0.001
Sum	72.251	1160.545	5.977	5.756	1.273	1017.846
Sum Sq. Dev.	0.436	6.638	0.066	0.123	0.338	5918.259
Observations	79	79	79	79	79	79

Variables defined as those of Tanzania with the first letter changed to “K” for Kenya

Table 4A3: Uganda data descriptive statistics

	LOG(UM2VA)	LOG(URGDP)	LOG(UBILO)	LOG(UINFA)	LOG(UEXCAG)	LOG(UTRAS)
Mean	1.908	10.953	0.095	0.062	0.042	10.429
Median	1.896	11.020	0.087	0.053	0.033	15.862
Maximum	2.236	11.563	0.178	0.216	0.296	20.523
Minimum	1.619	10.234	0.037	-0.044	-0.142	0.000
Std. Dev.	0.129	0.353	0.033	0.048	0.091	9.204
Skewness	0.179	-0.281	0.794	0.907	0.617	-0.222
Kurtosis	2.407	1.903	3.121	4.434	3.317	1.121
Jarque-Bera	1.542	4.870	8.144	17.141	5.214	11.960
Probability	0.462	0.088	0.017	0.000	0.074	0.003
Sum	146.893	843.376	7.308	4.762	3.262	803.043
Sum Sq. Dev.	1.272	9.465	0.082	0.174	0.626	6438.925
Observations	77	77	77	77	77	77

Variables defined as those of Tanzania with the first letter changed to "U" for Uganda

Table 4A4: Comparison of descriptive statistics for the income velocity of circulation

	Tanzania	Kenya	Uganda
Mean	5.542	2.503	6.749
Median	5.142	2.524	6.654
Maximum	9.213	2.920	9.357
Minimum	3.933	2.138	4.642
Std. Dev.	1.194	0.187	0.925
Skewness	1.334	0.103	0.329
Kurtosis	3.943	2.370	2.737
Jarque-Bera	26.363	1.449	1.652
Probability	0.000	0.485	0.438
Sum	437.779	197.704	533.145
Sum Sq. Dev.	111.213	2.724	66.706
Observations	79	79	79

Untransformed data

Table 4A5: Lag structure of the selected equations

Equation number	Equations evaluated	Selected lag structure
Tanzania		
First equation full sample	2500	ARDL(1, 3, 0, 1, 0)
Second equation full sample	2500	ARDL(1, 3, 0, 1, 0)
Third equation full sample	2500	ARDL(1, 3, 0, 1, 0)
Equation m-money sub-sample	500	ARDL(1, 3, 2, 4)
Kenya		
First equation full sample	2500	ARDL(2, 3, 1, 4, 2)
Second equation full sample	12500	ARDL(4, 4, 0, 3, 2, 2)
First equation m-money sub-sample	2500	ARDL(1, 4, 4, 1, 4)
Second equation m-money sub-sample	2500	ARDL(4, 3, 3, 1, 4)
Uganda		
First equation full sample	2500	ARDL(1, 1, 1, 0, 4)
Second equation full sample	2500	ARDL(2, 1, 1, 0, 4)
Equation m-money sub-sample	500	ARDL(4, 1, 0, 3)

Table 4B1: Tanzania short run determinants of velocity, full sample equations

Variable/term	1	2	3
DLOG(TRGDP)	1.062	1.061	1.064
Probability	0.000	0.000	0.000
DLOG(TRGDP(-1))	0.041	-0.002	0.051
Probability	0.522	0.971	0.436
DLOG(TRGDP(-2))	0.145	0.131	0.151
Probability	0.003	0.006	0.002
DLOG(ATREND)	-5.408	-6.256	-4.849
Probability	0.000	0.000	0.000
Error correction (-1)	-0.362	-0.405	-0.339
Probability	0.000	0.000	0.000
R^2	0.911	0.916	0.909

Table 4B2: Tanzania short-run determinants of velocity, m-money sub-sample equation

Variable/term	4
DLOG(TRGDP)	0.896
Probability	0.000
DLOG(TRGDP(-1))	0.382
Probability	0.000
DLOG(TRGDP(-2))	0.233
Probability	0.000
DLOG(TEXCAG)	0.077
Probability	0.451
DLOG(TEXCAG(-1))	-0.283
Probability	0.008
DLOG(TTRAS)	0.025
Probability	0.000
DLOG(TTRAS(-1))	0.010
Probability	0.000
DLOG(TTRAS(-2))	0.002
Probability	0.317
DLOG(TTRAS(-3))	0.005
Probability	0.007
Error correction (-1)	-0.397
Probability	0.000
R^2	0.957

Table 4C1: Kenya short run determinants of velocity, full sample equations

Variable/term	1	2
DLOG(KM2VA(-1))	0.188	-0.101
Probability	0.050	0.344
DLOG(KM2VA(-2))		-0.263
Probability		0.008
DLOG(KM2VA(-3))		-0.301
Probability		0.003
DLOG(KRGDP)	0.949	1.077
Probability	0.000	0.000
DLOG(KRGDP(-1))	-0.539	-0.420
Probability	0.000	0.000
DLOG(KRGDP(-2))	-0.284	-0.081
Probability	0.001	0.476
DLOG(KRGDP(-3))		0.306
Probability		0.004
DLOG(KBILO)	0.547	
Probability	0.000	
DLOG(KINFA)		0.749
Probability		0.000
DLOG(KINFA(-1))		-0.201
Probability		0.033
DLOG(KINFA(-2))		-0.241
Probability		0.012
DLOG(ATREND)	11.197	-43.447
Probability	0.469	0.000
DLOG(ATREND(-1))	-69.562	26.725
Probability	0.024	0.000
DLOG(ATREND(-2))	53.992	
Probability	0.003	
DLOG(ATREND(-3))	-8.944	
Probability	0.001	
DLOG(KTRAS)	-0.002	
Probability	0.415	
DLOG(KTRAS(-1))	-0.006	
Probability	0.005	
D(KMDUM)		-0.032
Probability		0.046
D(KMDUM(-1))		-0.052
Probability		0.003
Error correction (-1)	-0.198	-0.154
Probability	0.000	0.000
R^2	0.871	0.935

Table 4C2: Kenya short-run determinants of velocity, m-money sub-sample equations

Variable/term	3	4
DLOG(KM2VA(-1))		0.061
Probability		0.593
DLOG(KM2VA(-2))		-0.319
Probability		0.004
DLOG(KM2VA(-3))		-0.222
Probability		0.035
DLOG(KRGDP)	0.861	0.948
Probability	0.000	0.000
DLOG(KRGDP(-1))	-1.955	-1.061
Probability	0.000	0.000
DLOG(KRGDP(-2))	-1.436	-0.464
Probability	0.000	0.004
DLOG(KRGDP(-3))	-0.726	
Probability	0.000	
DLOG(KBILO)	0.338	
Probability	0.007	
DLOG(KBILO(-1))	-0.059	
Probability	0.653	
DLOG(KBILO(-2))	-0.220	
Probability	0.093	
DLOG(KBILO(-3))	-0.328	
Probability	0.009	
DLOG(KINFA)		0.706
Probability		0.000
DLOG(KINFA(-1))		-0.269
Probability		0.042
DLOG(KINFA(-2))		-0.237
Probability		0.061
DLOG(ATREND)	-56.766	-25.170
Probability	0.000	0.000
DLOG(KTRAS)	0.183	0.148
Probability	0.000	0.000
DLOG(KTRAS(-1))	0.011	0.012
Probability	0.000	0.000
DLOG(KTRAS(-2))	0.008	0.008
Probability	0.000	0.000
DLOG(KTRAS(-3))	0.005	0.006
Probability	0.001	0.000
Error correction (-1)	-0.233	-0.140
Probability	0.000	0.000
R^2	0.954	0.953

Table 4D1: Uganda short-run determinants of velocity, full sample equations

Variable/term	1	2
DLOG(UM2VA(-1))		0.119
Probability		0.001
DLOG(URGDP)	1.041	0.981
Probability	0.000	0.000
DLOG(UINFA)	0.534	
Probability	0.000	
DLOG(UEXCAG)		-0.007
Probability		0.883
DLOG(UTRAS)	0.000	
Probability	0.820	
DLOG(UTRAS(-1))	0.003	
Probability	0.094	
DLOG(UTRAS(-2))	-0.001	
Probability	0.729	
DLOG(UTRAS(-3))	-0.004	
Probability	0.031	
D(UMDUM)		-0.014
Probability		0.598
D(UMDUM(-1))		-0.089
Probability		0.001
D(UMDUM(-2))		0.007
Probability		0.775
D(UMDUM(-3))		-0.078
Probability		0.004
Error correction (-1)	-0.110	-0.207
Probability	0.000	0.000
R^2	0.945	0.937

Table 4D2: Uganda short-run determinants of velocity, m-money sub-sample equations

Variable/term	3
DLOG(UM2VA(-1))	0.146
Probability	0.005
DLOG(UM2VA(-2))	0.041
Probability	0.445
DLOG(UM2VA(-3))	-0.145
Probability	0.010
DLOG(URGDP)	0.694
Probability	0.000
DLOG(UTRAS)	0.053
Probability	0.000
DLOG(UTRAS(-1))	0.017
Probability	0.000
DLOG(UTRAS(-2))	0.008
Probability	0.000
Error correction (-1)	-0.449
Probability	0.000
R^2	0.967

Chapter 5
Conclusion

This work has been motivated by the phenomenal growth of mobile money, that has been experienced among developing countries in the last two decades. Unlike other financial developments experienced in these countries, the use of mobile money has enabled extension of some basic formal financial services to the unbanked population, in economies that are predominantly cash-based, with relatively large rural population. While it has been widely credited for its contribution to financial inclusion and stabilization of rural incomes through remittances, the increasing use of mobile money for purchase of goods and services has received little attention. To get a more complete view of how mobile money has affected incomes, we consider it important to include the its use for purchase of goods and services, which we refer to as primary income channel, in the analysis. In the meantime, the prevailing empirical studies have relied mostly on generic measures of financial innovation, such as time trend, the ratio of currency to broad money and the ratio of time deposits to demand deposits to make inferences about the impact of mobile money on monetary policy.

In this work we make contribution to the existing literature about the impact of mobile money in two ways. First we have developed three new Keynesian DSGE models for analyzing the impact of mobile money through the primary income and the secondary income channels. This contrasts with the focus on the secondary income channel (i.e. the remittance channel) that, as far as we know, has been covered by the prevailing literature. The DSGE models have been developed in three stages. We began, in Chapter 2, by developing Model 1, that allowed mobile money to play a role in the primary income channel alone, and then we made two extensions in Chapter 3, one by introducing the secondary income channel in Model 2, and another by introducing capital in Model 3. By developing the three models in stages, we have been able to study how the various economic features interact with mobile money, separately.

In the first stage, we characterized the DSGE model to represent a developing economy with two sectors—urban and rural. The households in the urban, work in the manufacturing firms that produce sticky price goods, traded in frictionless market. They have access to saving technology, while the rural households do not. The rural sector is in turn characterized by two labour sharing industries—the farming industry whose goods are traded in a frictionless market, and the non-farming industry whose goods are traded using a friction prone distant payment technology. Farm and manufactured goods are consumed by all households in the economy, while non-farm goods are consumed by urban households alone. Both industries in the rural area produce flexible price goods. The payment friction in the purchase of non-farm goods takes the form of transaction fees that the buyer of these goods has to pay to the provider of the distant payment services. This makes the amount received by the producer of non-farm goods less than the amount paid by the buyer.

The introduction of secondary income channel has been achieved by adding a mixed household that has two members: one living and working in the rural and the other, a migrant who stays and works in the urban. The two members of this household pool their resources in order to maximize their shared utility, which they achieve through remittances, until their consumption is equalized. However, since remittances are made using the prevailing money transfer technology, their consumption ends up being different by a magnitude defined by the transaction fees. Therefore, mobile money plays a role of narrowing this difference. This setting establishes microfoundations for remittances, based on the altruistic motive. It therefore constitutes a further extension of the AW model, which assumes an ad hoc remittance rule, also based on altruism. We then made further extension to Model 3, by adding sector specific capital to Model 2, with a view to providing a more rounded picture of the economic impact of mobile money. This is achieved by relaxing the assumptions of the households living in the urban such that they are able to own capital and rent it to specific industries—manufacturing and farming. The non-farming industry production function is left without capital, by assuming that it produces labour intensive artisanal goods.

Second, in Chapter 4, we carried out empirical analysis of the impact of mobile money on income velocity of circulation in three East African countries, namely Tanzania, Kenya and Uganda. We postulate that mobile money like other financial innovations, would increase income velocity of circulation for two reasons. One is by increasing the efficiency of transaction balances which translates to reduction in demand for money and two is by promoting higher density of exchanges among transacting parties, as it removes the barriers of distance and time among its users. We use the number of mobile money transactions to represent mobile money in the estimations of income velocity of circulation equations for each country, while controlling for monetization process, that appears to be an important determinant of the long-run downward trend in the velocity. By using the number of mobile money transaction we trust that our study captures the effect of mobile money better than other studies that have relied on indirect measures of financial innovation. The estimations were carried out using ARDL bounds test approach to cointegration.

The DSGE models have revealed a number of predictions about the impact of mobile money through the primary and the secondary income channels. All three models predict that introduction of mobile money will have overall positive benefits to the economy and that the rural will take disproportionately larger share of the benefits. By reducing the payment friction, mobile money raises both the primary and disposable incomes in the rural, relative to those of the urban. Mobile money increases the quantity of output, driven by the rural non-farm goods industry, while reducing the difference between output at consumers' price and output at factor cost. This happens because part of the value recovered from the transaction fees is passed over to the primary incomes generated by rural non-farming industry, as well as increasing the net remittances received by the rural households. The reduction of the transaction fees also increases the demand for non-farm goods as well as the gross remittances made by the migrant households to their counterparts in the rural. By including the primary income channel in our models, we have been able to show that rural incomes are impacted positively by mobile money, even in the absence of remittances, and that such benefits are spread more evenly among the households living in the rural.

Under the impulse response to productivity shocks we have seen that, mobile money plays a role of redistributing the response of income and consumption to shocks, in favour of the rural households. The factor cost value of non-farm goods sold to the urban households responds with an upward shift to productivity shocks, and so do the remittances. The redistribution of income in favour of the rural is also exhibited in the upward shift of the response of rural consumption to the shocks. This prediction also applies for expansionary monetary policy shock, as mobile money helps to redistribute its welfare benefits in favour of the rural. In addition, mobile money makes monetary policy shock more effective. These results demonstrate the role played by mobile money in the poverty reduction endeavour, thus underscoring the need for policy authorities to promote its growth.

Turning to the effect of remittances, the presence of remitting household in Model 2 distributes the response of output to introduction of mobile money, more evenly across sectors at steady state. It allows rural-urban trade-off of work hours, through the mixed household, and thus more hours are not only allocated to the non-farm goods industry when mobile money is introduced, but also to manufacturing through the mixed household. Regarding the effect of remittances on the response to shocks, the models predict that, the response of output to shocks will be more volatile because the mixed household allows labour hours to be traded between the rural and the urban. For instance, a positive productivity shock in farming does not draw labour hours from non-farming industry alone, but it also draws labour hours from manufacturing. Likewise, a positive productivity shock in the manufacturing draws labour hours from the rural. By contrast to output, remittances play a stabilizing role in the response of household consumption to shocks, as gains in the primary income of one sector get transmitted more efficiently to the other sector.

As for the presence of capital, it changes the response of incomes to introduction of mobile money in favour of rural wages, at steady state. The quantity of labour in farming drops faster than the quantity of capital, when mobile money is introduced, resulting in higher increase in the rural wages. With regard to shocks, inclusion of capital spreads the positive impact of manufacturing productivity shock to all industries. Whereas in Model 2, the value of farming output responds to positive manufacturing shock with a decline due to migration of labour into non-farming, in Model 3 it responds positively, because the shock reduces the price of capital goods, also used in farming. This results in the value of output in both rural industries responding positively. Also the response of rural production becomes substantially stabilized and the persistence extends for a much longer period, when capital is present, reflecting the increase in the number of households with ability to optimize consumption across time.

From the monetary policy perspective, the DSGE models have shown that mobile money integrates the rural economy more into the national economy. This is exhibited by increase in the weight of rural shocks in the variance of output, inflation and interest rate under the mobile money scenario, compared to the baseline scenario. It implies that central banks need to pay more attention to the state of the rural economy in their policy design, under the mobile money scenario compared to the baseline scenario. In addition, when capital is included, the weight of farming shock in the variance of interest rate increases substantially. This is a demonstration of the fact that when capital is involved, farming becomes more deeply integrated into national economy. It exposes the behaviour of the mixed household, that invests in farming, to the stabilizing force of interest rate—effectively giving it a Ricardian household status.

We carried out model validation by comparing selected second moments produced by the models with those produced by data, and found that Model 3, i.e. the model with capital, represents data better than the models without capital. This supports the argument that investment in the rural benefits from the incomes of the migrants. It also shows that including capital in the DSGE models may make a difference. We then estimated optimal policy rules using Model 3 with IRR and found that a policy rule that maximizes welfare in the presence of mobile money is one that is relatively more aggressive, compared to the one that maximizes welfare under the scenario without mobile money. This is consistent with the observation that mobile money integrates the rural economy more into the national economy. It also implies that central banks need to revise their policy rules with expectation of prescribing stronger policy responses to real shocks, after the introduction of mobile money.

The results of the empirical estimations indicate that there is a statistically significant positive relationship between mobile money transactions and the income velocity of circulation in Tanzania, Kenya and Uganda. This relationship is however, economically weak in Tanzania and Uganda. Using mobile money dummy, on the other hand, reveals a relatively stronger economic relationship with velocity. This implies that central banks need to be mindful of this development, and adjust the rate of increase in money supply downwards, to avoid the inflationary outcome of higher velocity. They also imply that the ability of governments to raise seigniorage revenue safely is impaired. However, mobile money presents governments with means to improve efficiency in revenue collection, and therefore, governments need to embrace the mobile money technology to recover the seigniorage space that may have been lost, and boost revenue collection even further. This up-turn in velocity of circulation though, is expected to last for as long as the uptake of mobile money increases. Once the up-take reaches its peak, the long-term downward trend in velocity will resurface, because the strength of structural transformation that governs the long-term behaviour of velocity among developing countries remains the major underlying force. We thus expect the seigniorage revenue space to be restored in these economies, as they run out of absorptive capacity for mobile money.

Finally, regarding areas for further research, the DSGE models constructed in this work could be extended in a number of ways. First, is by assigning the money transfer services to a fully developed financial services industry with proper microfoundations. Adding a financial sector to the model may also be used to study the impact of mobile money on savings and credit. While the impact of mobile money on saving and credit has so far been limited, with time it could evolve to have sizeable consequences, especially considering the potential that lies in the digital solutions. Second, is by adapting it to study the impact that mobile money is having on government revenue collection as it increases transparency, reduces opportunities for corruption, helps to mitigate illicit transactions, and broadens the tax base. Making such extensions is a crucial task in the endeavour to complete the picture of the impact of mobile money.

References

Abiona, O., and Koppensteiner, M. F. (2020). Financial Inclusion, Shocks, and Poverty: Evidence from the Expansion of Mobile Money in Tanzania. Journal of Human Resources, 1018-9796R1.

Abu-Qarn, A. S., & Abu-Bader, S. (2009). Getting income shares right: A panel data investigation for countries of the OECD. *Economic Development Quarterly*, *23*(3), 254-266.

Adam C. and Walker SEJ (2015), Mobile money and monetary policy in East African countries, University of Oxford. Oxford: United Kingdom.

Adil, M. H., Hatekar, N., & Sahoo, P. (2020). The impact of financial innovation on the money demand function: an empirical verification in India. Margin: The Journal of Applied Economic Research, 14(1), 28-61.

Ahmad, A. H., Green, C., & Jiang, F. (2020). Mobile money, financial inclusion and development: A review with reference to African experience. Journal of Economic Surveys, 34(4), 753-792.

Ajaz, T., Nain, M. Z., & Kamaiah, B. (2016). Inflation and openness in India: an asymmetric approach. *Macroeconomics and Finance in Emerging Market Economies*, *9*(2), 190-203.

Aker, J. C., & Blumenstock, J. E. (2015). “The economic impacts of new technologies in Africa”. The Oxford handbook of Africa and economics, 2, 354-371.

Aker, J.C., and Fafchamps, M. (2014). Mobile phone coverage and producer markets: Evidence from West Africa. World Bank Policy Research Working Paper. Washington, D.C.: World Bank.

Akinlo, A. E. (2012). Financial development and the velocity of money in Nigeria: An empirical analysis. The Review of Finance and Banking, 4(2), 97-113.

Alih, P. M., Sarmidi, T., Shaari, A. H., & Said, F. F. (2018). Investigating the relationship between financial innovation and money demand in Malaysia: An ARDL approach to Cointegration. *International Journal of Accounting*, *3*(15), 66-85.

Alrabadi, D. W. H., & Kharabsheh, B. A. (2016). Financial deepening and economic growth: The case of Jordan. *Journal of Accounting and Finance*, *16*(6), 158.

Anand, R., & Prasad, E. S. (2010). *Optimal price indices for targeting inflation under incomplete markets* (No. w16290). National Bureau of Economic Research.

Andersson-Manjang, S. K. (2021). The Mobile Money Prevalence Index (MMPI): a country-level indicator for assessing the adoption, activity and accessibility of mobile money. *Activity and Accessibility of Mobile Money (September 20, 2021)*.

Aron J. (2017) "'Leapfrogging': A Survey of the Nature and Economic Implications of Mobile Money" CSAE Working Paper WPS/2017-02.

Aron J. (2018) "Mobile Money and the Economy: A Review of the Evidence" (16)

Aron, J., Muellbauer J. and Sebudde R. (2015) "Inflation forecasting models for Uganda: is mobile money relevant?" Centre for the Study of African Economies (CSAE) Working Paper WPS/2015-17 [V the presentation] (16)

Arrau, P., De Gregorio, J., Reinhart, C. M., & Wickham, P. (1995). The demand for money in developing countries: assessing the role of financial innovation. *Journal of Development Economics*, *46*(2), 317-340.

Ascari, G., & Ropele, T. (2013). Disinflation effects in a medium-scale new keynesian model: money supply rule versus interest rate rule. *European Economic Review*, *61*, 77-100.

Attanasio, O. P., Guiso, L., & Jappelli, T. (2002). The demand for money, financial innovation, and the welfare cost of inflation: An analysis with household data. *Journal of Political Economy*, *110*(2), 317-351.

Balele, N., Kessy, N., Mpemba, Z., Aminiel, F., Sije, G. and Mung'ong'o, E. (2018), "Financial sector reforms and innovations and their implications on monetary policy transmission in Tanzania", Working Paper Series, WP No 13: Bank of Tanzania.

Bank of Tanzania (2007), Annual Report 2006/07.

Bank of Tanzania (2008), Monetary Policy Statement June 2008.

Bank of Tanzania (2012), Monetary Policy Statement June 2012.

Bank of Tanzania (2020), Financial Sector Supervision Annual Report 2020.

Bank of Tanzania (2021), Monthly Economic Review June 2021.

Bank of Tanzania (2022), Annual Report 2021/22.

Bank of Tanzania (2023), Monthly Economic Review June 2023.

Bank of Tanzania (2024), Public Notice Changes in Monetary Policy Framework January 2024.

Bateman, M., Duvendack, M., & Loubere, N. (2019). Is fin-tech the new panacea for poverty alleviation and local development? Contesting Suri and Jack's M-Pesa findings published in Science. Review of African Political Economy, 46(161), 480-495.

Batista, C., & Vicente, P. C. (2021). *Is Mobile Money Changing Rural Africa?: Evidence from a Field Experiment*. Centre for Research and Analysis of Migration, Department of Economics, University College London.

Bayangos, V., & Jansen, K. (2011). Remittances and competitiveness: The case of the Philippines. *World Development*, *39*(10), 1834-1846.

Beck, T., & Cull, R. (2013). Banking in Africa. The World Bank.

Beegle, K., De Weerdt, J., & Dercon, S. (2011). Migration and economic mobility in Tanzania: Evidence from a tracking survey. *Review of Economics and Statistics*, *93*(3), 1010-1033.

Bigsten, A. (1996). The circular migration of smallholders in Kenya. *Journal of African Economies*, *5*(1), 1-20.

Bilyk, V. (2006). Financial Innovations and the Demand for Money in Ukraine. National University.

Blaug, M. (1997). Say's law of markets: What did it mean and why should we care?. *Eastern economic journal*, *23*(2), 231-235.

Blumenstock, J. E., Fafchamps, M., & Eagle, N. (2011). Risk and reciprocity over the mobile phone network: evidence from Rwanda. *Available at SSRN 1958042*.

Bondzie, E. A., & Armah, M. K. (2022). A DSGE model of fiscal stabilizers and informality in Sub-Sahara Africa. *Cogent Economics & Finance*, *10*(1), 2137985.

Bordo, M. D., & Jonung, L. (1981). The long run behavior of the income velocity of money in five advanced countries, 1870–1975: An institutional approach. *Economic Inquiry*, *19*(1), 96-116.

Bordo, M. D., & Jonung, L. (1987). The Stochastic Properties of Velocity: A New Interpretation.

Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society: Series B (Methodological)*, 37(2), 149-163.

Calvo, G. A., & Leiderman, L. (1992). Optimal inflation tax under precommitment: Theory and evidence. *The American Economic Review*, 179-194.

Campbell, J. Y., & Mankiw, N. G. (1989). Consumption, income, and interest rates: Reinterpreting the time series evidence. NBER macroeconomics annual, 4, 185-216.

Can, U., Can, Z. G., Bocuoglu, M. E., & Dogru, M. E. (2021). The effectiveness of the post-Covid-19 recovery policies: Evidence from a simulated DSGE model for Turkey. Economic Analysis and Policy, 71, 694-708.

Canagarajah, S., Newman, C., & Bhattamishra, R. (2001). Non-farm income, gender, and inequality: evidence from rural Ghana and Uganda. *Food policy*, *26*(4), 405-420.

Central Bank of Kenya (2023), Thirty-First Bi-Annual Report of the Monetary Policy Committee, October 2023.

CGAP (2015) Consultative Group to Assist the Poor. Tanzania's Mobile Money Revolution <https://www.cgap.org/research/infographic/tanzanias-mobile-money-revolution>

Chandavarkar, A. G. (1977). Monetization of developing economies. *Staff Papers*, *24*(3), 665-721.

Chironga, M., De Grandis, H., & Zouaoui, Y. (2017). Mobile financial services in Africa: Winning the battle for the customer. *McKinsey & Co*.

Cho, D. W., & Miles, W. (2007). Financial innovation and the stability of money demand in Korea. Southwestern Economic Review, 34, 51-59.

Chowdhury, M. B., & Rabbi, F. (2014). Workers' remittances and Dutch disease in Bangladesh. *The Journal of International Trade & Economic Development*, 23(4), 455-475.

Christiano, L. J., Eichenbaum, M. S., & Trabandt, M. (2018). On DSGE models. *Journal of Economic Perspectives*, *32*(3), 113-140.

Christiano, L. J., Trabandt, M., & Walentin, K. (2010). DSGE models for monetary policy analysis. In *Handbook of monetary economics* (Vol. 3, pp. 285-367).

Cinquegrana, G. (2010). Debt and net financial wealth: a comparative analysis for some European countries.

Comninos, A., Esselaar, S., Ndiwalana, A., & Stork, C. (2008). M-banking the Unbanked. *Towards Evidence-based ICT Policy and Regulation policy paper series; 2008, v. 1, no. 4*.

Costa, C. (2018). Understanding DSGE models: Theory and applications. Vernon Press.

Dabrowski, M. (2017). Potential impact of financial innovation on financial services and monetary policy. *CASE Research Paper*, (488).

Davoodi, M. H. R., Dixit, M. S., & Pinter, G. (2013). *Monetary transmission mechanism in the East African Community: An empirical investigation*. International Monetary Fund.

de Brauw, A., Mueller, V., & Woldehanna, T. (2013). Does internal migration improve overall well-being in Ethiopia?. *Ethiopia Strategy Support Program II*, *55*.

Demirguc-Kunt, A., Klapper, L., & Singer, D. (2017). Financial inclusion and inclusive growth: A review of recent empirical evidence.

Demombynes, G., & Thegeya, A. (2012). Kenya's mobile revolution and the promise of mobile savings. *World Bank policy research working paper*, (5988).

Di Castri, S., & Gidvani, L. (2014). Enabling Mobile Money Policies in Tanzania: A 'Test and Learn' Approach to Enabling Market-Led Digital Financial Services. *Available at SSRN 2425340*.

Dotsey, M. (1984). An investigation of cash management practices and their effects on the demand for money. *FRB Richmond Economic Review*, *70*(5), 3-12.

Dreger, C., & Wolters, J. (2009). Money velocity and asset prices in the euro area. *Empirica*, *36*(1), 51-63.

Driscoll, M. J., & Lahiri, A. K. (1983). Income-velocity of money in agricultural developing economies. *The review of economics and statistics*, 393-401.

East African Community (2022), accessed 21 April 2022, <https://www.eac.int/eac-history>

Economides, N., & Jeziorski, P. (2017). Mobile money in Tanzania. *Marketing Science*, *36*(6), 815-837.

Eijkman, F., Kendall, J., & Mas, I. (2010). Bridges to cash: The retail end of M-PESA. Savings and development, 219-252.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276.

Fafchamps, M., & Shilpi, F. (2003). The spatial division of labour in Nepal. *The Journal of Development Studies*, *39*(6), 23-66.

FinScope Tanzania (2017)

FinScope Tanzania (2023)

FinScope Uganda (2018)

Fischer, A. M. (2007). Measuring Income Elasticity for Swiss Money Demand: What do the cantons say about financial innovation? *European Economic Review*, *51*(7), 1641-1660.

Fregert, K. (2008). The choice between state-and time-dependent price rules. *Available at SSRN 1272871*.

Friedman, M. (1959). The demand for money: some theoretical and empirical results. *Journal of Political economy*, *67*(4), 327-351.

Friedman, M., & Schwartz, A. J. (1983). Monetary trends in the United States and the United Kingdom: Their relations to income, prices, and interest rates 1867–1975. *Chicago, IL: University of Chicago Press.*

Financial Sector Deepening Trust (FSDT) (2018), Case study, The story of digital finance in Tanzania (2018).

Gali, J. (2015). Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications. Princeton University Press.

Gali, J., López-Salido, J. D., & Vallés, J. (2004). Rule-of-thumb consumers and the design of interest rate rules (No. w10392). National Bureau of Economic Research.

Gilman, L. (2016). The Impact of Mobile Money Interoperability in Tanzania: Early Data and Market Perspectives on Account-to-Account Interoperability. *London: GSMA*.

Goldfeld, S. M., Fand, D. I., & Brainard, W. C. (1976). The case of the missing money. *Brookings papers on economic activity*, *1976*(3), 683-739.

Goldstone, J. A. (1991). Monetary versus velocity interpretations of the "Price Revolution": a comment. *The Journal of Economic History*, *51*(1), 176-181.

Gollin, D. (2002). Getting income shares right. *Journal of political Economy*, *110*(2), 458-474.

GSMA (2020) State of the Industry Report on Mobile Money 2019

GSMA database https://www.gsma.com/mobilemoneymetrics/#global

Hart, J., & Clemens, M. (2019). A search and matching approach to business-cycle migration in the euro area.

Hassler, U., & Wolters, J. (2006). Autoregressive distributed lag models and cointegration. In *Modern econometric analysis* (pp. 57-72). Springer, Berlin, Heidelberg.

Hawkins, J. (2001) "Electronic finance and monetary policy" BIS Papers No 7 (29)

Hinson, R., Lensink, R., & Mueller, A. (2019). Transforming agribusiness in developing countries: SDGs and the role of FinTech. *Current Opinion in Environmental Sustainability*, *41*, 1-9.

Hoddinott, J. (1994). A model of migration and remittances applied to Western Kenya. *Oxford economic papers*, 459-476.

Hossain, M. S., & Sunmoni, A. (2021). Do remittances influence household investment decisions? Evidence from Sub-Saharan Africa. *Department of Economics University of Reading Whiteknights Reading Discussion Paper*, (2021-04).

Hughes, N. and Lonie, S. (2007). M-PESA: mobile money for the "unbanked" turning cellphones into 24-hour tellers in Kenya. Innovations: technology, governance, globalization, 2(1-2), 63-81.

Hwang, B. H., & Tellez, C. (2016). The proliferation of digital credit deployments.

Ilahi, N., & Jafarey, S. (1999). Guestworker migration, remittances and the extended family: evidence from Pakistan. *Journal of development Economics*, *58*(2), 485-512.

ILO (2018) Women and men in the informal economy: A statistical picture

International Monetary Fund (2011), Uganda: Letter of Intent, Memorandum of Economic and Financial Policies, and Technical Memorandum of Understanding, December 20, 2011.

Ivanov, M., Petkovski, M., & Naumovska, E. (2014). Money-in-the-utility-function: Model simulations and money demand estimation in the case of the Republic of Macedonia. *South East European Journal of Economics and Business (Online)*, *9*(2), 7.

Jack, W., & Suri, T. (2011). Mobile money: The economics of M-PESA (No. w16721). National Bureau of Economic Research.

Jack, W., Ray, A., & Suri, T. (2013). Transaction networks: Evidence from mobile money in Kenya. *American Economic Review*, *103*(3), 356-61.

Jafarey, S., Masters, A. (2003). Output, prices, and the velocity of money in search equilibrium. Journal of Money, Credit and Banking, 871-888. KIPPRA (2020), Kenya Economic Report 2020.

Jenik, I., Lyman, T., & Nava, A. (2017). Crowdfunding and financial inclusion. *CGAP (Consultative Group to Assist the Poor) working paper*, *41*.

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. *The quarterly journal of economics*, *122*(3), 879-924.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and statistics*, *52*(2), 169-210.

Judd, J. P., & Scadding, J. L. (1982). The search for a stable money demand function: A survey of the post-1973 literature. *Journal of Economic literature*, *20*(3), 993-1023.

Kendall, J., & Voorhies, R. (2014). The mobile-finance revolution; How cell phones can spur development. *Foreign Aff.*, *93*, 9.

Kenya National Bureau of Statistics (2019). FinAccess 2019 Household Survey

Kenya National Bureau of Statistics (2022). Statistical Abstract 2022.

Kessy, P. J., Nyella, J., & O'Connell, S. A. (2017). Monetary Policy in Tanzania. *Tanzania: The Path to Prosperity*, *3*, 241.

King, R. G., & Levine, R. (1993). Finance and growth: Schumpeter might be right. The quarterly journal of economics, 108(3), 717-737.

KIPPRA (2020) Kenya Economic Report 2020: Creating an Enabling Environment for Inclusive Growth in Kenya

Krolikowski, A. (2014). Can mobile-enabled payment methods reduce petty corruption in urban water provision? Water Alternatives, 7(1).

Krugman, P. (1991). Increasing returns and economic geography. *Journal of political economy*, *99*(3), 483-499.

Labán, R. (1992). *Essays on financial innovation and stabilization* (Doctoral dissertation, Massachusetts Institute of Technology).

Lai, C. F. (2018). Fiscal policy and macroeconomic fluctuations in a fixed exchange rate regime. *Asian Economic and Financial Review, 8*(10), 1257-1273.

Lee, C. W., & Yu, H. Y. (2021). Money Supply, Inflation and Economic Growth in China: An ARDL Bounds Testing Approach. *Journal of Applied Finance and Banking*, *11*(1), 73-80.

Lee, J. N., Morduch, J., Ravindran, S., Shonchoy, A., & Zaman, H. (2021). Poverty and migration in the digital age: Experimental evidence on mobile banking in Bangladesh. *American Economic Journal: Applied Economics*, *13*(1), 38-71.

Lenka S. and Bairwa A. (2016) "Does financial inclusion affect monetary policy in SAARC countries?" Cogent Economics & Finance, 4:1, 1127011, DOI: (28)

Lepoutre, J., & Oguntoye, A. (2018). The (non-) emergence of mobile money systems in Sub-Saharan Africa: A comparative multilevel perspective of Kenya and Nigeria. *Technological Forecasting and Social Change*, *131*, 262-275.

Lieberman, C. (1977). The transactions demand for money and technological change. *The Review of economics and Statistics*, 307-317.

Lippi, F., & Secchi, A. (2009). Technological change and the households' demand for currency. *Journal of Monetary Economics*, *56*(2), 222-230.

Lown, C. S., Peristiani, S., & Robinson, K. J. (1999). What was behind the M2 breakdown? *Available at SSRN 192730*.

Lucas Jr, R. E. (1976, January). Econometric policy evaluation: A critique. In *Carnegie-Rochester conference series on public policy* (Vol. 1, pp. 19-46). North-Holland.

Lucas, R. E. (2015). Internal migration in developing economies: An overview. *KNOMAD's working paper, 6*.

Lucas, R. E., & Stark, O. (1985). Motivations to remit: Evidence from Botswana. *Journal of political Economy*, *93*(5), 901-918.

Mattern, M., & McKay, C. (2018). Building inclusive payment ecosystems in Tanzania and Ghana.

Maurer, B. (2012). Mobile money: Communication, consumption and change in the payments space. *Journal of Development Studies*, *48*(5), 589-604.

Mawejje, J. and Lakuma, P. (2019) “Macroeconomic effect of mobile money evidence from Uganda” Financial Innovation

Mbiti, I. and Weil, D. (2016) “Mobile Banking: The Impact of M-Pesa in Kenya”, National Bureau of Economic Research.

Mbutor, M. O., & Uba, I. A. (2013). The impact of financial inclusion on monetary policy in Nigeria. *Journal of Economics and International Finance*, *5*(8), 318-326

Mele, A., & Stefanski, R. (2019). Velocity in the long run: Money and structural transformation. Review of Economic Dynamics, 31, 393-410.

Mohan, R. (2006). Economic growth, financial deepening and financial inclusion. *Reserve Bank of India Bulletin*, *1305*.

Montiel, P., Adam, C. S., Mbowe, W., & O'Connell, S. (2012). Financial Architecture and the Monetary Transmission Mechanism in Tanzania.

Morawczynski, O. and Pickens, M. (2009). Poor people using mobile financial services: observations on customer usage and impact from M-PESA. (242)

Morgan, P., & Pontines, V. (2014). Financial stability and financial inclusion.

Munyegera, G. K., & Matsumoto, T. (2016). Mobile money, remittances, and household welfare: Panel evidence from rural Uganda. *World Development*, *79*, 127-137.

Muscatelli, V. A. (1988). The Long-Run behavior of the Velocity of Circulation: The International Evidence.

Muthiora, B. (2015). Enabling mobile money policies in Kenya: Fostering a digital financial revolution. *GSMA Mobile Money for the Unbanked*, 1-28.

Nagayasu, J. (2012). Financial innovation and regional money. *Applied Economics*, *44*(35), 4617-4629.

Nagler, P. (2015). Occupational choice in the developing world. Boekenplan.

Nampewo D., and Opolot, J. (2016) “Financial Innovations and Money Velocity in Uganda” African Development Review, Vol. 28, No. 4, 2016, 371–382.

National Bureau of Statistics Tanzania, (2022). National Accounts Statistics of Tanzania Mainland 2015-2021.

Ndebbio, J. E. U. (2004). Financial deepening, economic growth and development: Evidence from selected sub-Saharan African Countries.

Ndirangu, L., & Nyamongo, E. M. (2015). “Financial innovations and their implications for monetary policy in Kenya. Journal of African Economies”, 24(suppl_1), i46-i71.

Newman, C., & Canagarajah, S. (2000). *Gender, poverty, and nonfarm employment in Ghana and Uganda* (Vol. 2367). World Bank Publications.

Nielsen, Ø. J., Rayamajhi, S., Uberhuaga, P., Meilby, H., & Smith-Hall, C. (2013). Quantifying rural livelihood strategies in developing countries using an activity choice approach. *Agricultural economics*, *44*(1), 57-71.

Nkoro, E., & Uko, A. K. (2016). Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation. *Journal of Statistical and Econometric methods*, *5*(4), 63-91.

Nnenna, O. M. (2012). Evaluating the nexus between financial deepening and stock market in Nigeria. *European Scientific Journal*, *8*(15).

Ochs, J., & Rush, M. (1983). The persistence of interest-rate effects on the demand for currency: Note. *Journal of Money, Credit and Banking*, *15*(4), 499-505.

Ondiege, P. (2015). Regulatory Impact on Mobile Money and Financial Inclusion in African Countries-Kenya, Nigeria, Tanzania and Uganda. Center for Global Development (CGD), 50.

Orekoya, S. (2017). Mobile money and monetary policy in Nigeria. *NIDC Quarterly*, *32*(34), 20-34.

Orphanides, A. (2010). Taylor rules. In *Monetary economics* (pp. 362-369). Palgrave Macmillan, London.

Oyvat, C. (2017). Migration in Kenya: Beyond Harris-Todaro. *Department of Economics Working Paper Series*.

Özer, M., & Karagöl, V. (2018). Relative effectiveness of monetary and fiscal policies on output growth in Turkey: an ARDL bounds test approach. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, *13*(3), 391-409.

Peiris, S. J., & Saxegaard, M. (2007). An estimated DSGE model for monetary policy analysis in low-income countries. *IMF Working Papers*, 1-31

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.

Plosser, C. I. (2012, May). Macro models and monetary policy analysis. In *Bundesbank-Federal Reserve Bank of Philadelphia Research Conference. http://www. philadelphiafed. org/publications/speeches/plosser/2012/05-25-12_bundesbank. pdf*.

Plyler, M. G., Haas, S., & Nagarajan, G. (2010). Community-level economic effects of M-PESA in Kenya. *Financial Services Assessment: College Park, MD, USA*, 1-8.

Popovska-Kamnar, N. (2014). The use of electronic money and its impact on monetary policy. *Journal of Contemporary Economic and Business Issues*, *1*(2), 79-92.

Quint, M. D., & Rabanal, M. P. (2013). *Monetary and macroprudential policy in an estimated DSGE model of the euro area*. International Monetary Fund.

Reddy, A. A. (2006). Occupational structure of workers in rural Andhra Pradesh. *Journal of Indian School of Political Economy*.

Rudebusch, G. D. (2005). Assessing the Lucas critique in monetary policy models. *Journal of money, credit and banking*, 245-272.

Sahay, R., Čihák, M., N'Diaye, P., & Barajas, A. (2015). Rethinking financial deepening: Stability and growth in emerging markets. *Revista de Economía Institucional*, *17*(33), 73-107.

Samreth, S. (2008). Estimating money demand function in Cambodia: ARDL approach.

Sander, C. (2004). Passing the Buck in East Africa, The Money Transfer Practice and Potential for Services in Kenya, Tanzania, and Uganda. *Nairobi: MicroSave*.

Sanderson, A., Mutandwa, L., & Le Roux, P. (2018). A review of determinants of financial inclusion. International Journal of Economics and Financial Issues, 8(3), 1.

Sekabira, H., and Qaim, M. (2017). Mobile money, agricultural marketing, and off-farm income in Uganda. Agricultural Economics, 48(5), 597-611

Senbeta, S. R. (2011). A Small Open Economy New Keynesian DSGE model for a foreign exchange constrained economy. *Available at SSRN 1812743*.

Shahe Emran, M., Morshed, A. K. M., & Stiglitz, J. E. (2007). Microfinance and Missing Markets. Joseph E., Microfinance and Missing Markets (March 2007).

Sharma, S. S., & Syarifuddin, F. (2019). Determinants of Indonesia’s income velocity of money. *Buletin Ekonomi Moneter dan Perbankan*, *21*(3), 323-342.

Sichei, M. M., & Kamau, A. W. (2012). Demand for money: Implications for the conduct of monetary policy in Kenya. *International Journal of Economics and Finance*, *4*(8), 72-82.

Sichei, M., & Kamau, A. (2010). Demand for Broad Money in Kenya: 1996–2009. *(Nairobi: Central Bank of Kenya)*.

Siddiki, J. U. (2000). Demand for money in Bangladesh: a cointegration analysis. *Applied Economics*, *32*(15), 1977-1984.

Siddiqui, T. (2004). Efficiency of migrant workers’ remittance: the Bangladesh case. *Asian Development Bank, Manila*.

Siklos, P. L. (1993). Income velocity and institutional change: Some new time series evidence, 1870-1986. *Journal of Money, Credit and Banking*, *25*(3), 377-392.

Simpasa A. and Gurara D. (2012) Inflation Dynamics in selected East African countries: Ethiopia, Kenya, Tanzania and Uganda, AfDB Brief.

Soderbom, M. (2008). Nonfarm microenterprise performance and the investment climate: evidence from rural Ethiopia (Vol. 4577). World Bank Publications.

Srivastava, R. (2011). Internal migration in India. *Human Development in India*.

Stähler, N., & Thomas, C. (2012). FiMod—A DSGE model for fiscal policy simulations. *Economic modelling*, *29*(2), 239-261.

Stichter, S. (1985). *Migrant laborers*. CUP Archive.

Sumner, D. A. (1981). Wage functions and occupational selection in a rural less developed country setting. *The Review of Economics and Statistics*, 513-519.

Suri, T., & Jack, W. (2016). The long-run poverty and gender impacts of mobile money. Science, 354(6317), 1288-1292.

Syrotian, R. (2012). Velocity of Money: Determinants in Ukraine. *Kyiv School of Economics*.

Tamborini, R., Trautwein, H. M., & Mazzocchi, R. (2014). Wicksell, Keynes, and the New Neoclassical Synthesis: What can we learn for monetary policy?. *Economic Notes: Review of Banking, Finance and Monetary Economics*, *43*(2), 79-114.

Tanzania Communications Regulatory Authority (TCRA): Report for the quarter ending June 2022

Thornton, D. L. (1983). Why does velocity matter. *Federal Reserve Bank of St Louis.*

Trager, L. (1984). Migration and remittances: urban income and rural households in the Philippines. *The Journal of Developing Areas*, *18*(3), 317-340.

Trapp, K. (2015). Measuring the labour income share of developing countries: Learning from social accounting matrices (No. 2015/041). WIDER Working Paper.

Uganda Bureau of Statistics (2021), Uganda Consumer Price Index

UNDP (2009). *Human development report 2009. Overcoming barriers*: Human mobility and development, New York:

Veniard, C. (2010). “How Agent Banking Changes the Economics of Small Accounts”. Global Savings Forum, Brief written for the Bill & Melinda Gates Foundation.

Walsh, C. E. (2017). *Monetary theory and policy*. MIT press.

Walsh, M. J. P. (2011). *Reconsidering the role of food prices in inflation*. International Monetary Fund. World Bank (2019) Sub-Saharan Africa Series: Mobile Money and Digital Financial Inclusion.

Waweru, K. M., & Kamau, J. W. (2017). The effect of mobile money on saving and money transfer practices for low-income earners in Kenya.

Weil, D., Mbiti, I., & Mwega, F. (2012). The implications of innovations in the financial sector on the conduct of monetary policy in East Africa. *Report submitted to the International Growth Centre Tanzania Country Program*.

Wiafe, E. A., Quaidoo, C., & Sekyi, S. (2022). Monetary policy effectiveness in the advent of mobile money activity: Empirical evidence from Ghana. *Cogent Economics & Finance, 10*(1), 2039343.

World Bank Global Findex Database (2017), accessed 21 April 2022 <https://globalfindex.worldbank.org/index.php/#data_sec_focus>

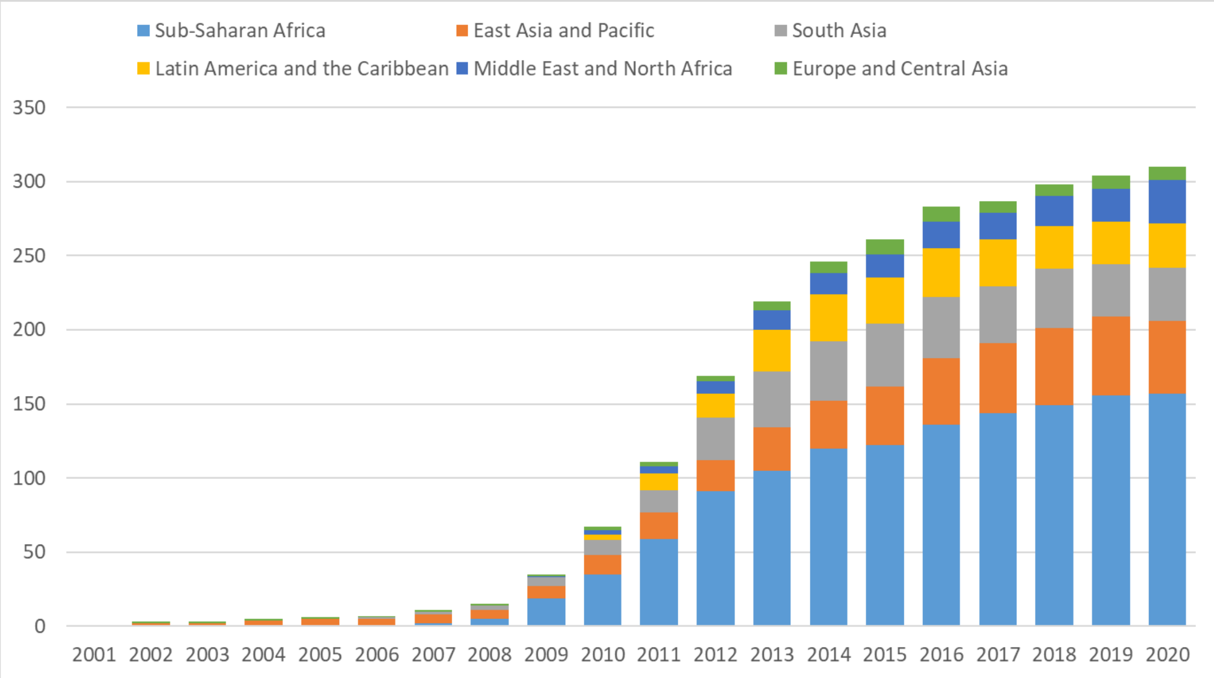
World Bank Group (2022), World Development Indicators, accessed 21 April 2022, <https://databank.worldbank.org/source/world-development-indicators>

Wynne, M. A. (1999). Core inflation: a review of some conceptual issues. Available at SSRN 355143.

Chapter 1 Appendices

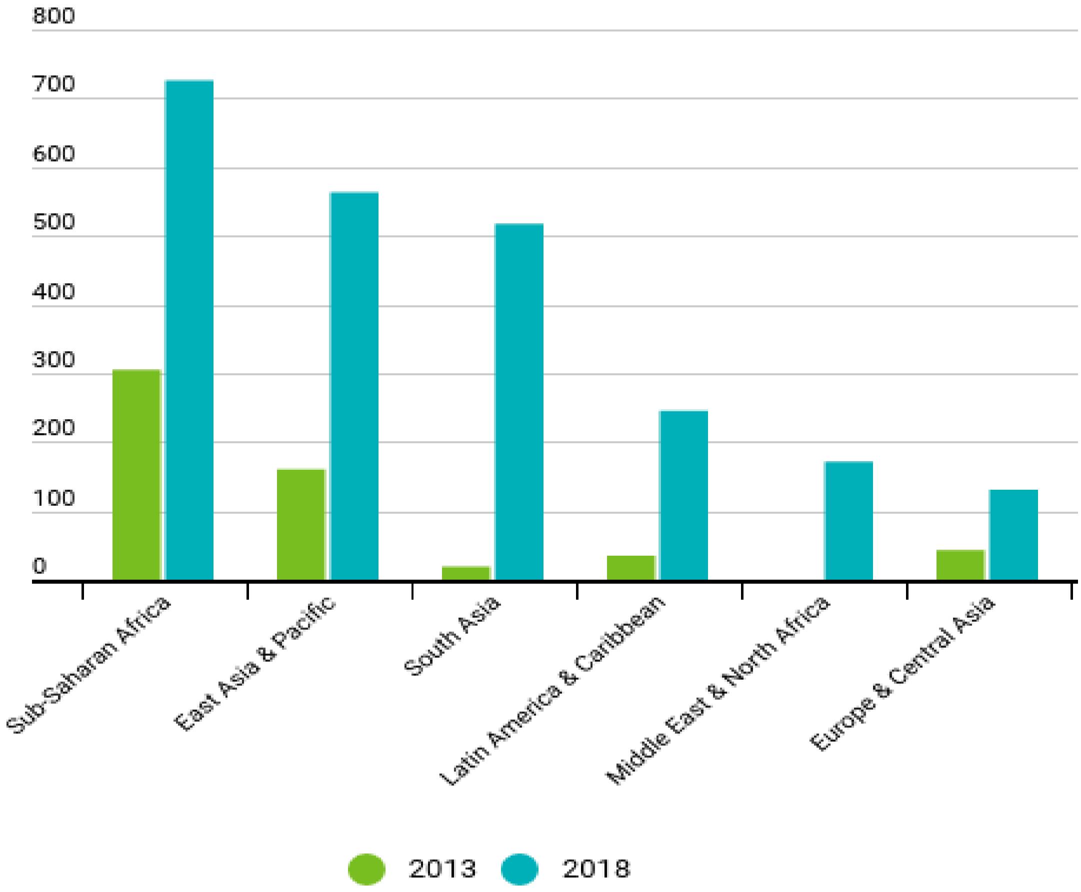
Appendix A: Figures

Figure A1: Evolution of global mobile money landscape – number of live services 2001 to 2020



Source: GSMA (2020)

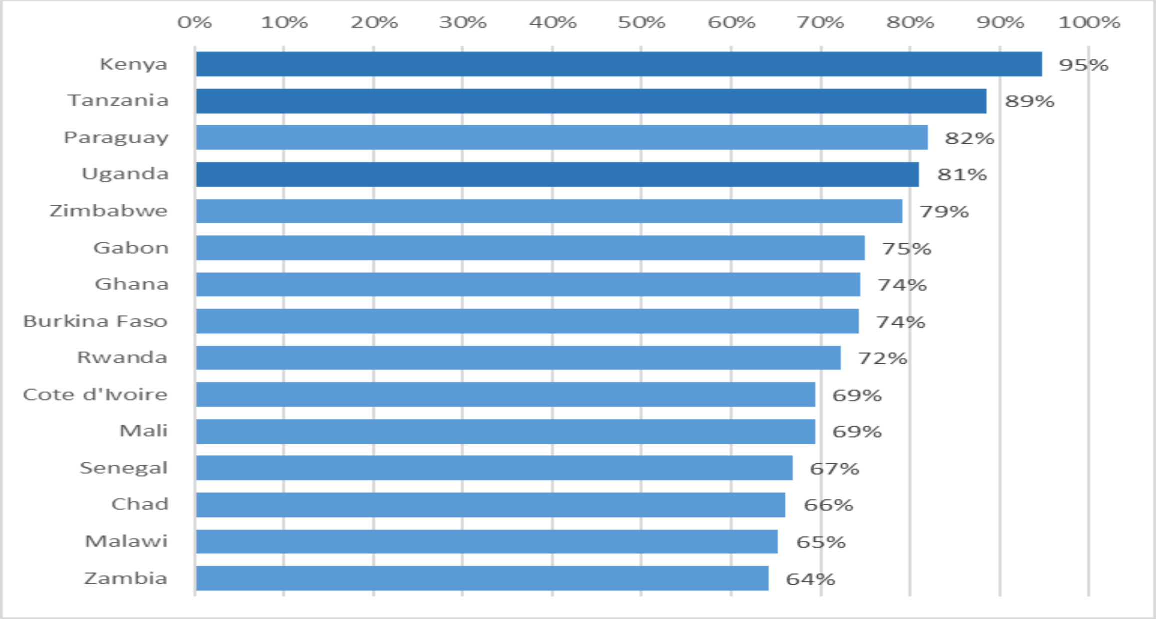
Figure A2: Registered mobile money accounts by region per 1,000 adults



Source: IMF, Financial Access Survey.

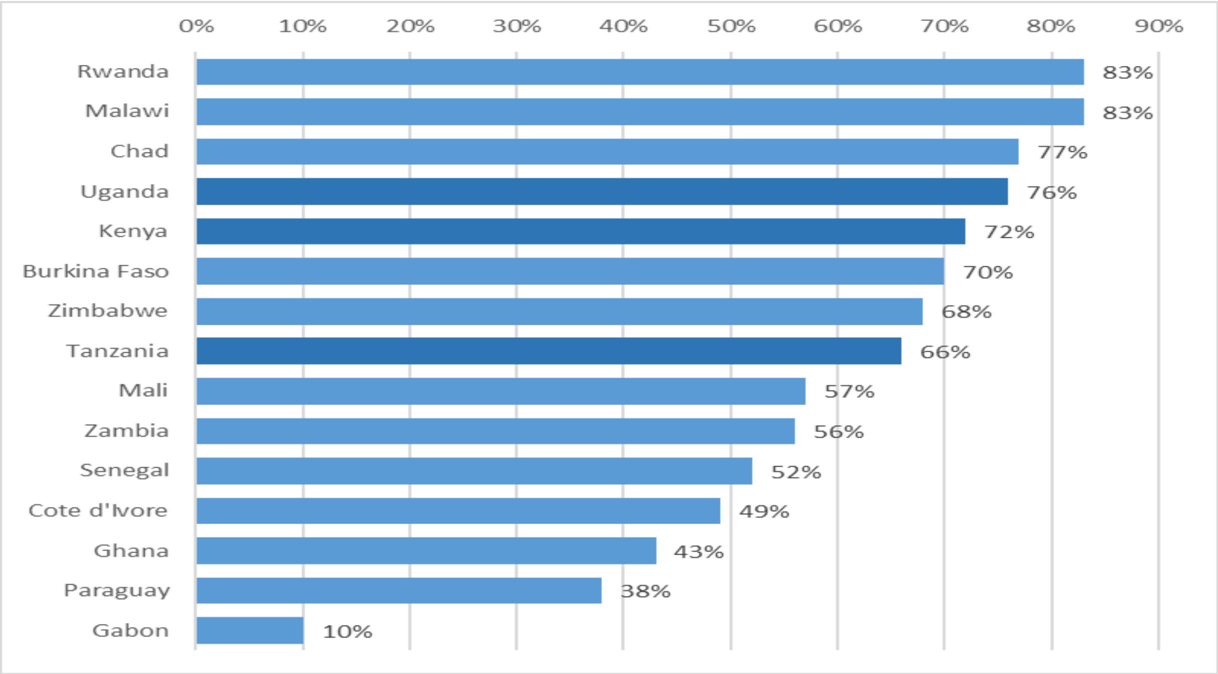
https://blogs.imf.org/2019/09/30/mobile-money-spreads-to-asia/

Figure A3: Top 15 countries with adult population receiving remittance through mobile phone in 2017



Source: Global Findex Database 2017

Figure A4: Proportion of population in the rural 2019 for the countries with highest population using mobile money in the world



Source: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=KE

Table A1: Tanzania timeline of mobile money related innovations and regulatory shocks

Year	Innovations on mobile money	Regulatory policy shocks
2005	Domestic VISA switch was introduced. This paved way for mobile financial services.	
2006		Amendment of the Bank of Tanzania (BOT) Act gave power to the National Payment Systems to act on the development of mobile money.
2007	Umoja switch was introduced *to facilitate interoperability across local banks.*	The BOT Guidelines for electronic payment systems were issued.
2008	1. E-Fulusi launched MobiPawa mobile money service. 2. Vodacom Tanzania launched M-Pesa mobile money service. 3. Zantel launched Z-Pesa mobile money service.	The BOT issued letters of no objection to the partner banks of Vodacom's M-PESA and Zantel's Z-Pesa allowing them to launch in 2008.
2009	Airtel launched Airtel-Money mobile money service.	Tanzania Communications Regulatory Authority (TCRA) passed a new know-your-customer (KYC) regulation requiring registration for all new and existing SIM cards.
2010	Tigo launched Tigo-Pesa mobile money service.	Non-exclusivity use of mobile network operator (MNO) agents was introduced such that one agent could represent multiple MNOs. This increased efficiency at agency level.
2012	1. Zantel relaunched its mobile money platform Z-Pesa, as Ezy-Pesa. 2. Vodacom introduced CARE scheme with Mwanga Community Bank to enable village saving and loans associations to open interest bearing saving accounts and deposit money through M-Pesa, without having to visit a bank branch.	
2015		The National Payment Systems (NPS) Act was developed NPS E-money regulations were issued.

2016	Mobile money interoperability rules were developed, giving rise to the first mobile money interoperability in Africa.	
2020		1. The BOT increased mobile money operators' daily transaction limit to customers from TZS 3.0 million to TZS 5.0 million, and daily balance from TZS 5.0 million to TZS 10.0 million, respectively. The purpose of this measure was to encourage customers to use digital payment platforms for transactions, amidst Covid-19 pandemic. 2. The BOT restricted issuance of electronic money license only to licensed mobile network operators (MNOs), with a view to strengthening the oversight and stability of the financial system. The restriction does not apply to banks and non MNOs entities already issued with electronic money issuance license.

Source: Di Castri and Gidvani, 2014; FSDT, 2018.

Table A2: Kenya timeline of mobile money related innovations and regulatory shocks

Year	Innovations on mobile money	Regulatory policy shocks
2005	1. The Kenya Electronic Payment and Settlement System (KEPSS) was established. 2. M-pesa pilot project started in Thika, north east of Nairobi.	
2006	1. M-pesa pilot project ended. 2. M-pesa changes to money transfer instead of microfinance.	
2007	Safaricom launched M-PESA mobile money services	Central Bank of Kenya (CBK) issued a Letter of no objection to Safaricom to establish mobile money service.

2008	M-pesa began to facilitate bill payments and bulk salary payments.	
2009	1. Airtel Networks Kenya launched Airtel-Money mobile money services. 2. Safaricom partnered with Kenya power to allow customers to pay electricity bills via m-pesa.	
2010	Telcom Kenya Ltd. launched T-Kash mobile financial services.	Kenya passed agent banking regulations that let banks compete directly with the existing M-PESA network.
2011	M-Shwari launched. This is a popular mobile phone–bank account operation with CBA, through M-PESA.	National Payment Systems (NPS) Act was passed by the parliament.
2014		1. National Payment System Act commencement was announced. 2. National Payment System Regulations were issued.
2013	Safaricom launched a product called Lipa-na-M-PESA that encourages retail payments over the M-PESA platform.	
2018	Person-to-person mobile money interoperability across MNOs was launched.	

Sources: Kenya's Payments Journey February 2023; Central Bank of Kenya, National Payment Strategy, 2022 – 2025; Muthiora (2015).

Table A3: Uganda timeline of mobile money related innovations and regulatory shocks

Year	Innovations on mobile money	Regulatory policy shocks
2009	MTN Uganda launched MoMo mobile money services.	The Bank of Uganda (BOU) issued a no-objection letter to Uganda's first mobile money service provider.
2010	Uganda Telecom Ltd launched M-Sente mobile money service.	
2011		BOU issued enhanced no objection letter to mobile money service providers.
2012	1. Warid Telecom launched Warid-Pesa mobile money services.	

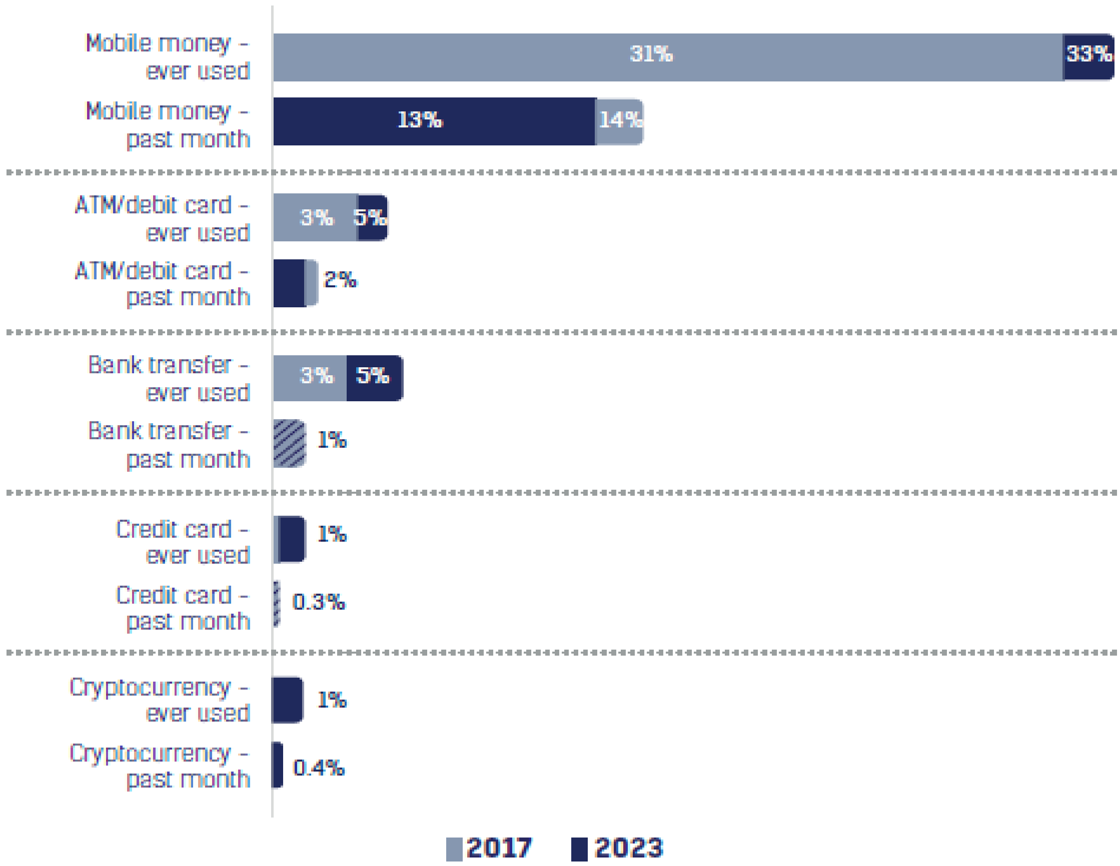
	2. MCash joined the mobile money market.	
2013	Orange Uganda launched Orange-money mobile money services.	BOU issued mobile money guidelines.
2016	1. Micropay electronic payment platform launched operations. 2. MTN Uganda, in partnership with Commercial Bank of Africa, introduced a savings and loan product. 3. Mokash was made accessible through a mobile phone.	Financial Institutions Act was amended to permit agent banking, Bancassurance and Islamic banking.
2017		Agent banking regulations issued.
2018	1. Uganda Bankers' Association launched a shared agent platform/switch to facilitate access to bank agents. 2. Banks rolled out agent networks across the country. 3. Mobile money inter-operability was launched among MNOs.	

Sources: Uganda's journey to inclusive finance through digital financial services (2018),
< https://www.paymenteye.com/2013/01/18/orange-launches-mobile-money-service-in-uganda/ >

Chapter 2 Appendices

Appendix B: Figures

Figure B1: Digital payment instruments used to purchase goods in Tanzania, all adults



Source: FinScope Tanzania (2023).

Appendix C: Selected impulse response results for Chapter 2

Model 1 comparison of IRR with MSR, farming shock IRFs

Figure C1A: Production at consumer price, response to farming shock

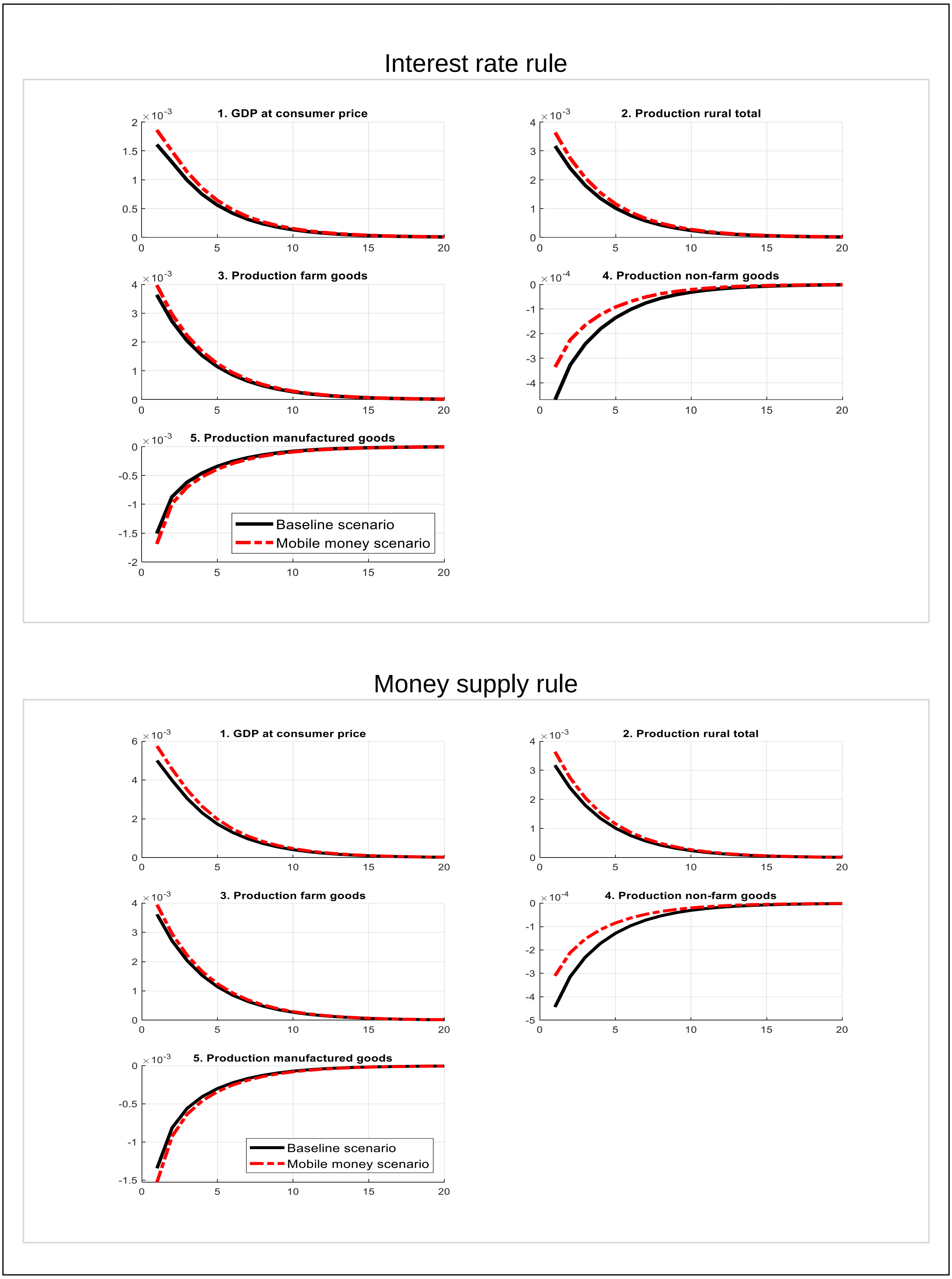


Figure C1B: Production at factor cost, response to farming shock

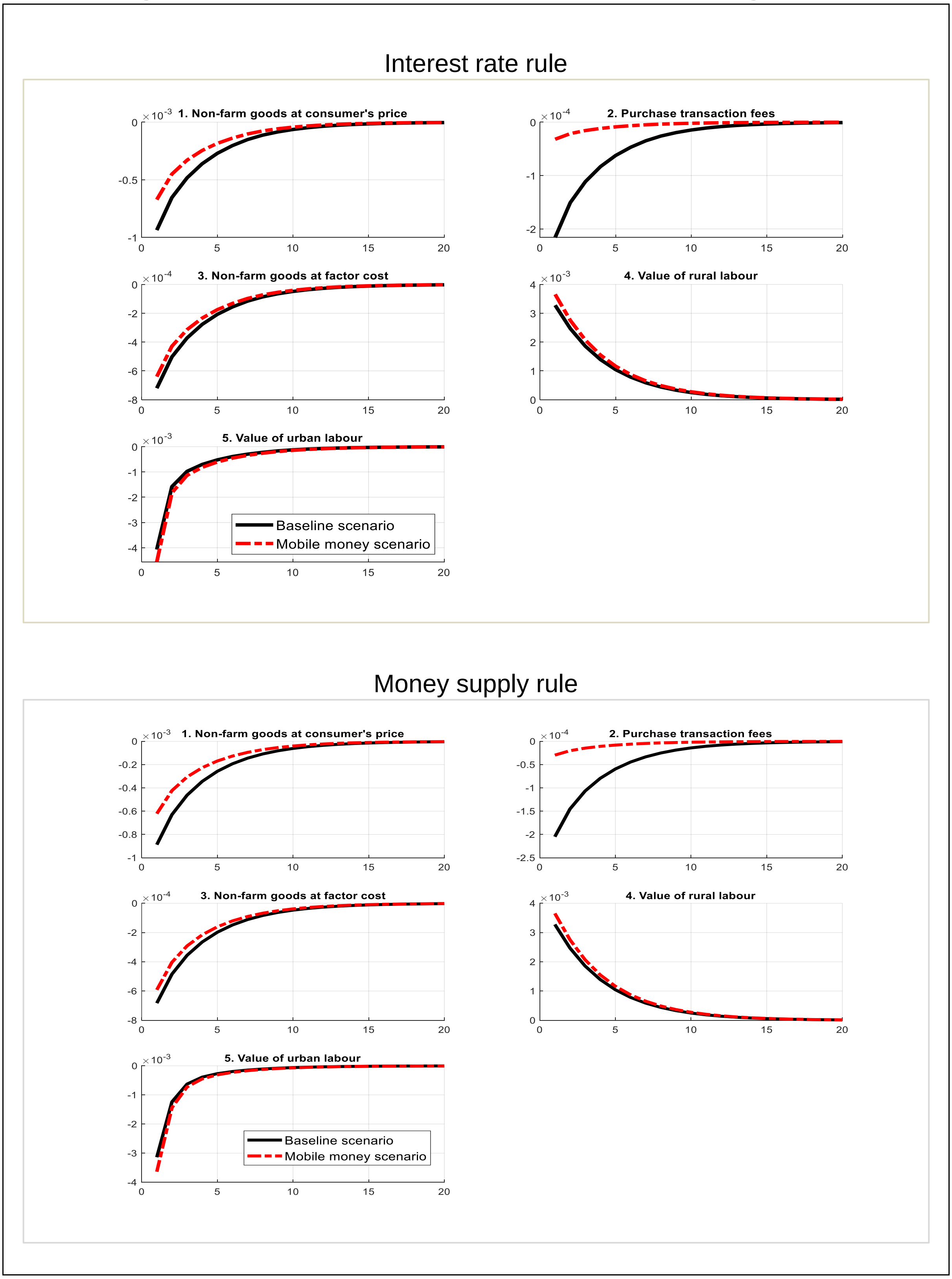


Figure C1C: Consumption and welfare, response to farming shock

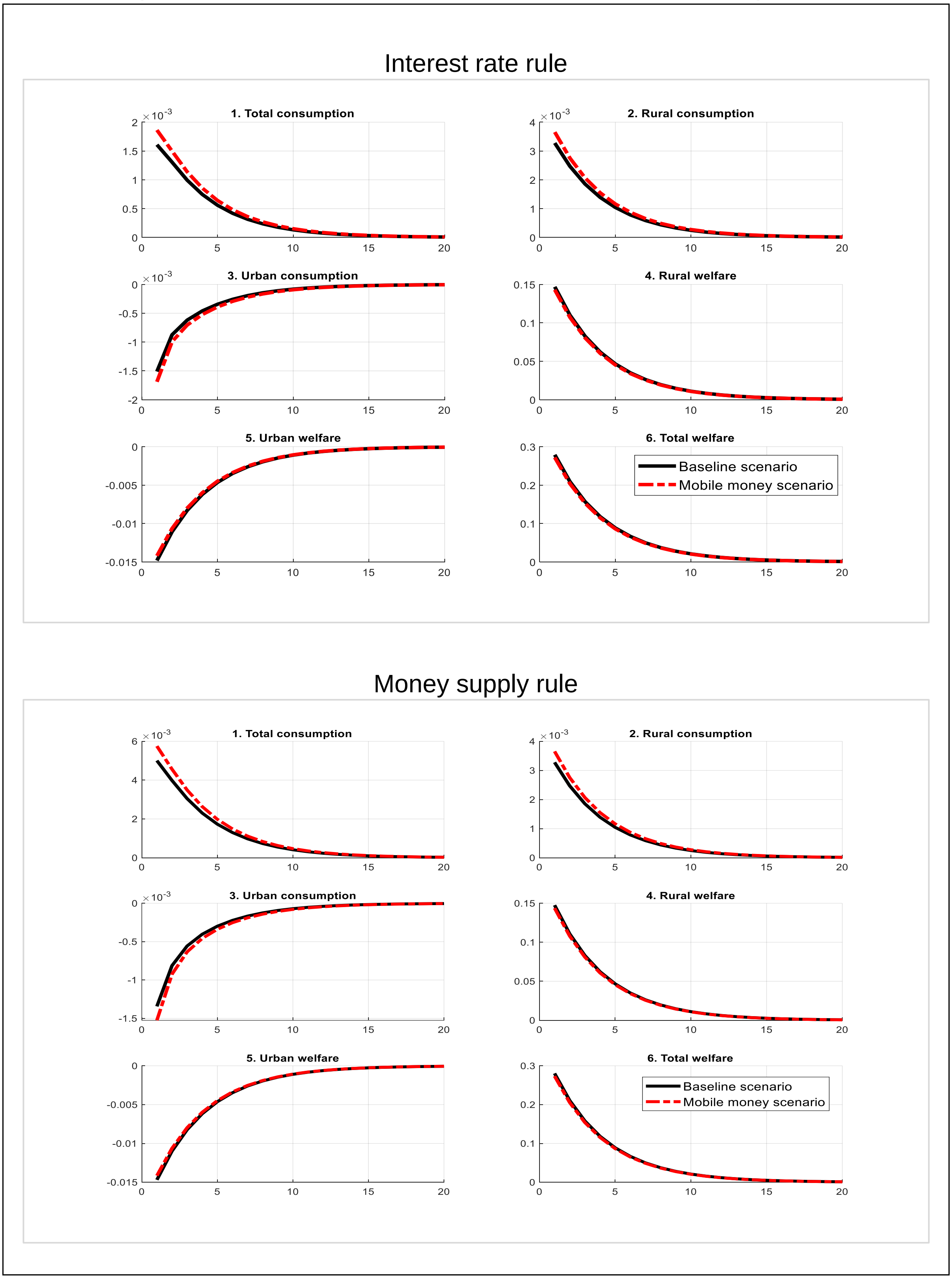


Figure C1D: Labour supplied, response to farming shock

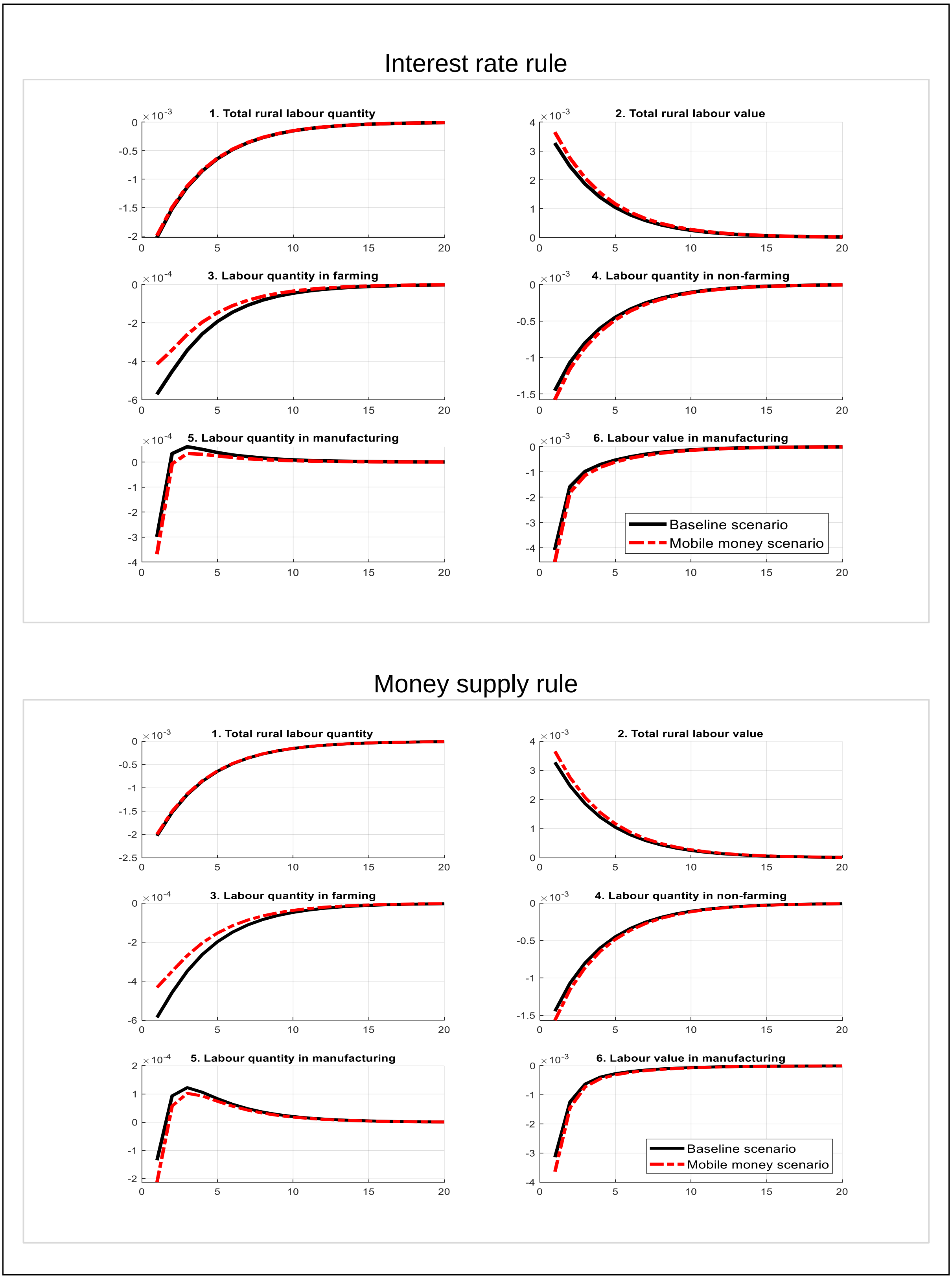


Figure C1E: Labour earning, response to farming shock

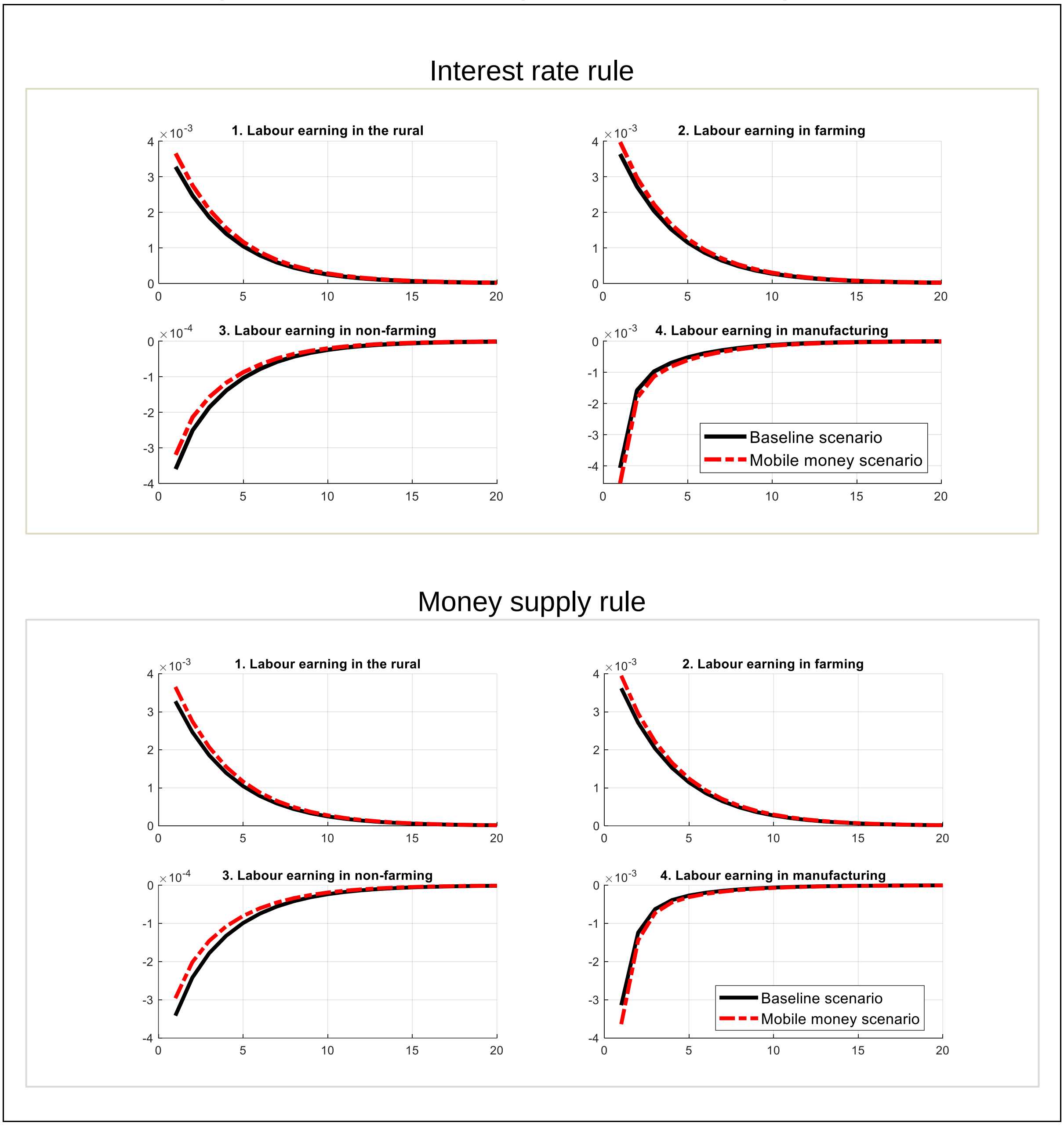


Figure C1F: Relative prices, response to farming shock

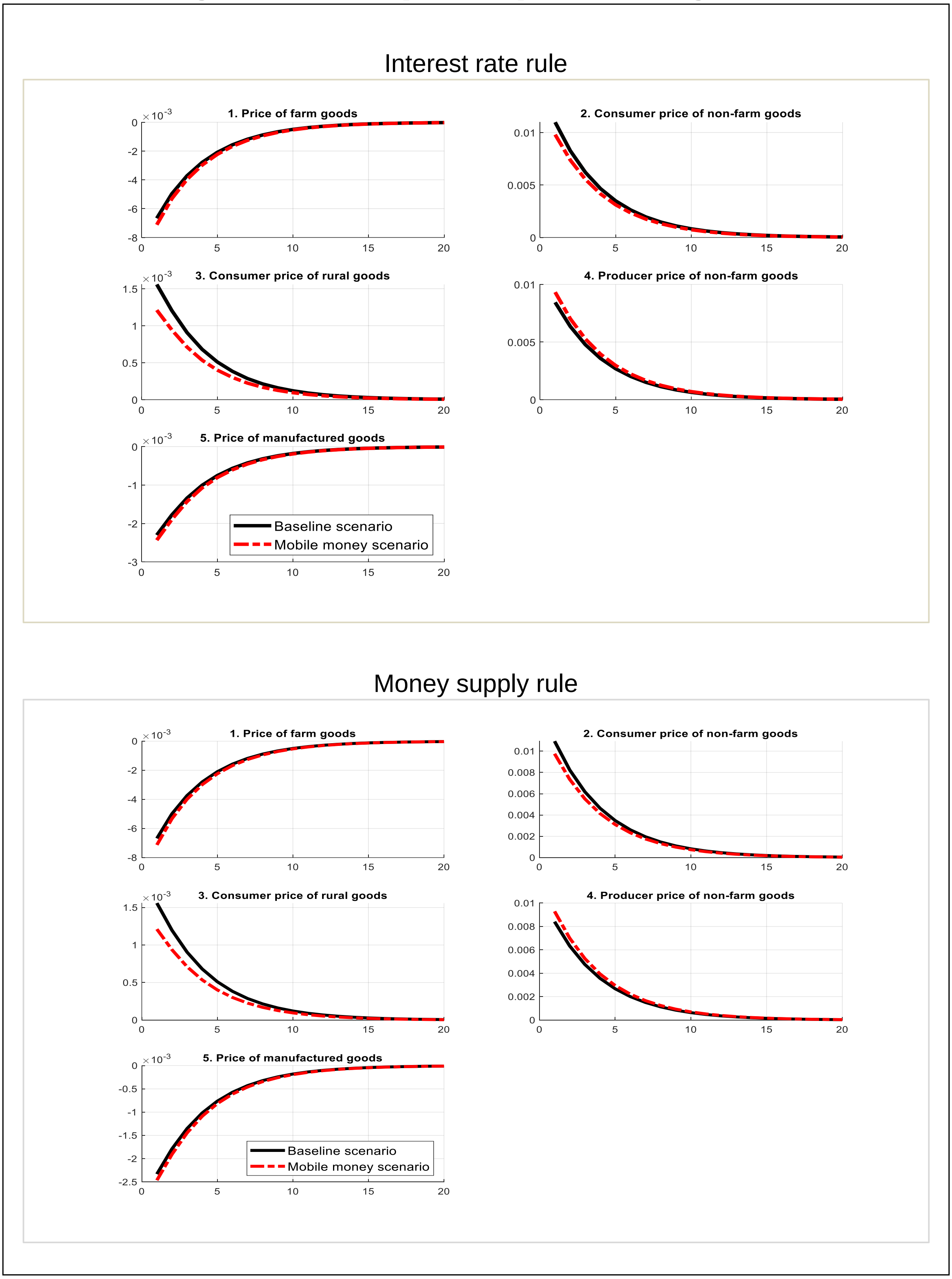


Figure C1G: Wage price ratios, response to farming shock

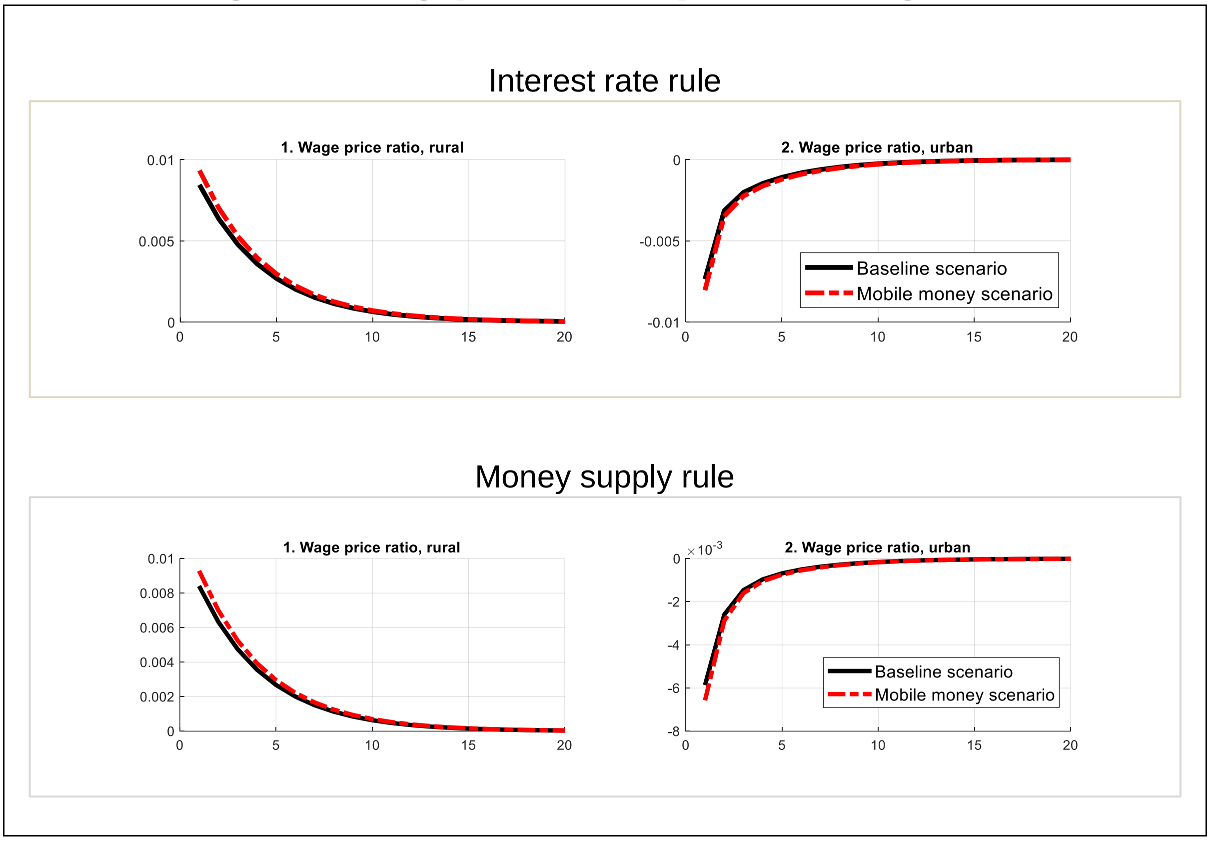
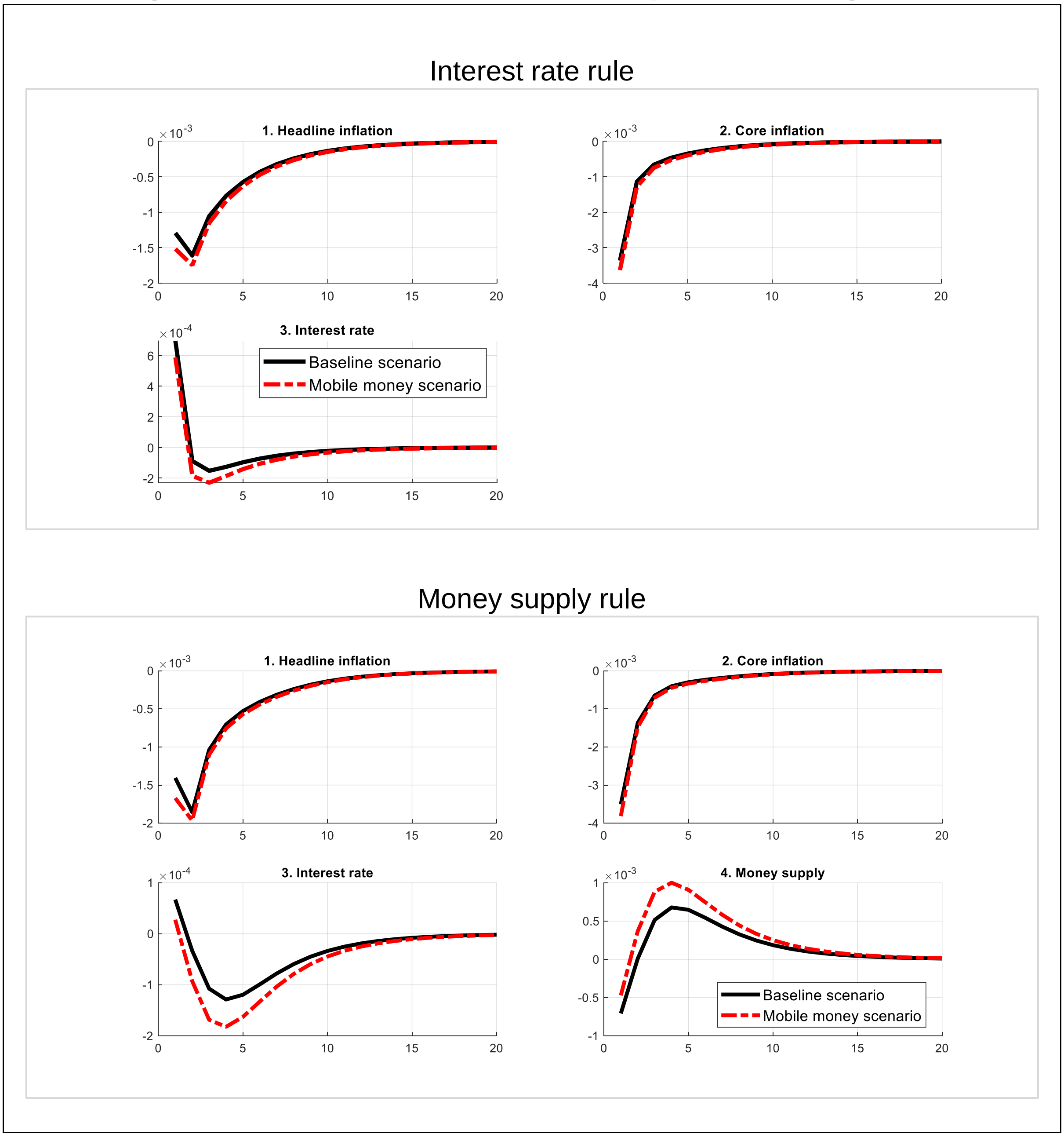


Figure C1H: Inflation and interest rate, response to farming shock



Model 1 comparison of IRR with MSR, non-farming shock IRFs

Figure C2A: Production at consumer price, response to non-farming shock

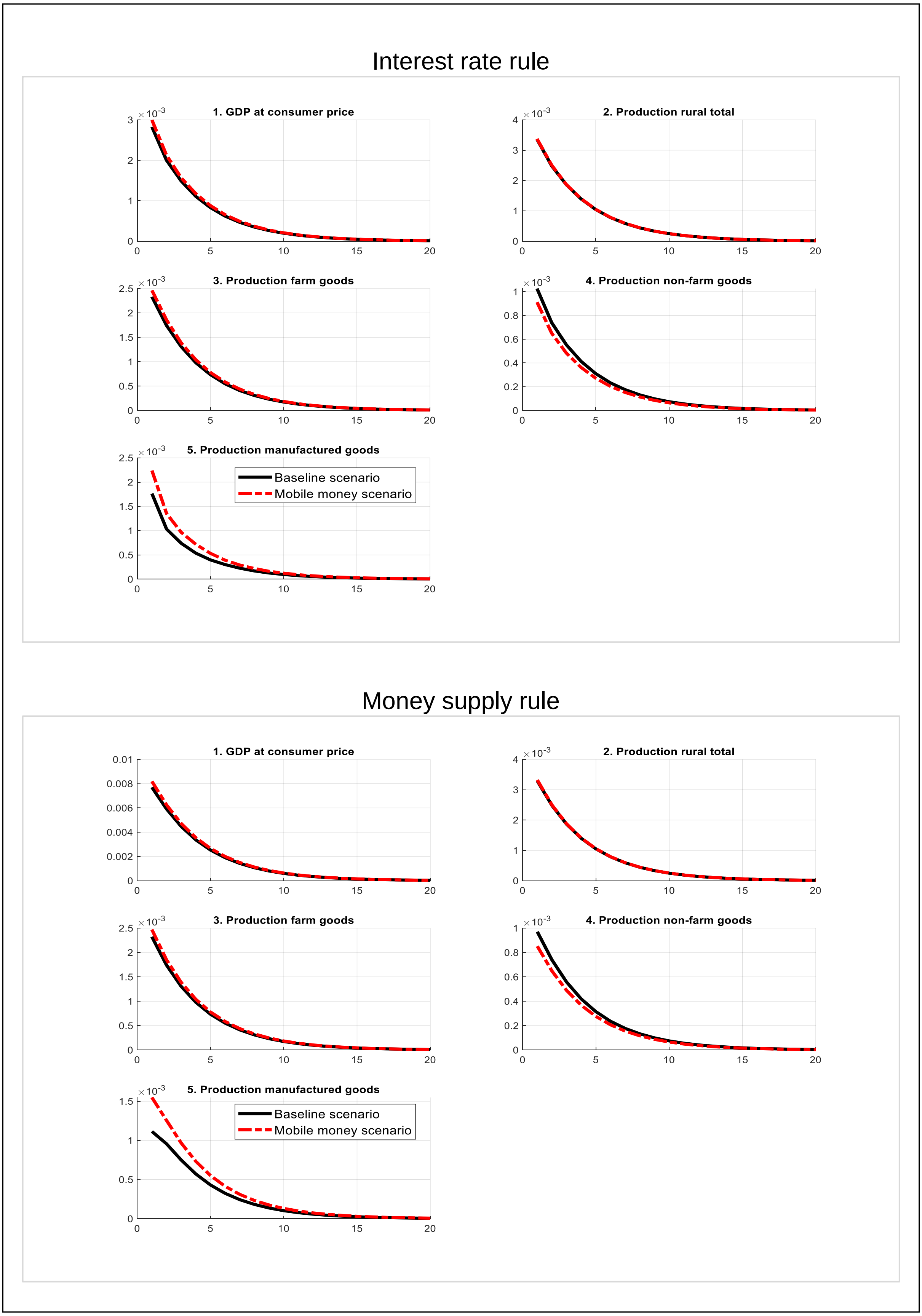


Figure C2B: Production at factor cost, response to non-farming shock

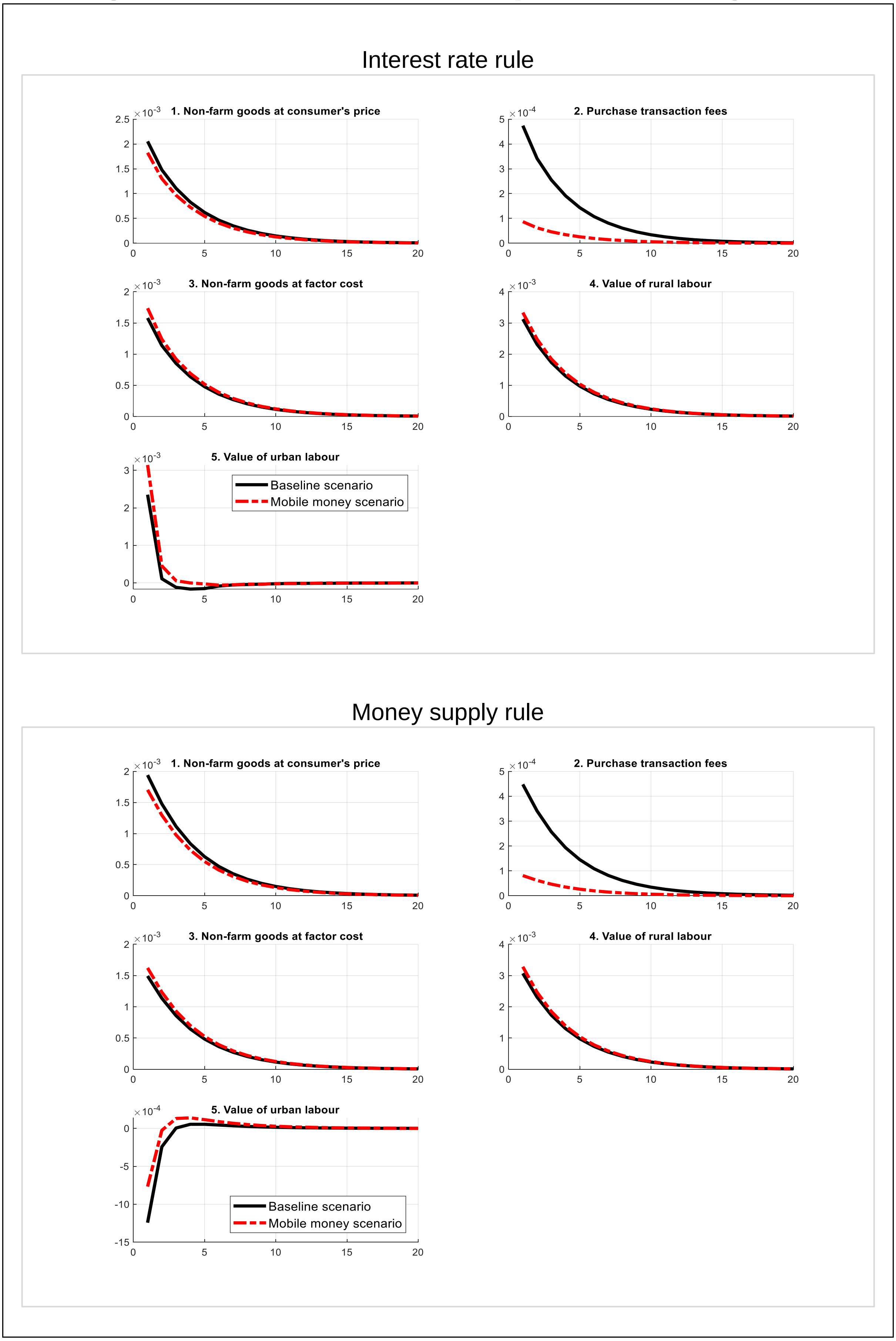


Figure C2C: Consumption and welfare, response to non-farming shock

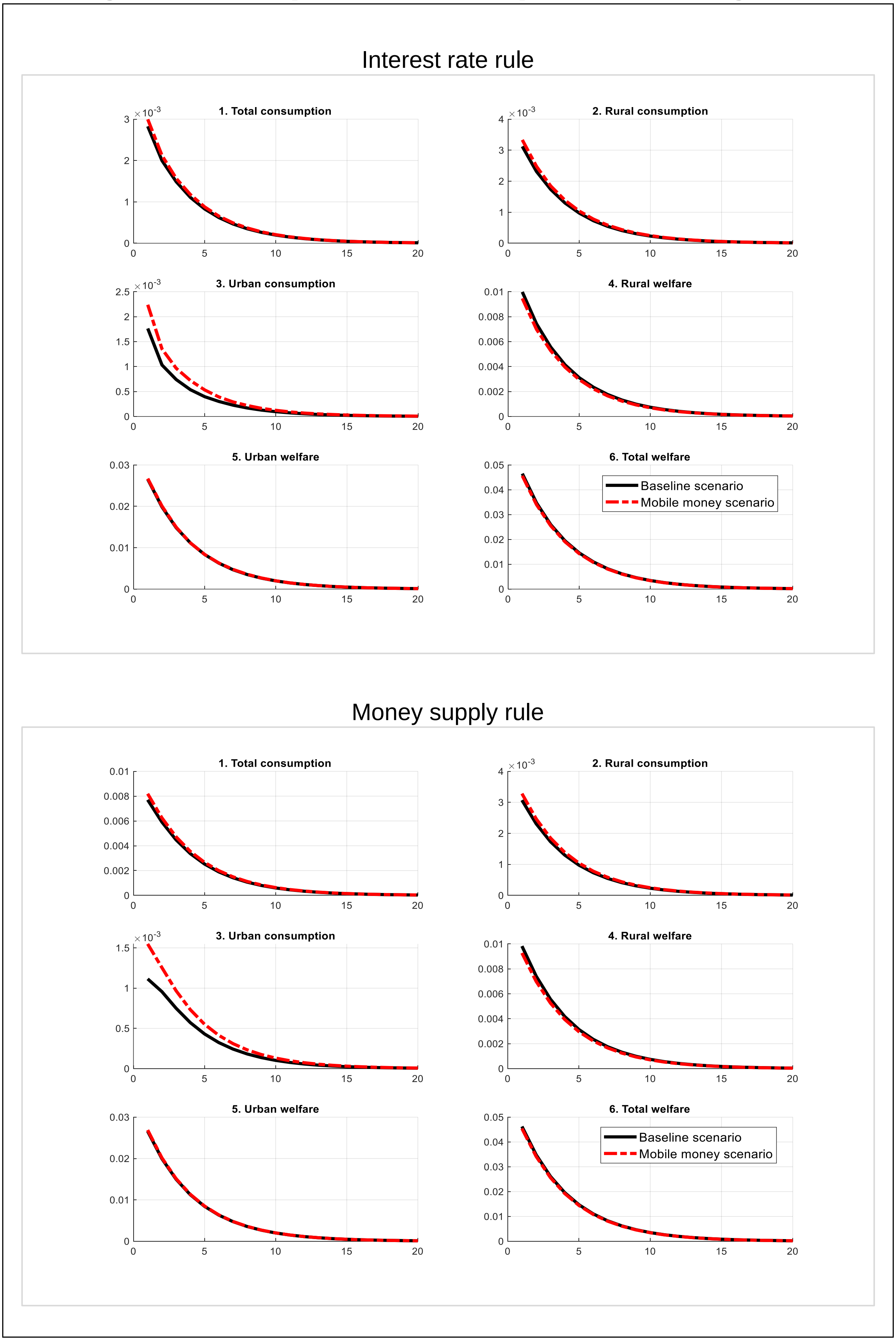
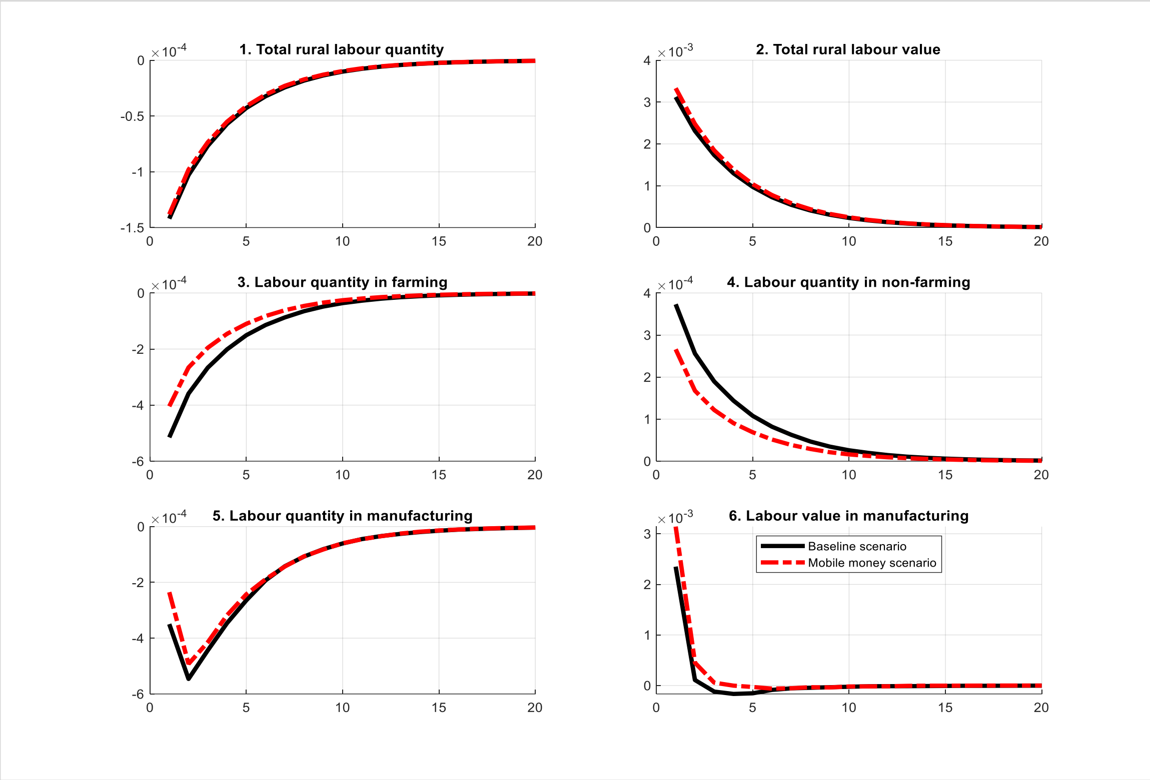


Figure C2D: Labour supplied, response to non-farming shock

Interest rate rule



Money supply rule

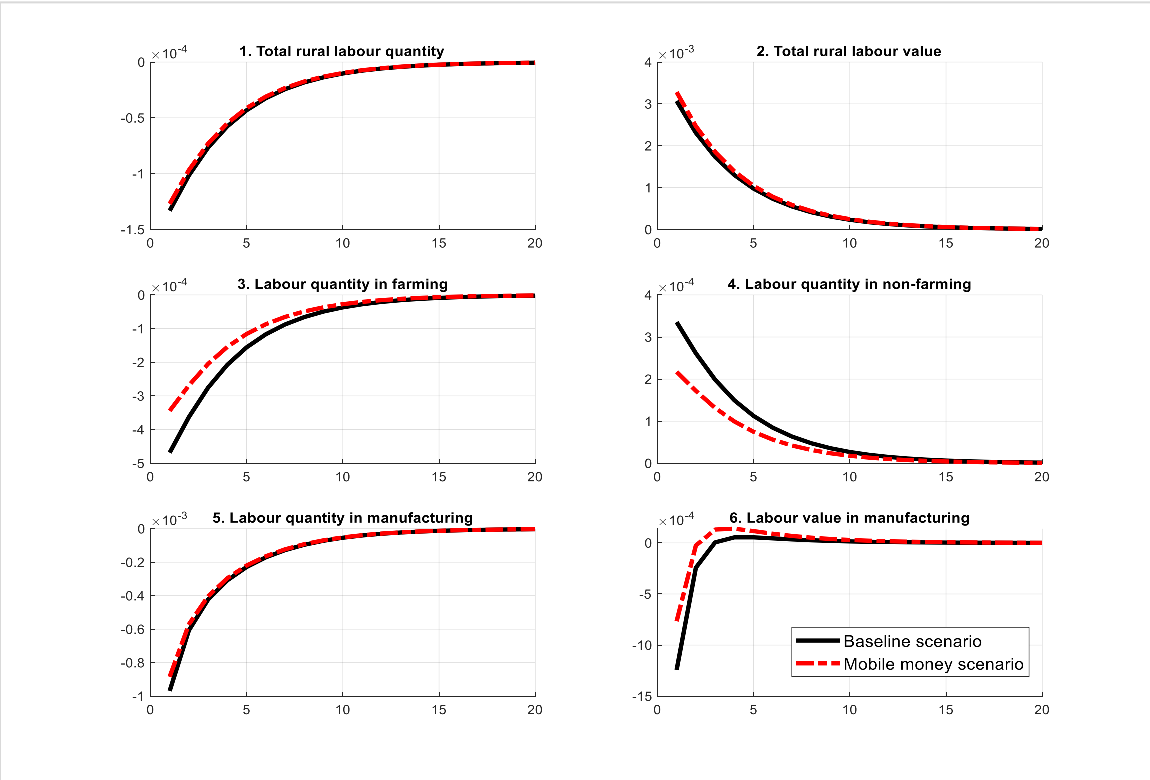


Figure C2E: Labour earning, response to non-farming shock

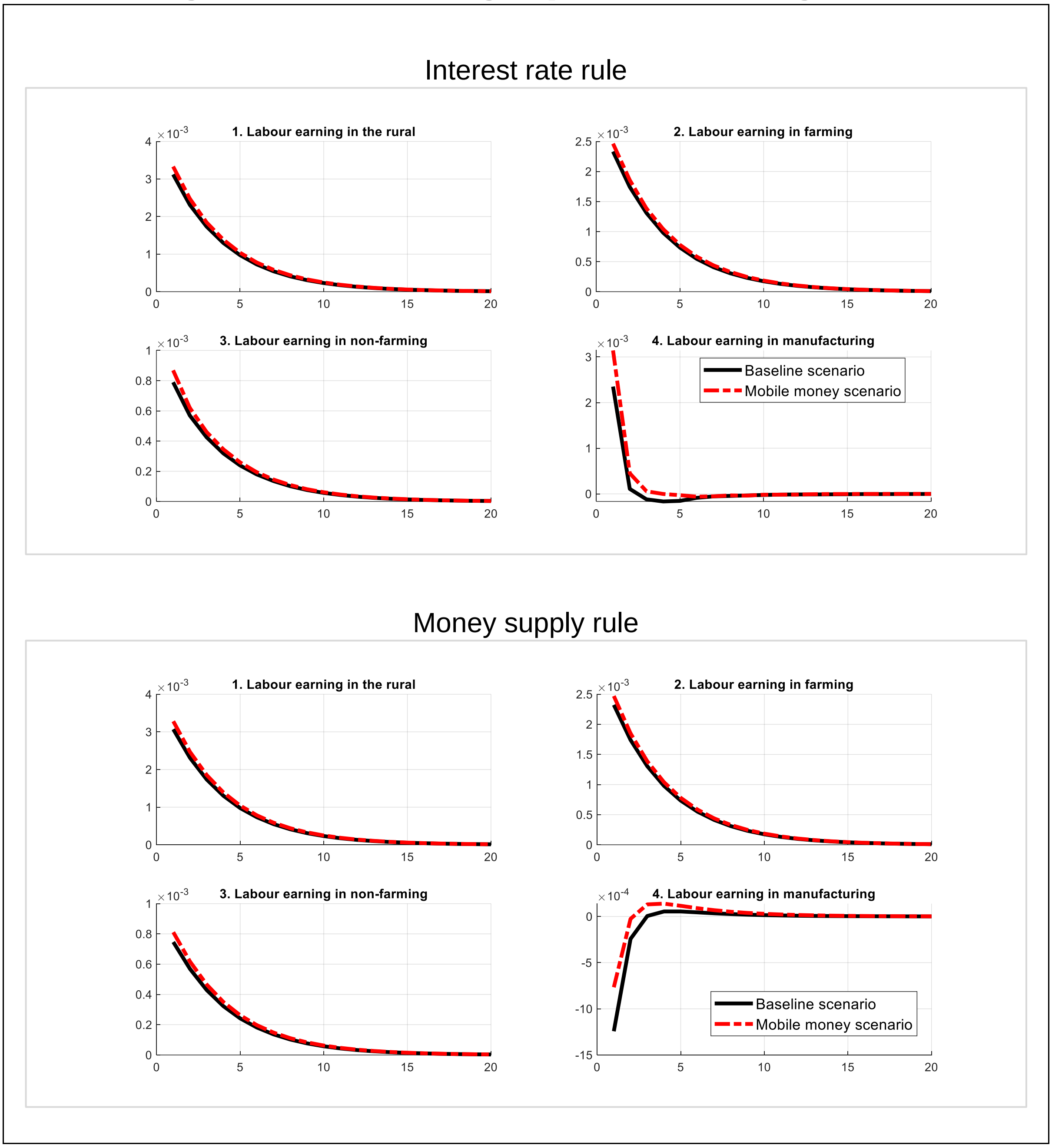


Figure C2F: Relative prices, response to non-farming shock

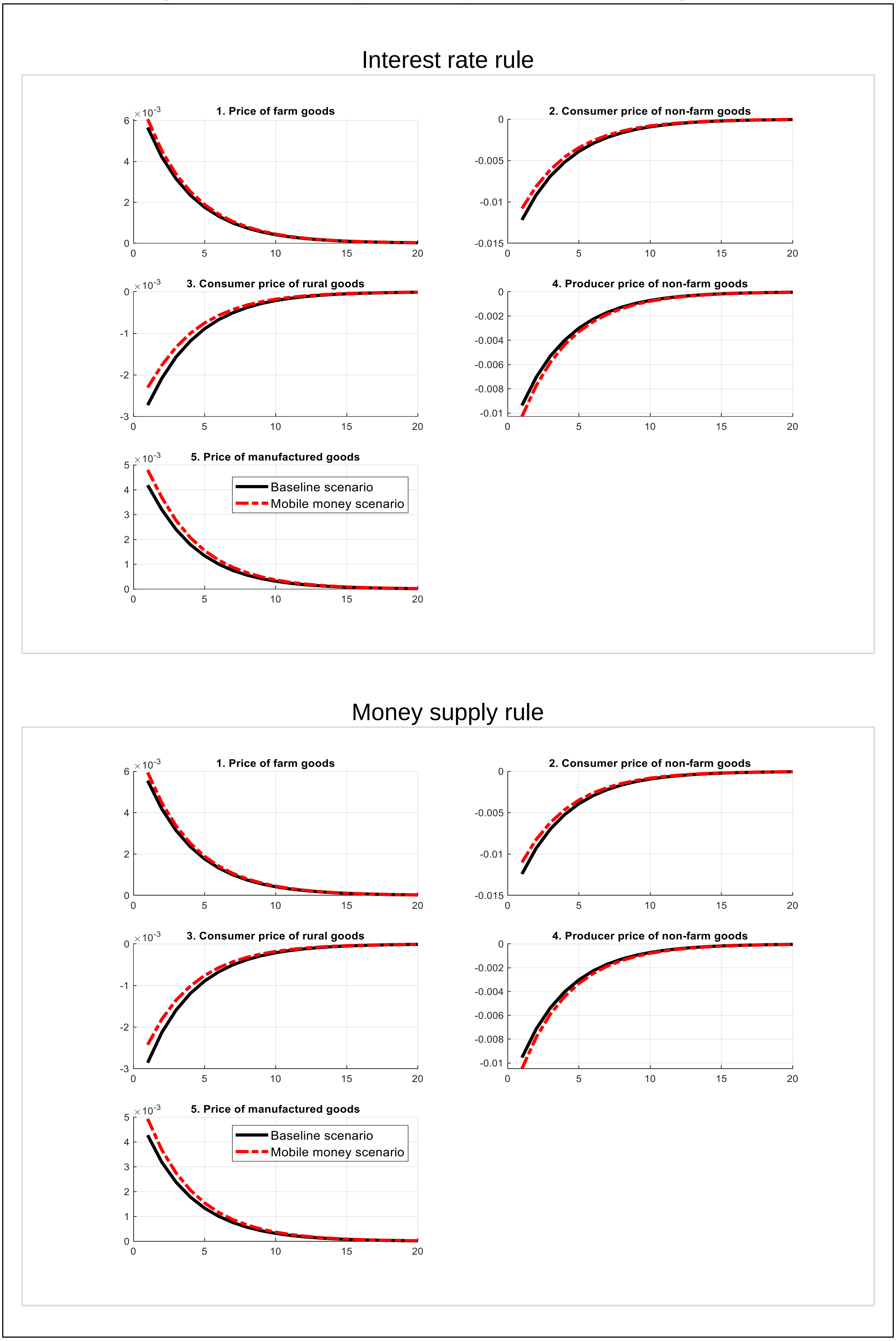


Figure C2G: Wage price ratios, response to non-farming shock

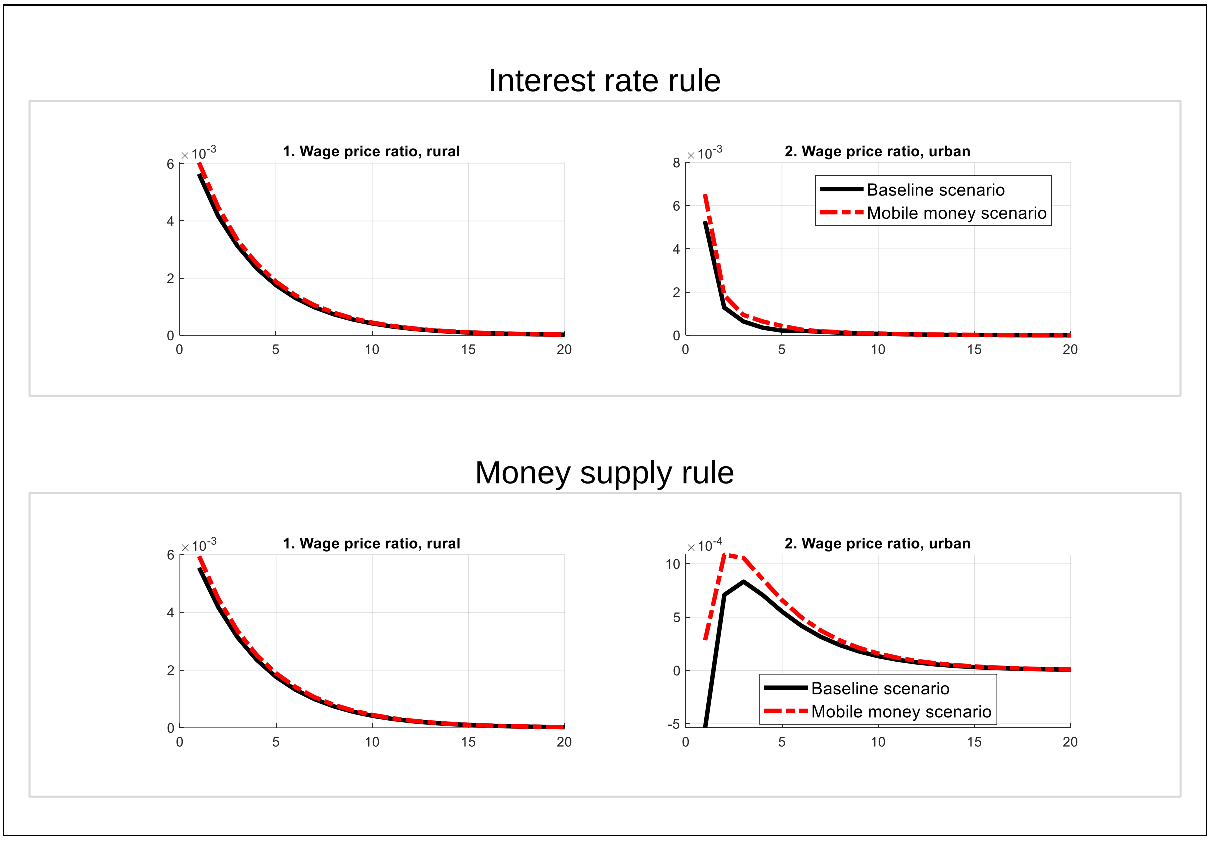
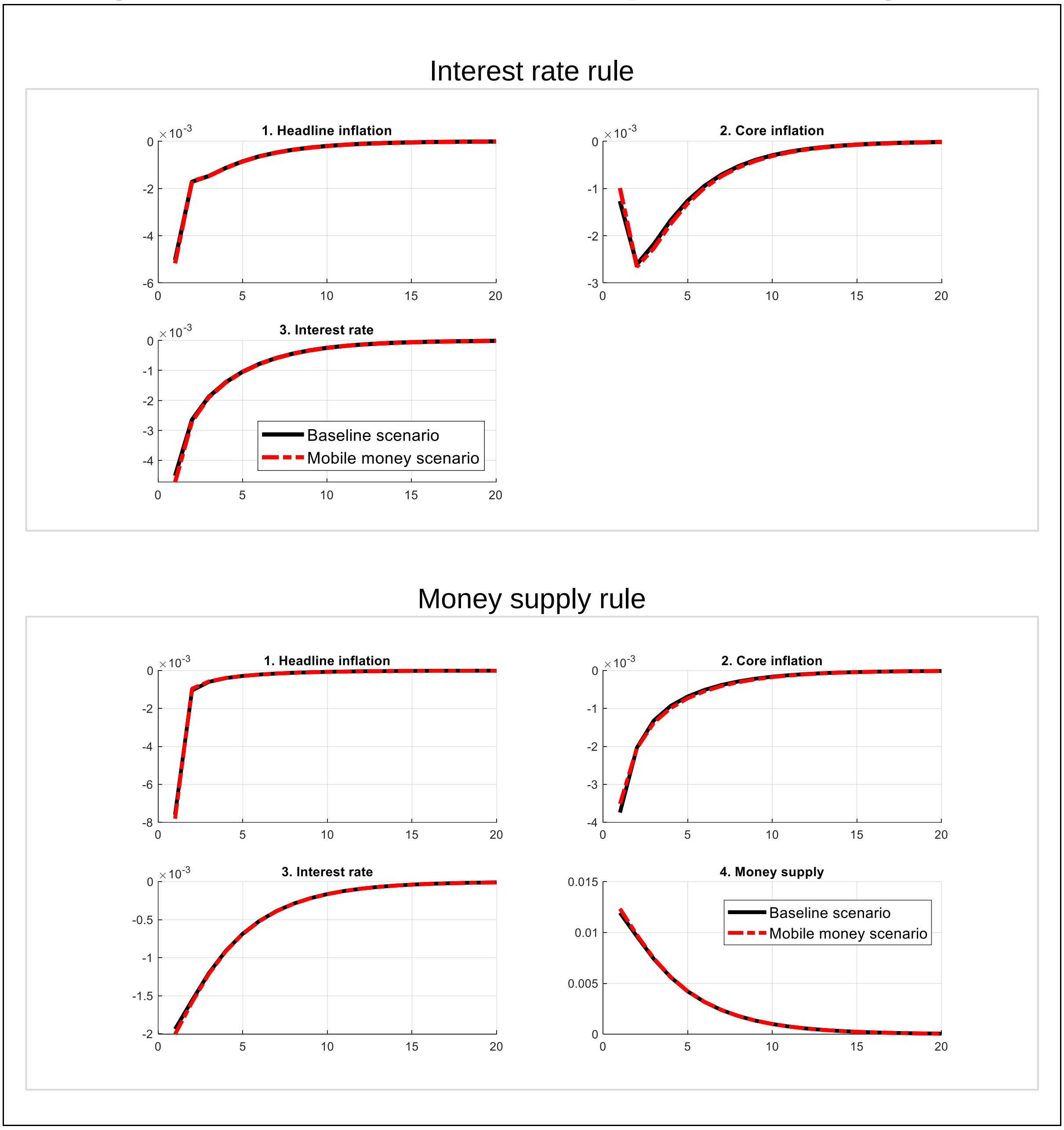


Figure C2H: : Inflation and interest rate, response to non-farming shock



Model 1 comparison of IRR with MSR, manufacturing shock IRFs

Figure C3A: Production at consumer price, response to manufacturing shock

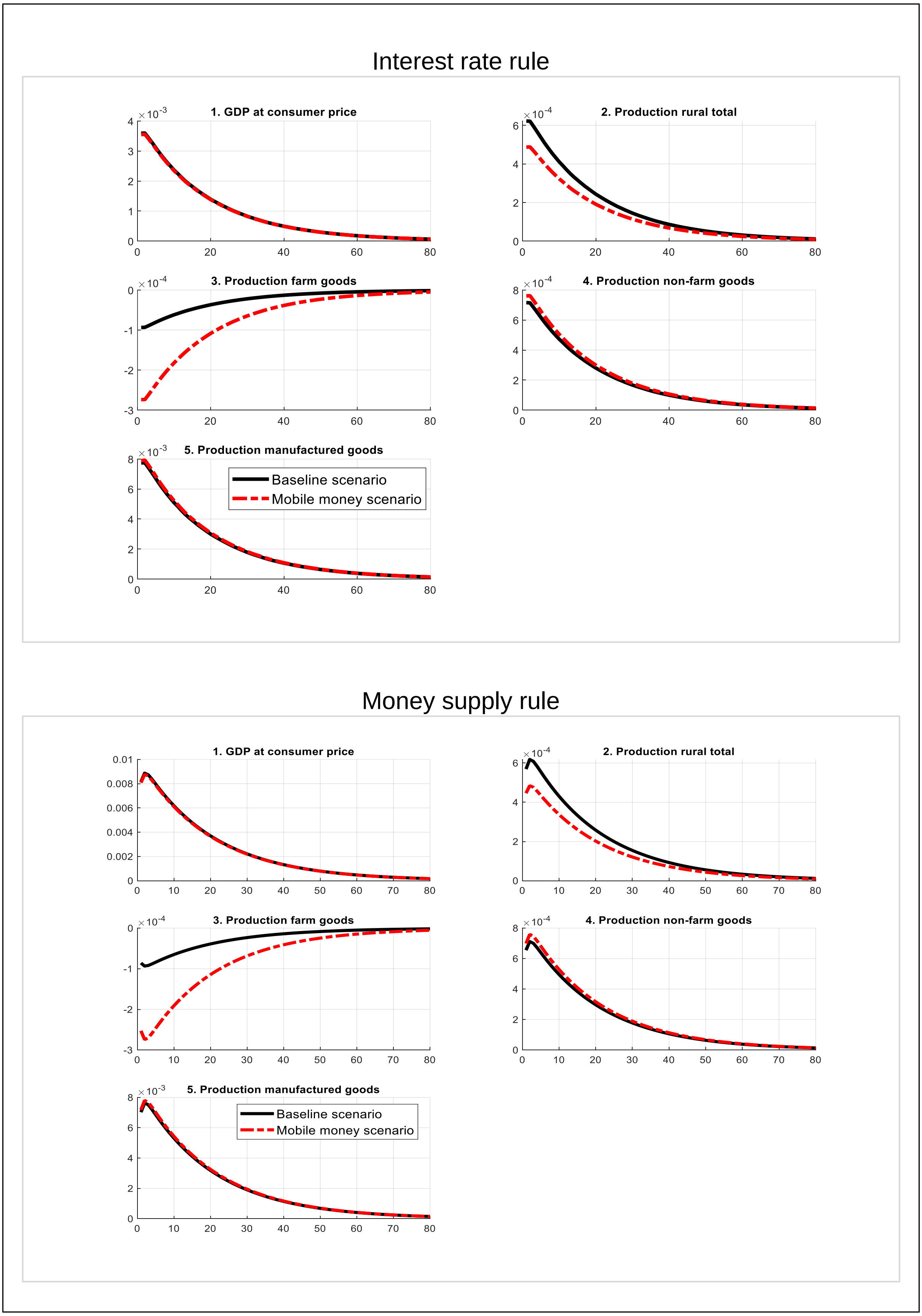


Figure C3B: Production at factor cost, response to manufacturing shock

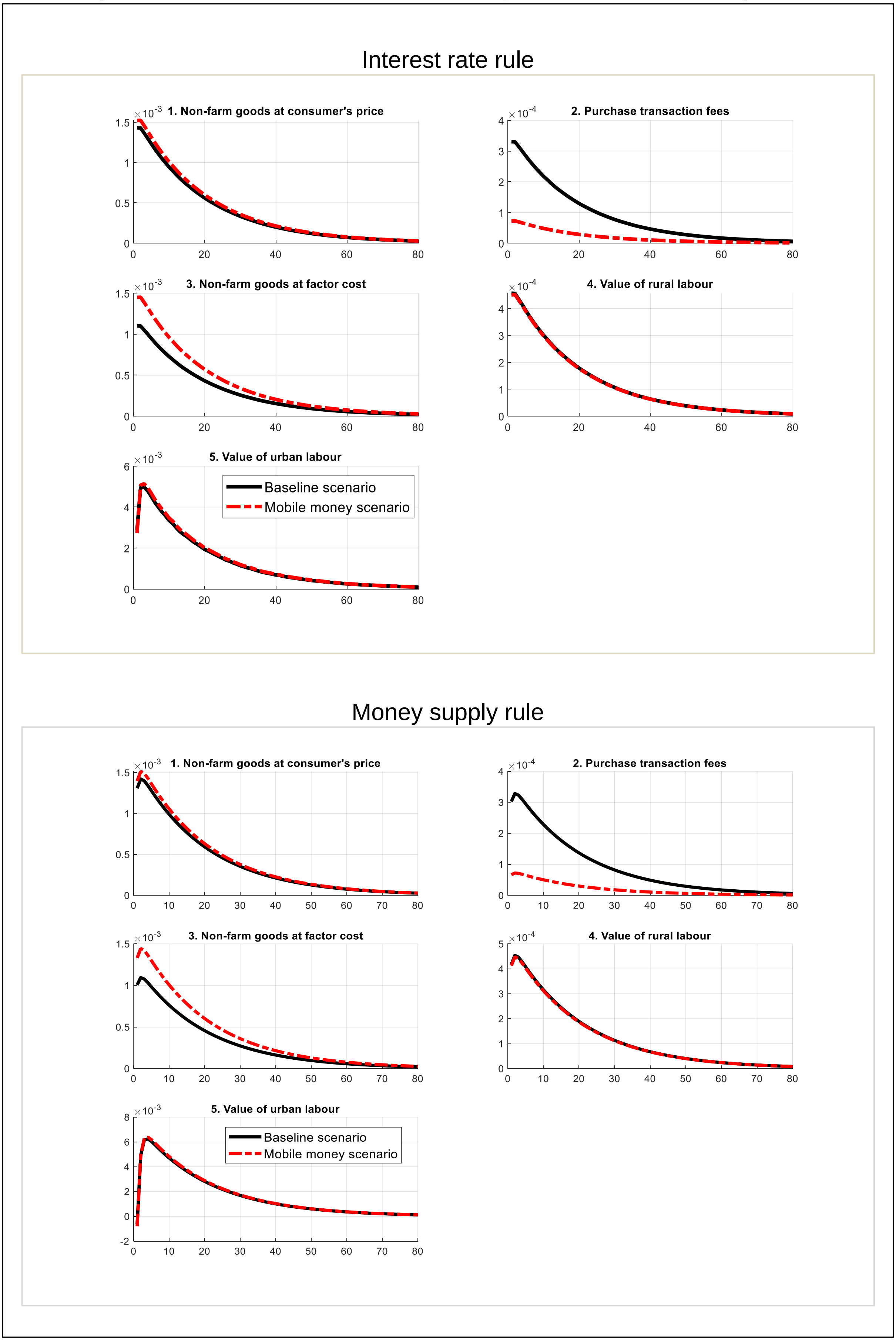


Figure C3C: Consumption and welfare, response to manufacturing shock

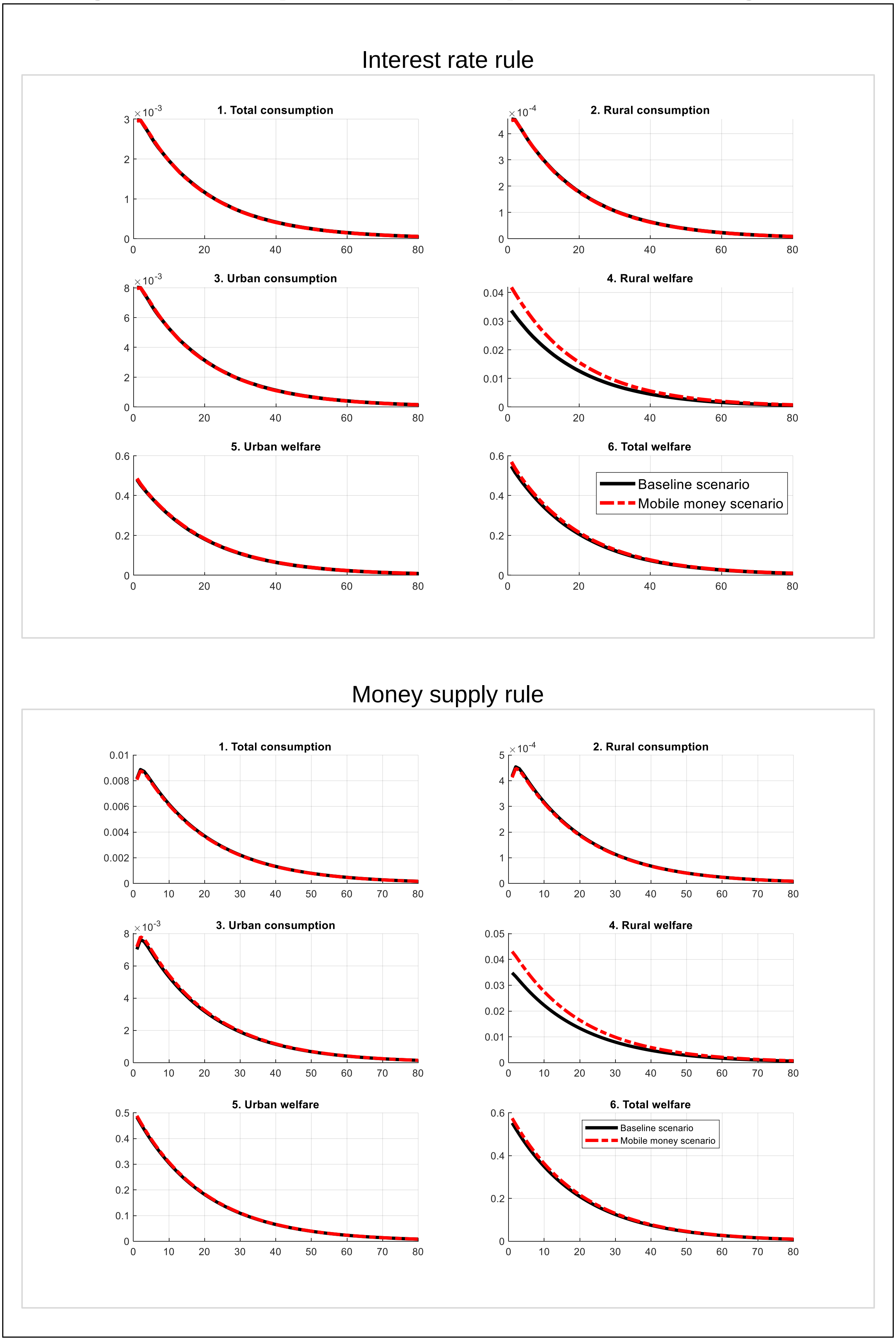


Figure C3D: Labour supplied, response to manufacturing shock

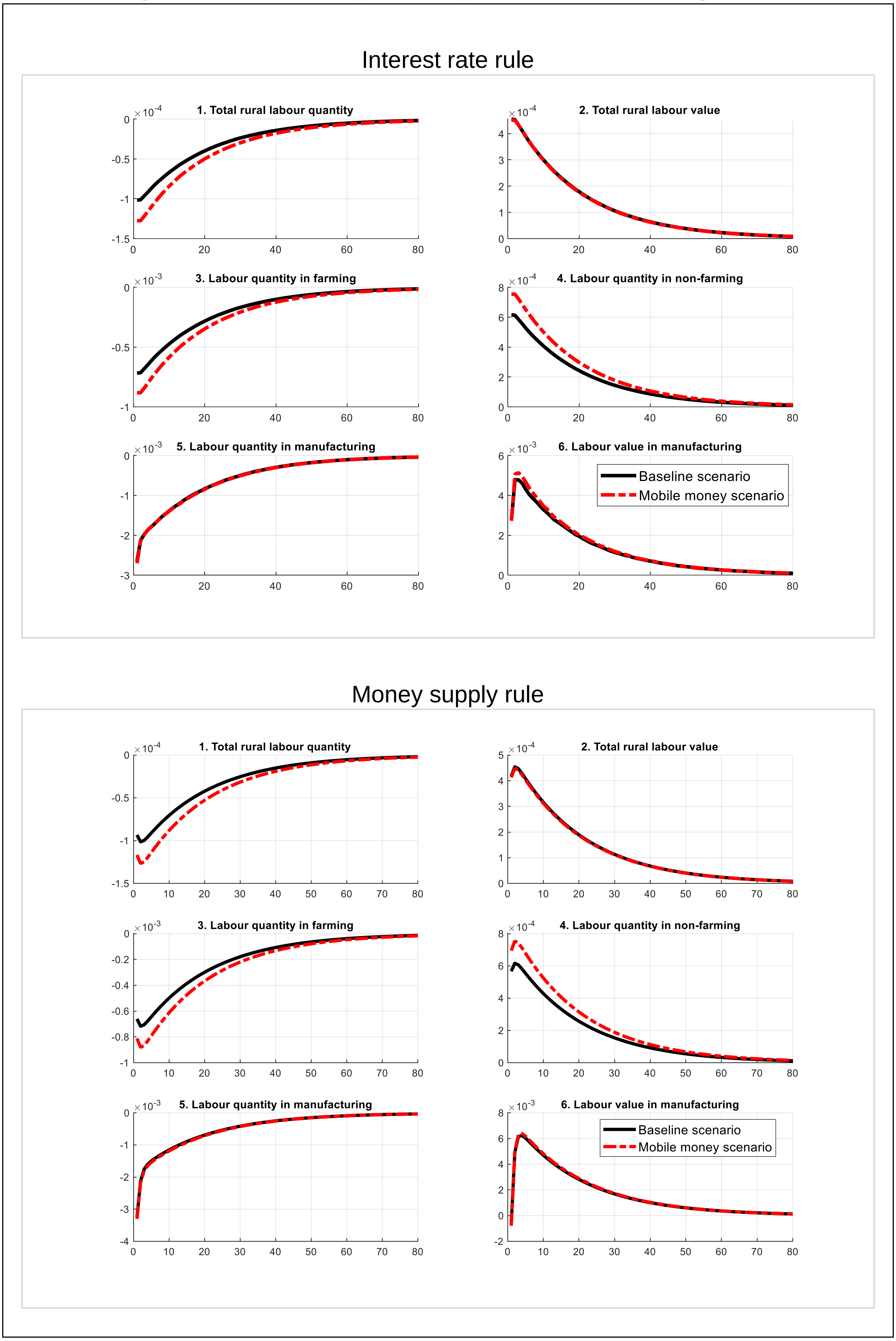


Figure C3E: Labour earning, response to manufacturing shock

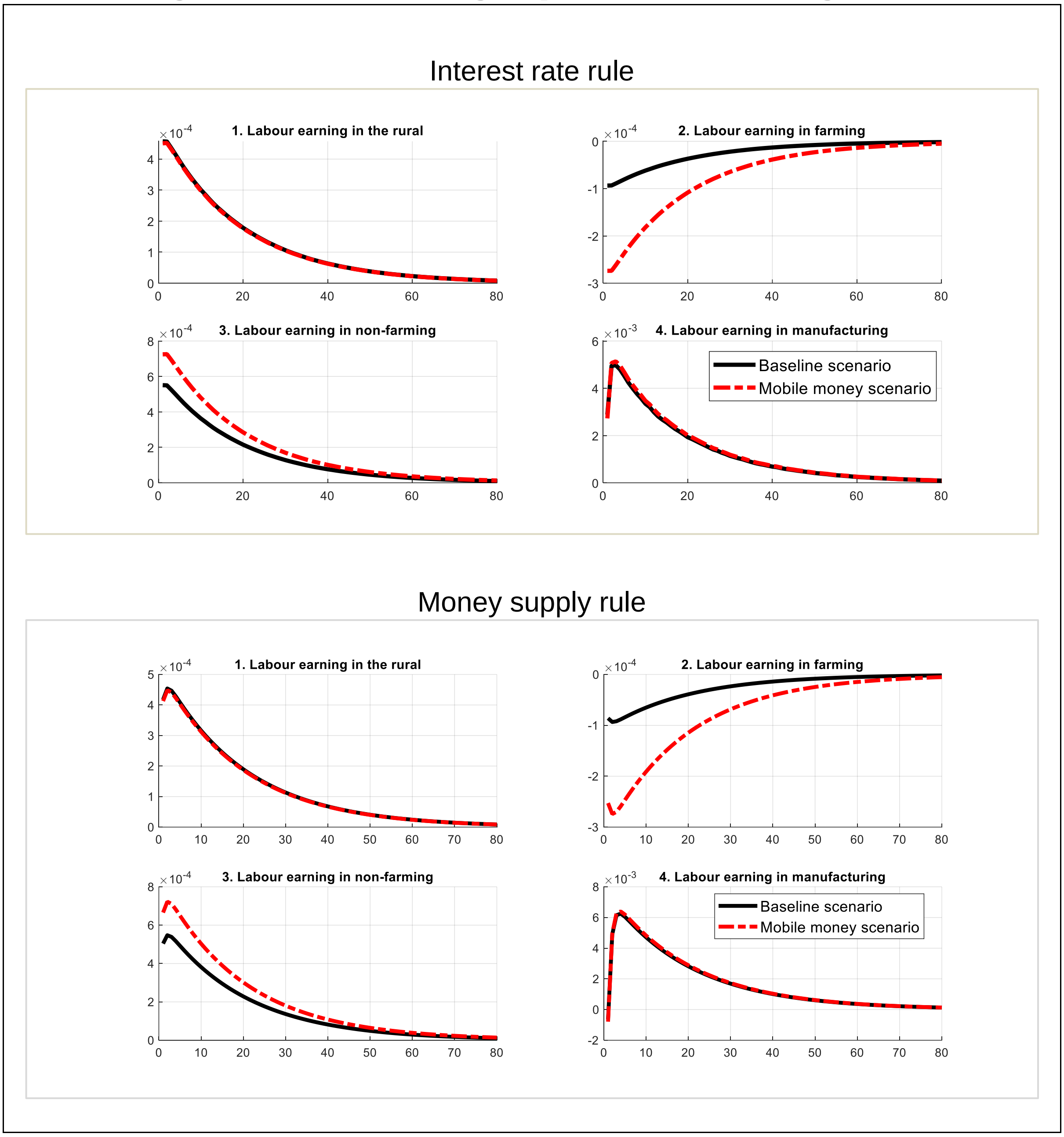


Figure C3F: Relative prices, response to manufacturing shock

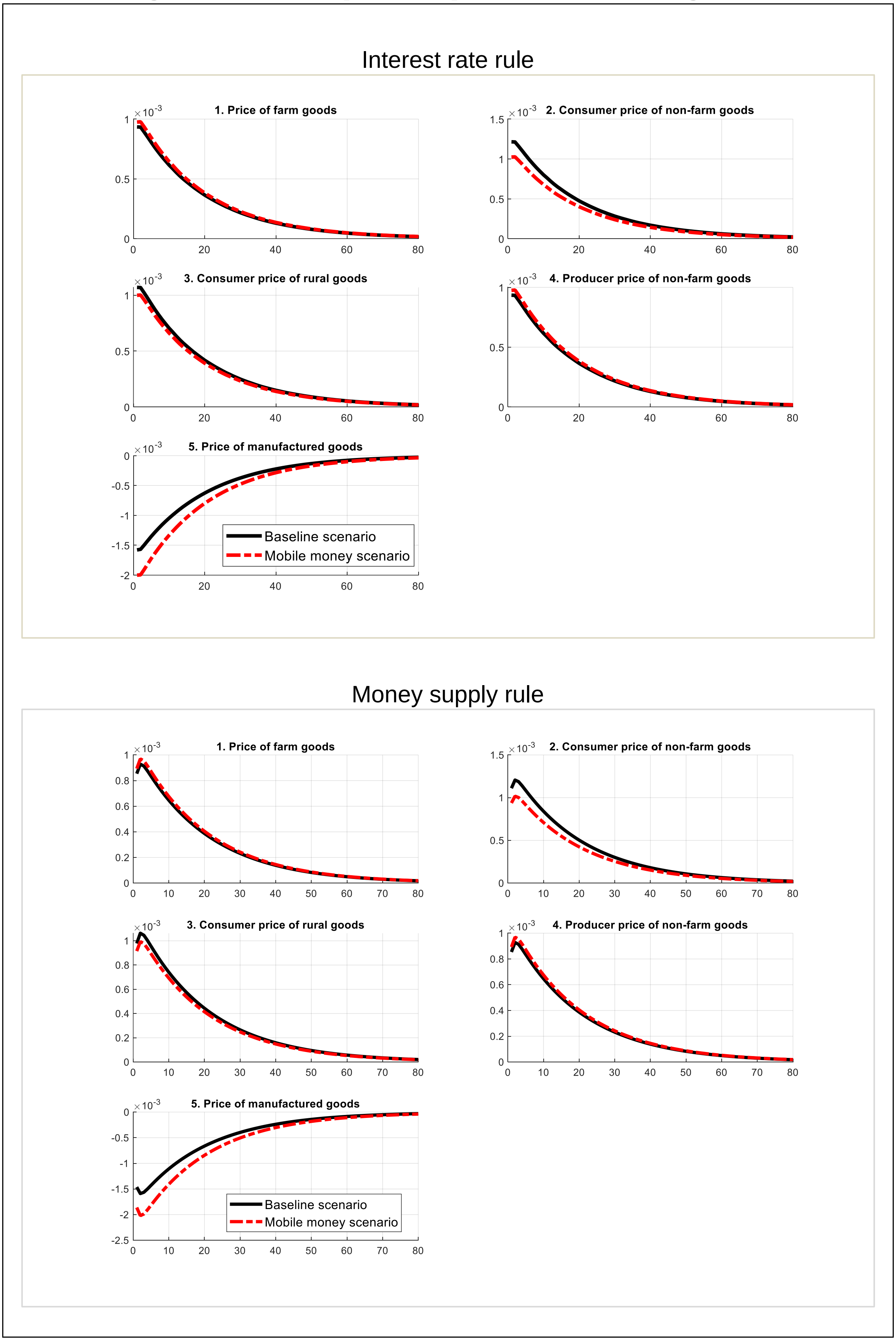


Figure C3G: Wage price ratios, response to manufacturing shock

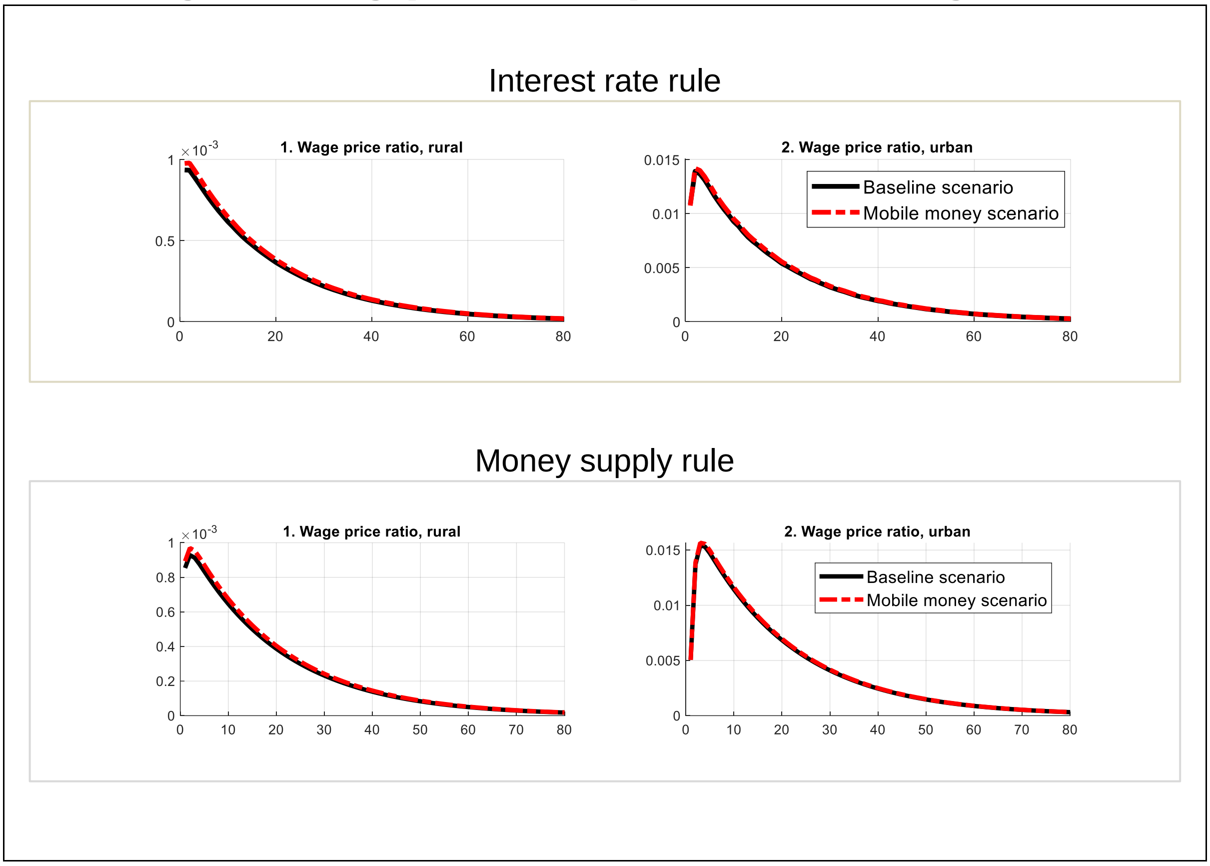
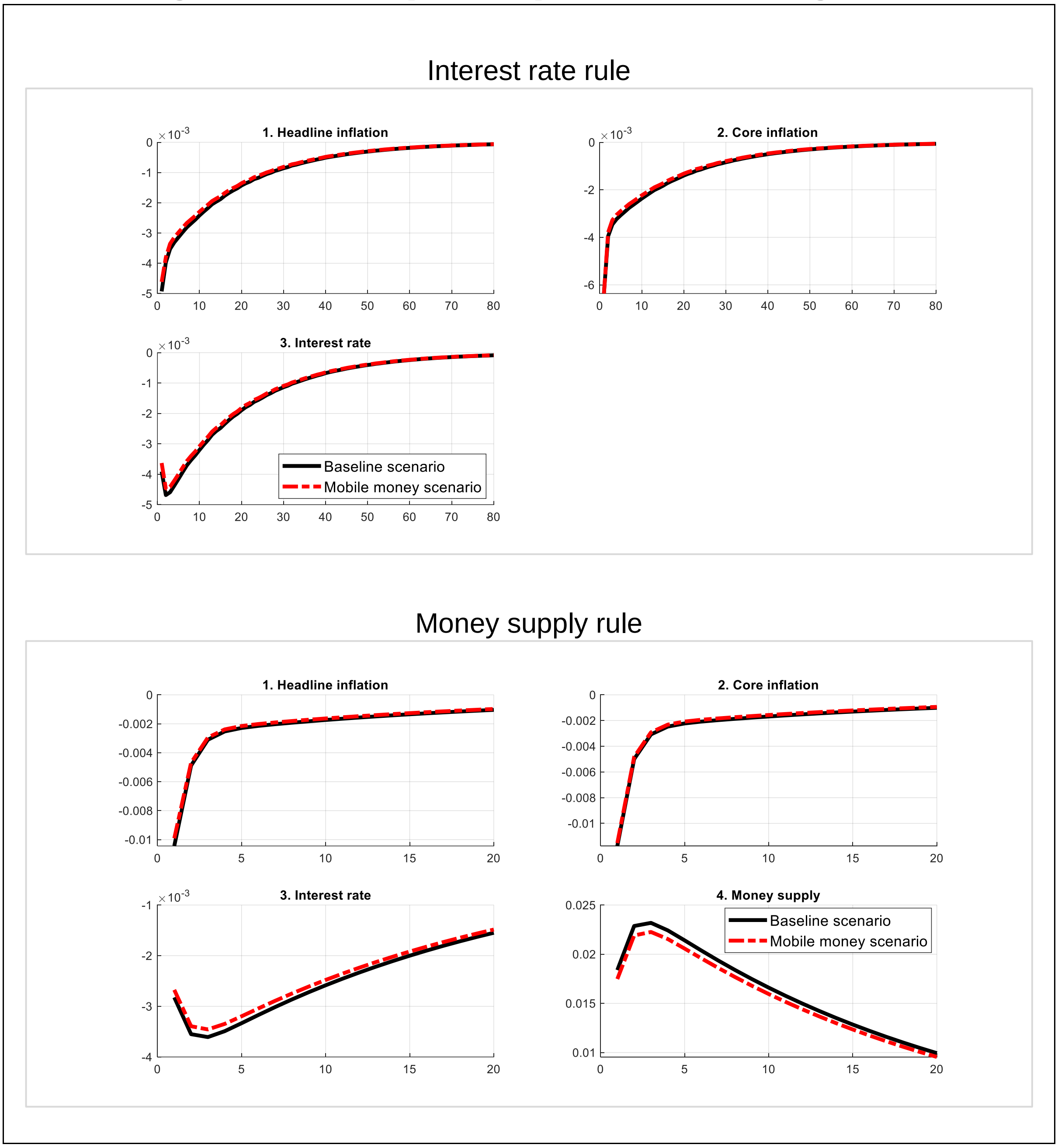


Figure C3H: Relative prices, response to manufacturing shock



Model 1 comparison of IRR with MSR policy shock IRFs

Figure C4A: Production at consumer price, response to policy shock

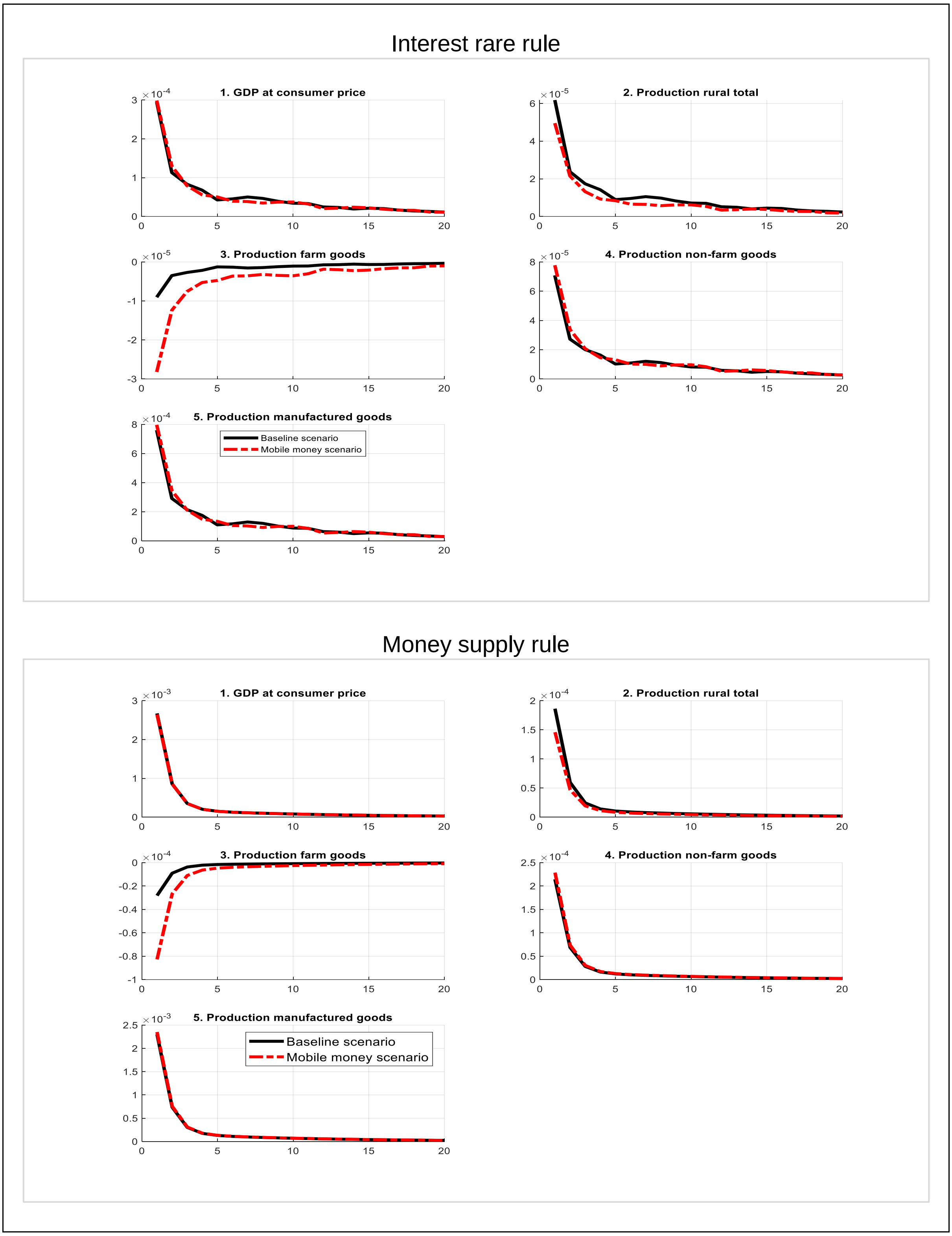


Figure C4B: Production at factor cost, response to policy shock

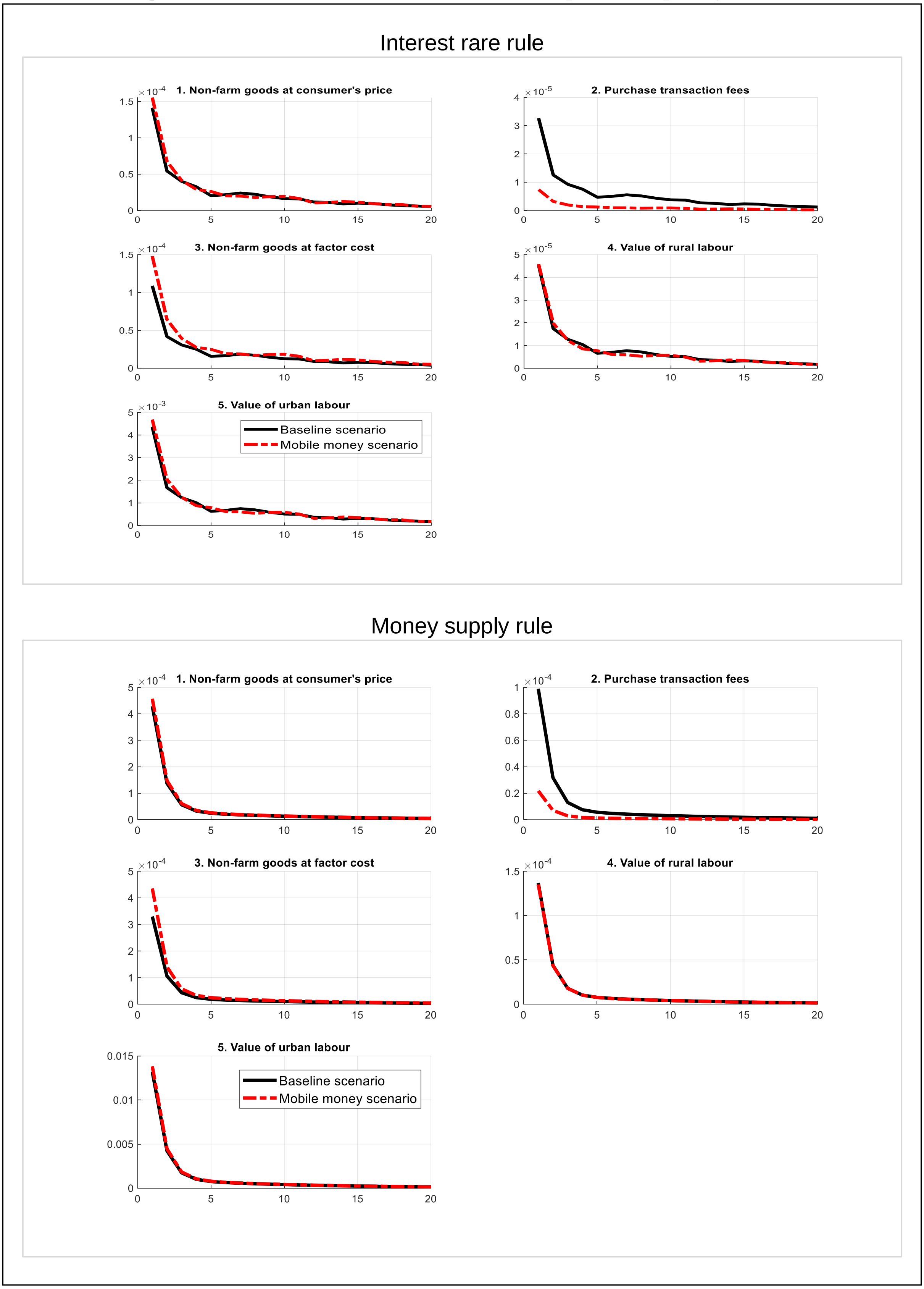
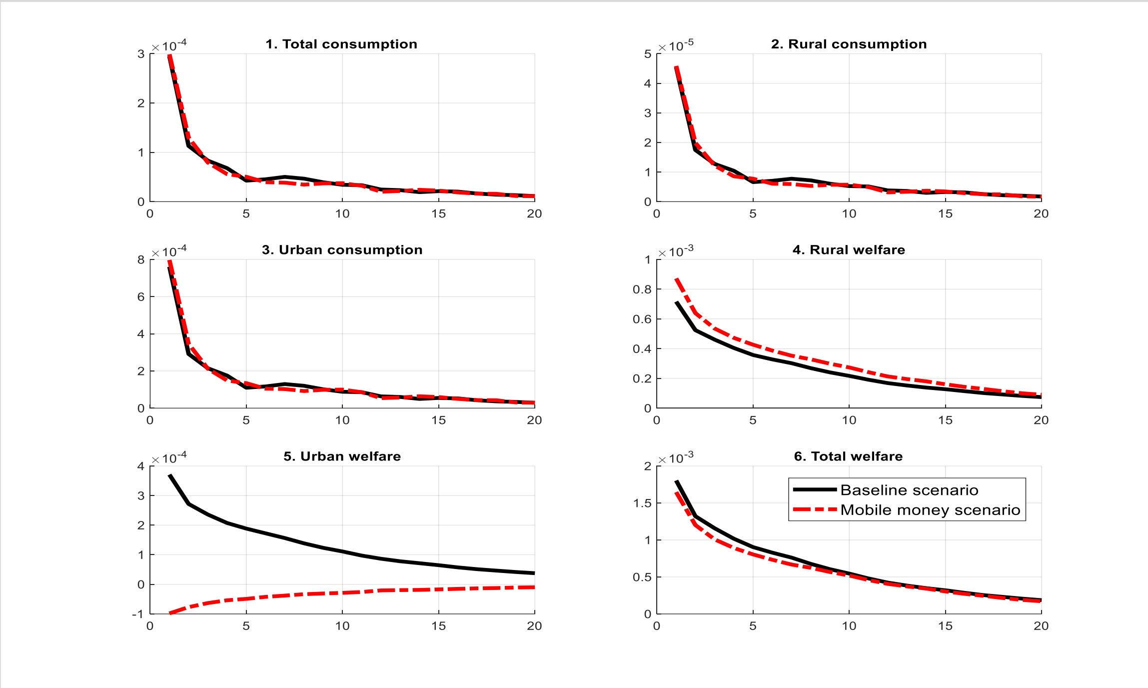


Figure C4C: Consumption and welfare, response to policy shock

Interest rare rule



Money supply rule

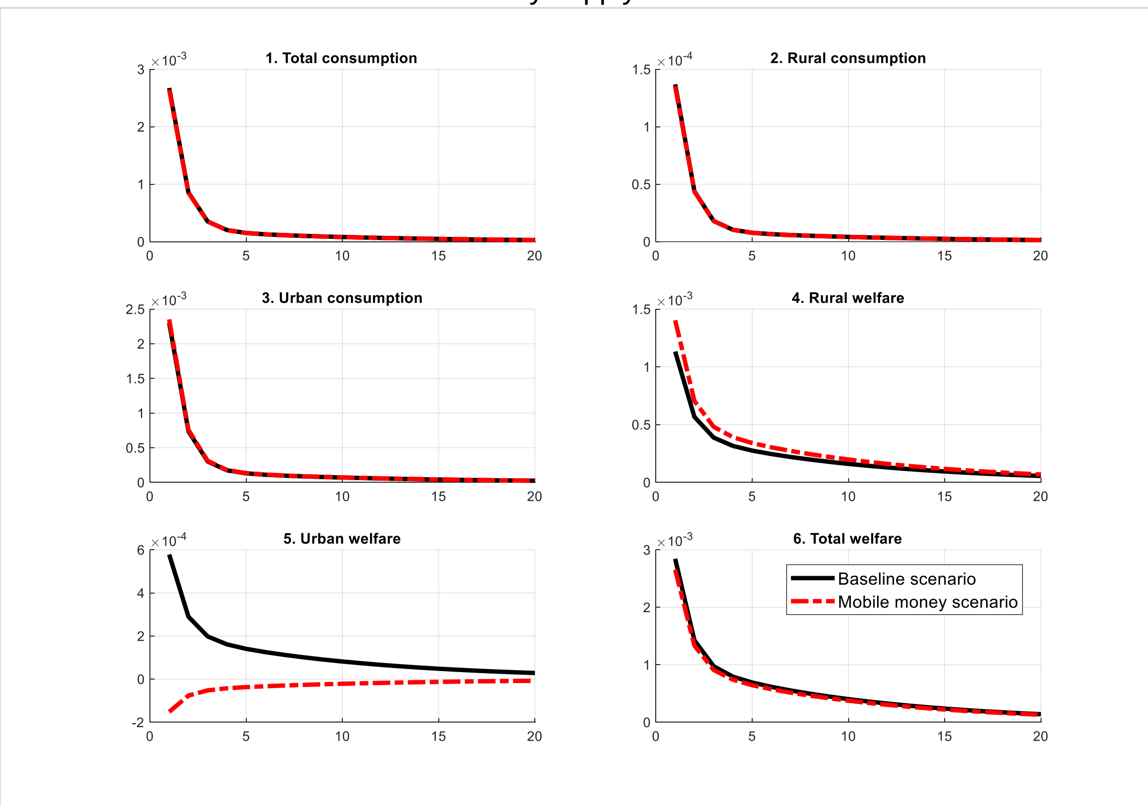
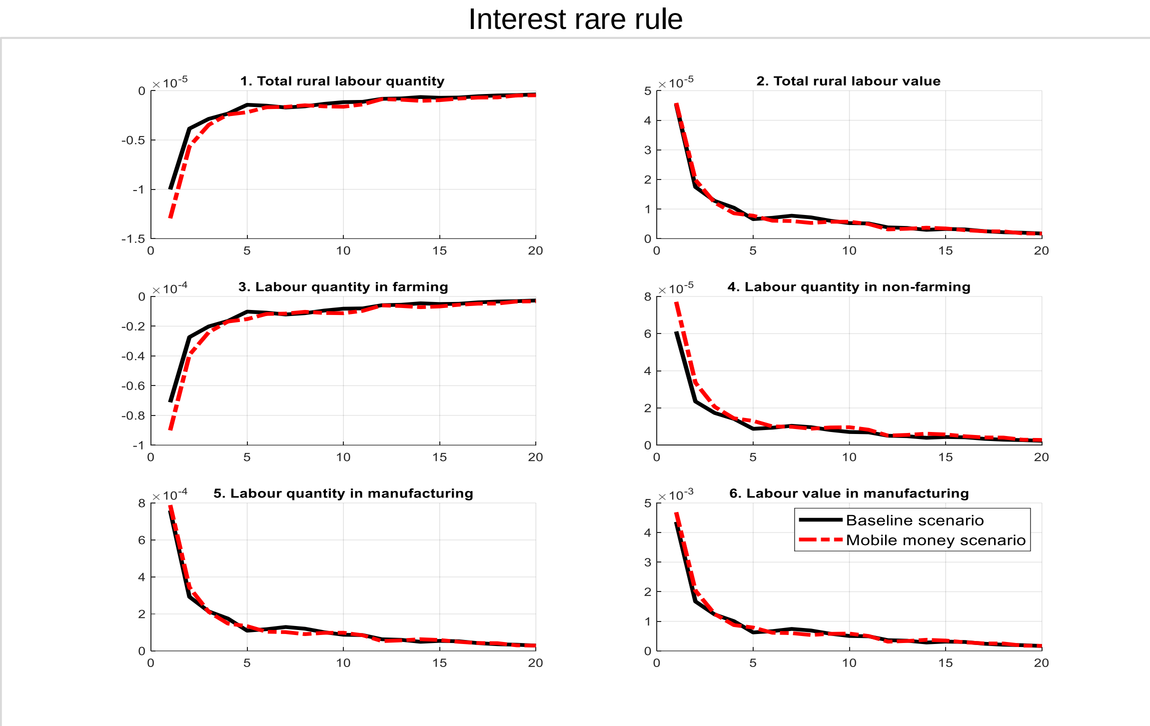


Figure C4D: Labour supplied, response to policy shock



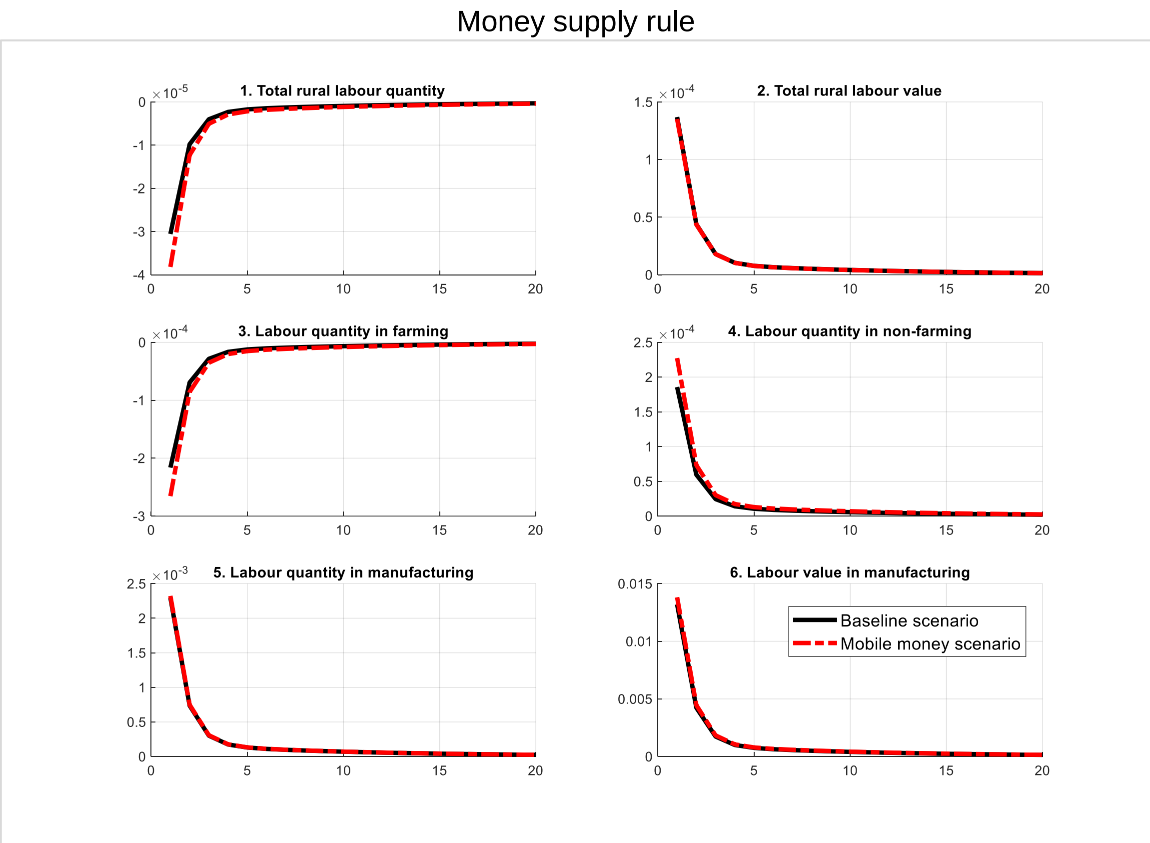


Figure C4E: Labour earning, response to policy shock

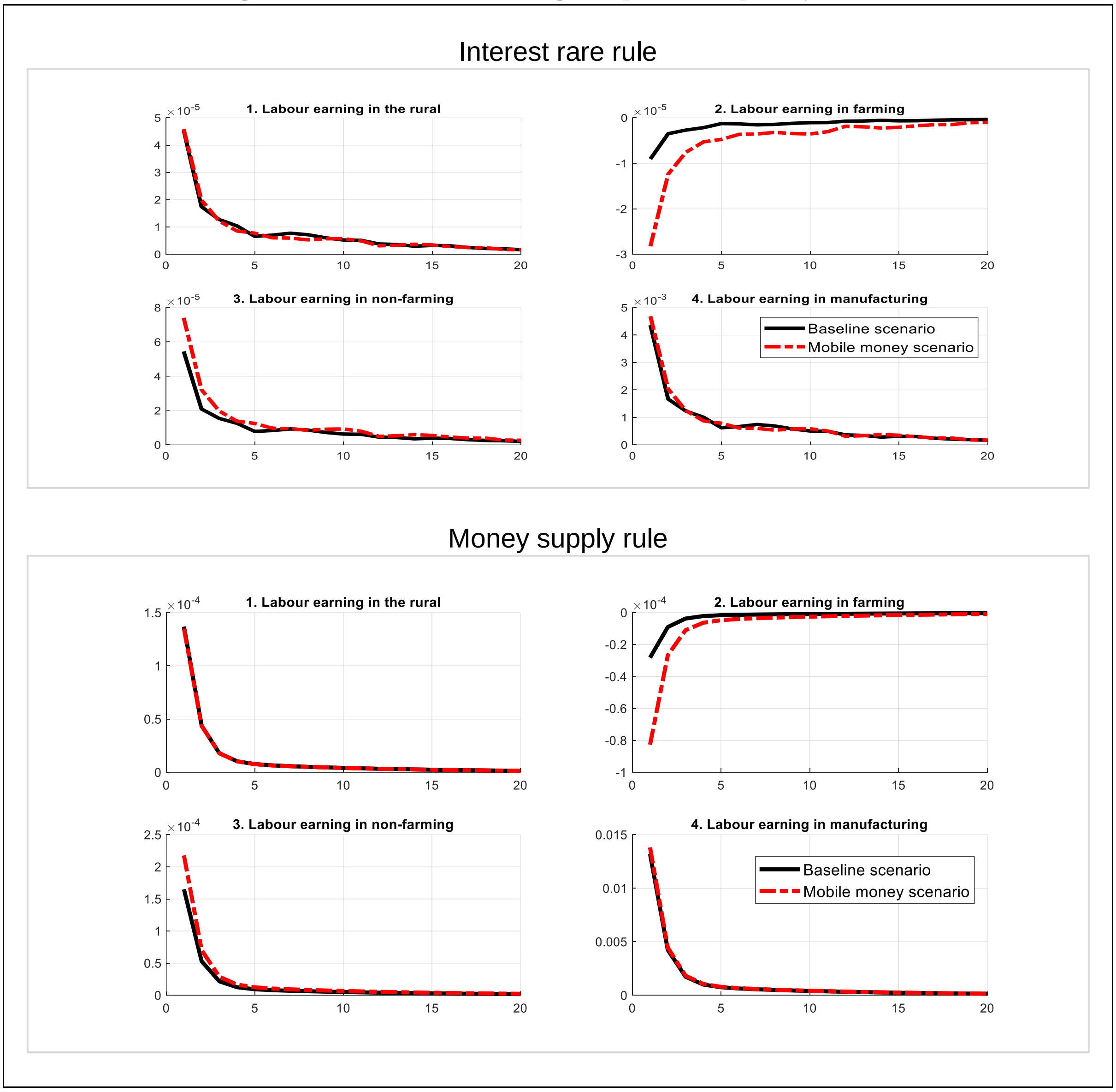


Figure C4F: Relative prices, response to policy shock

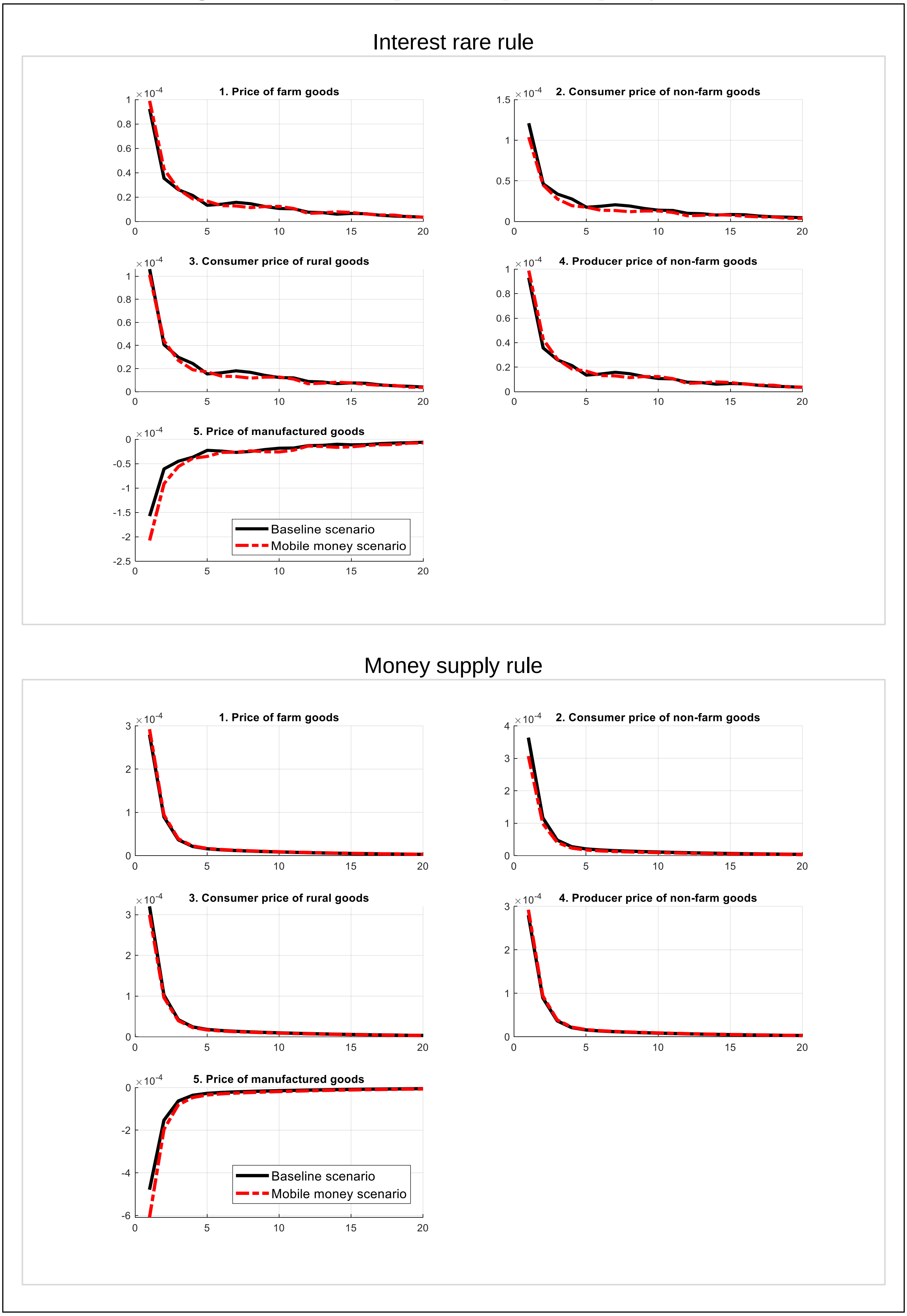


Figure C4G: Wage price ratios, response to policy shock

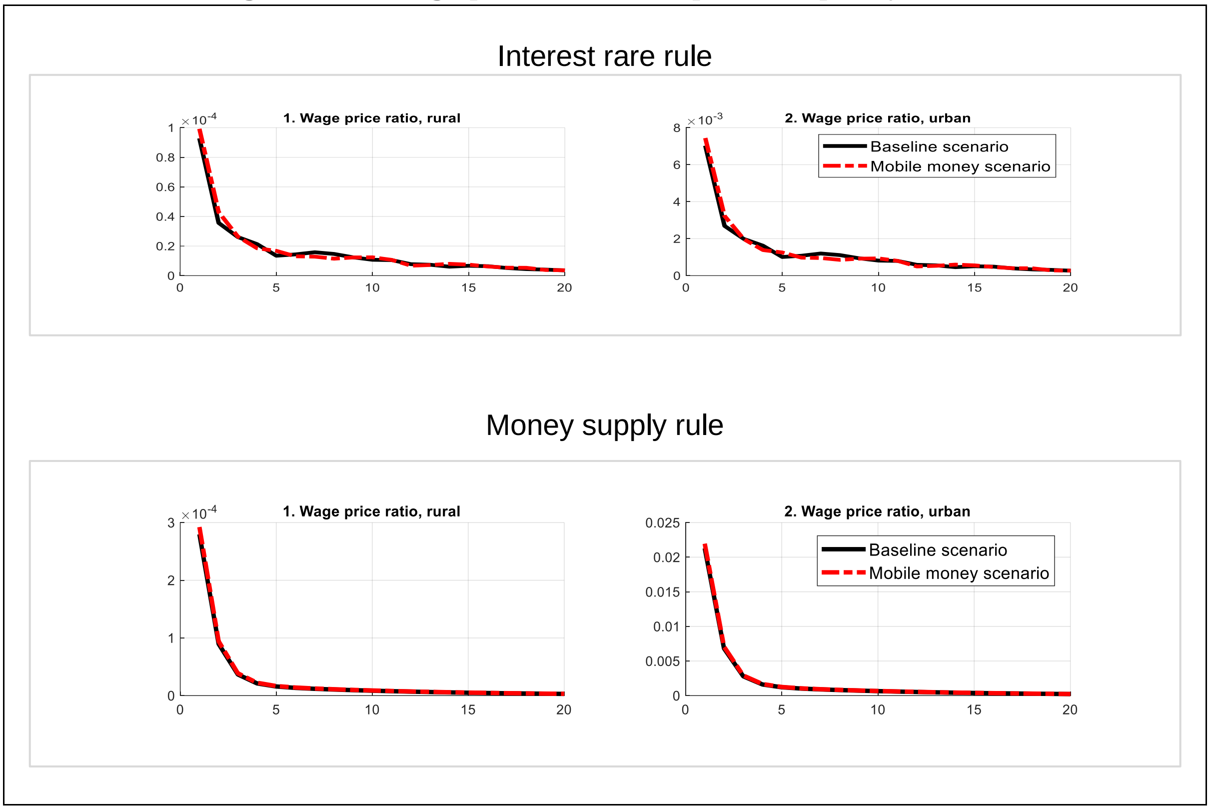
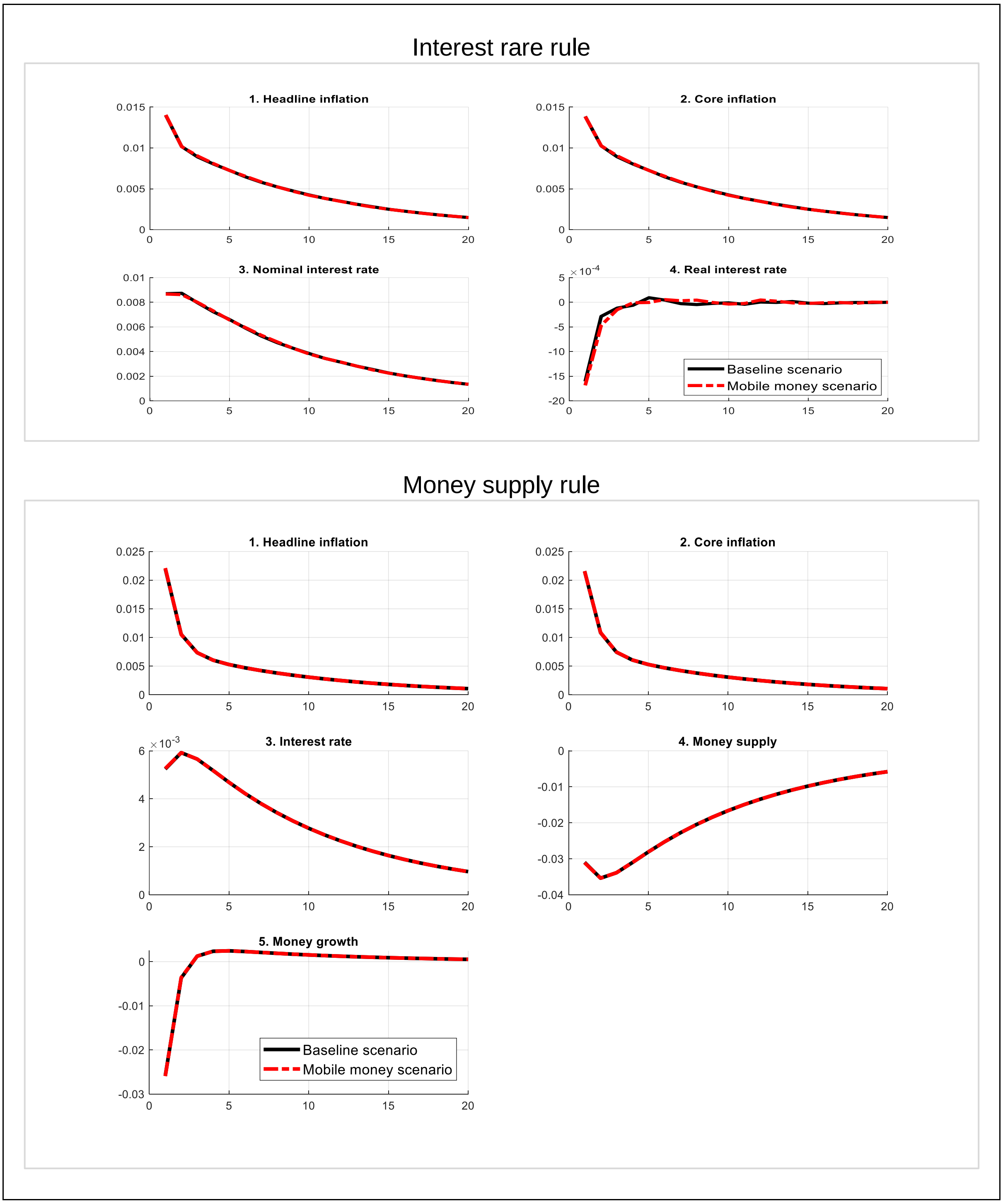


Figure C4H: Inflation and interest rate, response to policy shock



Model 1 selected comparison of policy options

Figure C5: Model 1 MRS versus IRR response of selected variables to non-farming shock, mobile money scenario

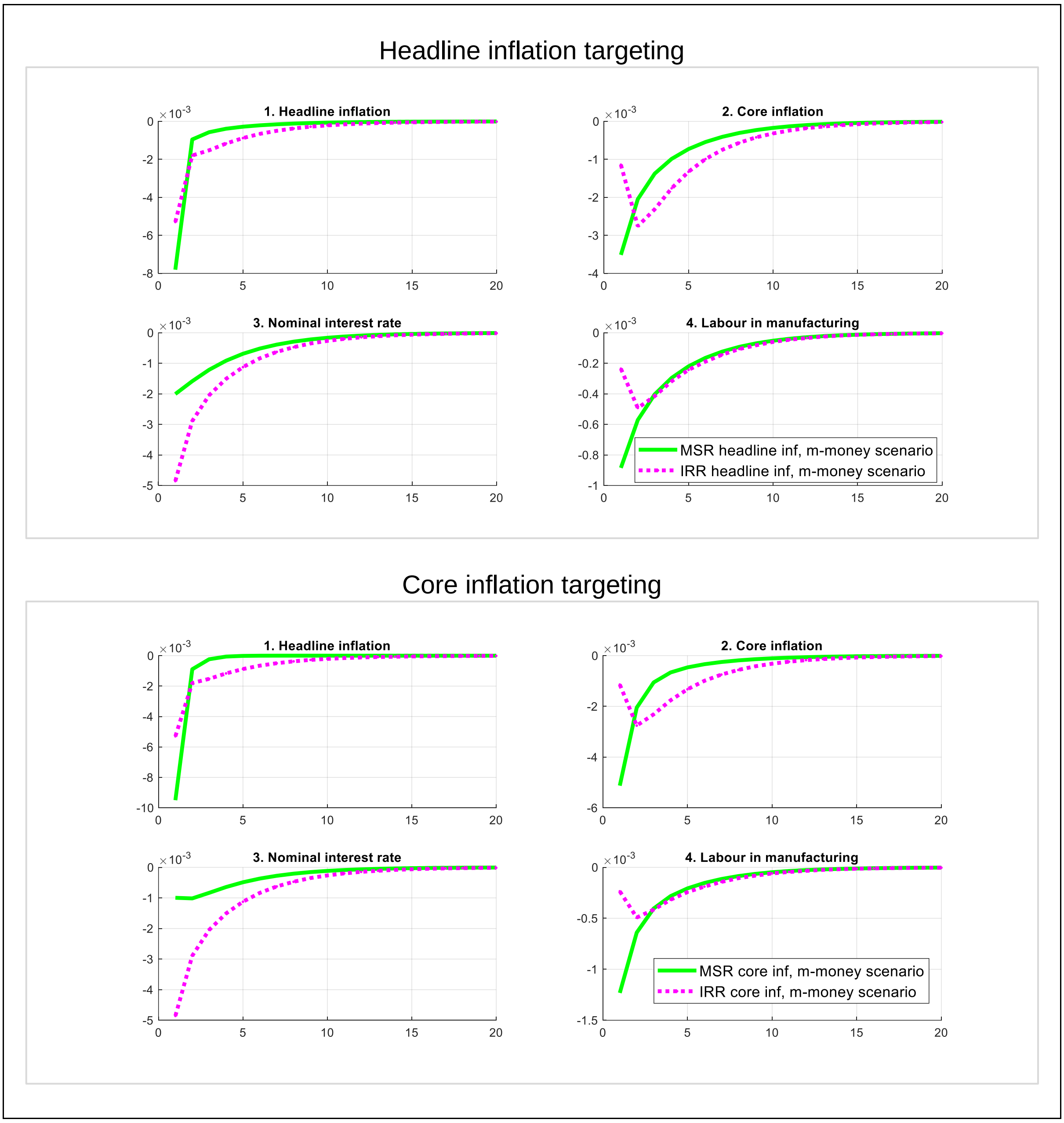
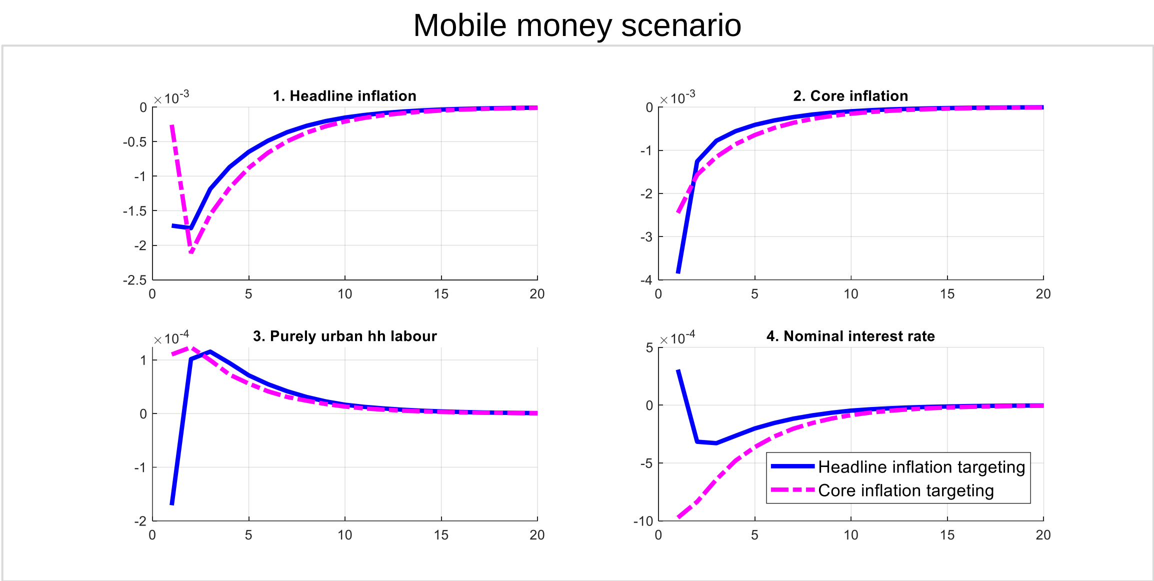


Figure C6: Model 1, headline inflation targeting versus core inflation targeting, response to farming shock



Chapter 3 Appendices

Appendix D: Selected Tables

Table D1: The cost of sending money by M-Pesa or Tigo-Pesa in Tanzania

	M-Pesa	Tigo-Pesa	Average
Transaction value in TZS	30,000	30,000	30,000
Transaction cost of transfer to registered customers in TZS	400	400	400
Percentage of value sent	1.33%	1.33%	1.33%
Transaction cost of transfer to unregistered customers in TZS	2,750	2,500	2,625
Percentage of value sent	9.17%	8.33%	8.75%
Average percentage of value sent	5.25%	4.83%	5.04%

Source: Tanzania M-Pesa tariffs September 2021 and Tigo-Pesa tariffs July 2022

Appendix E: Selected impulse response graphs for Model 2 and 3

Model 2 comparison of IRR with MSR farming shock IRFs

Figure E1A: Model 2 response of remittances and non-farm goods to farming shock

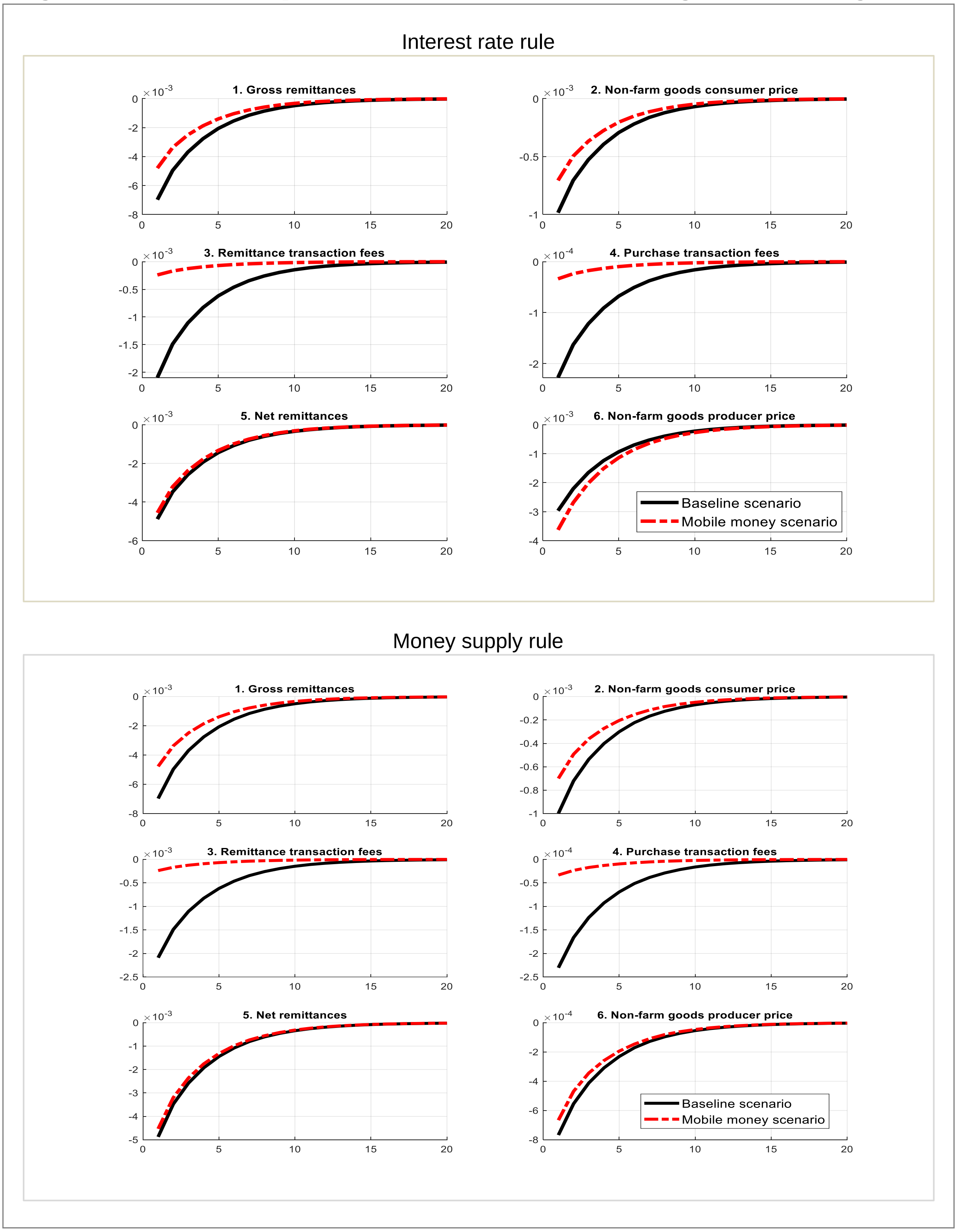


Figure E1B: Model 2 response of quantity and value output to farming shock

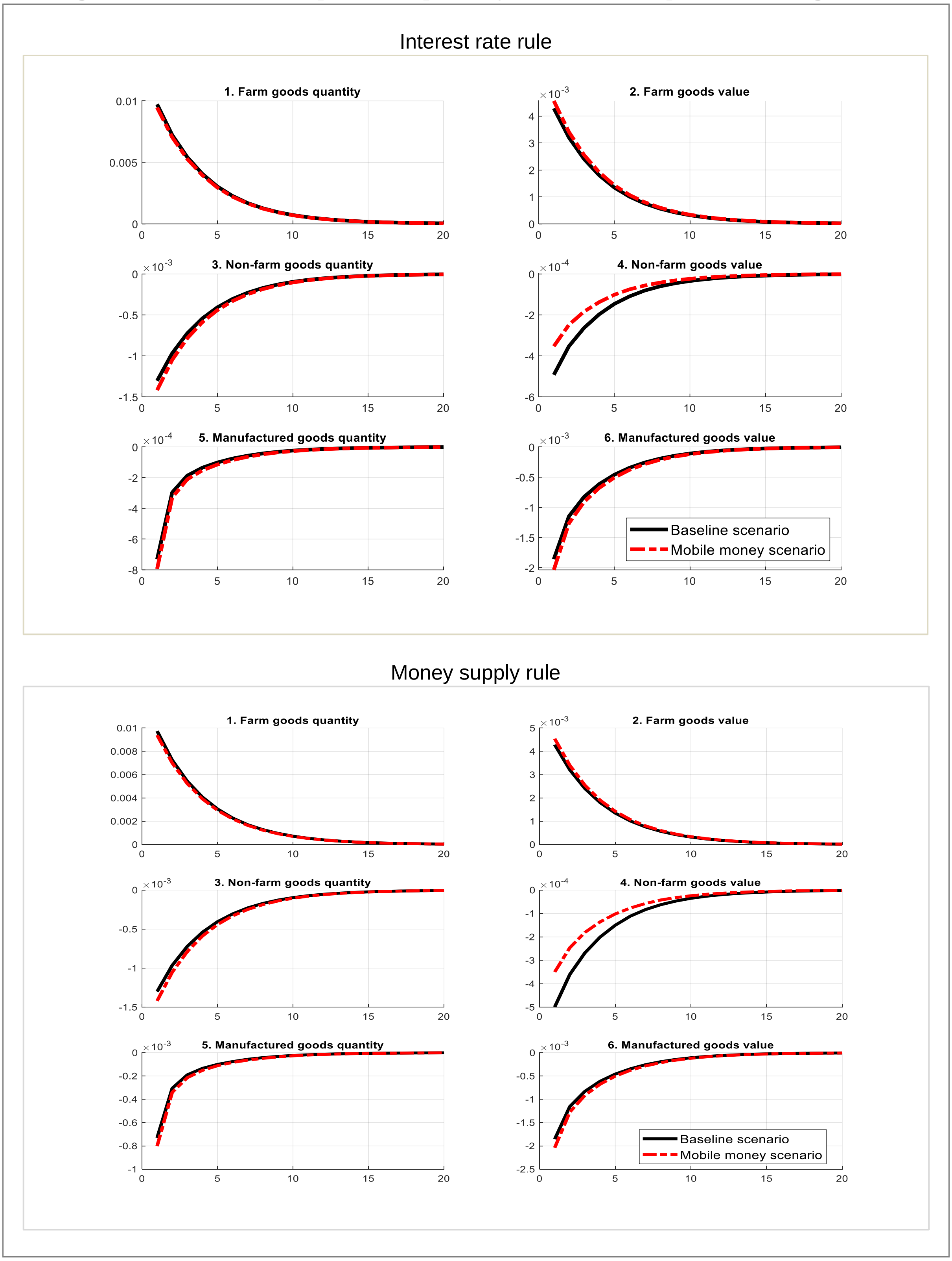


Figure E1C: Model 2 response of GDP aggregates to farming shock

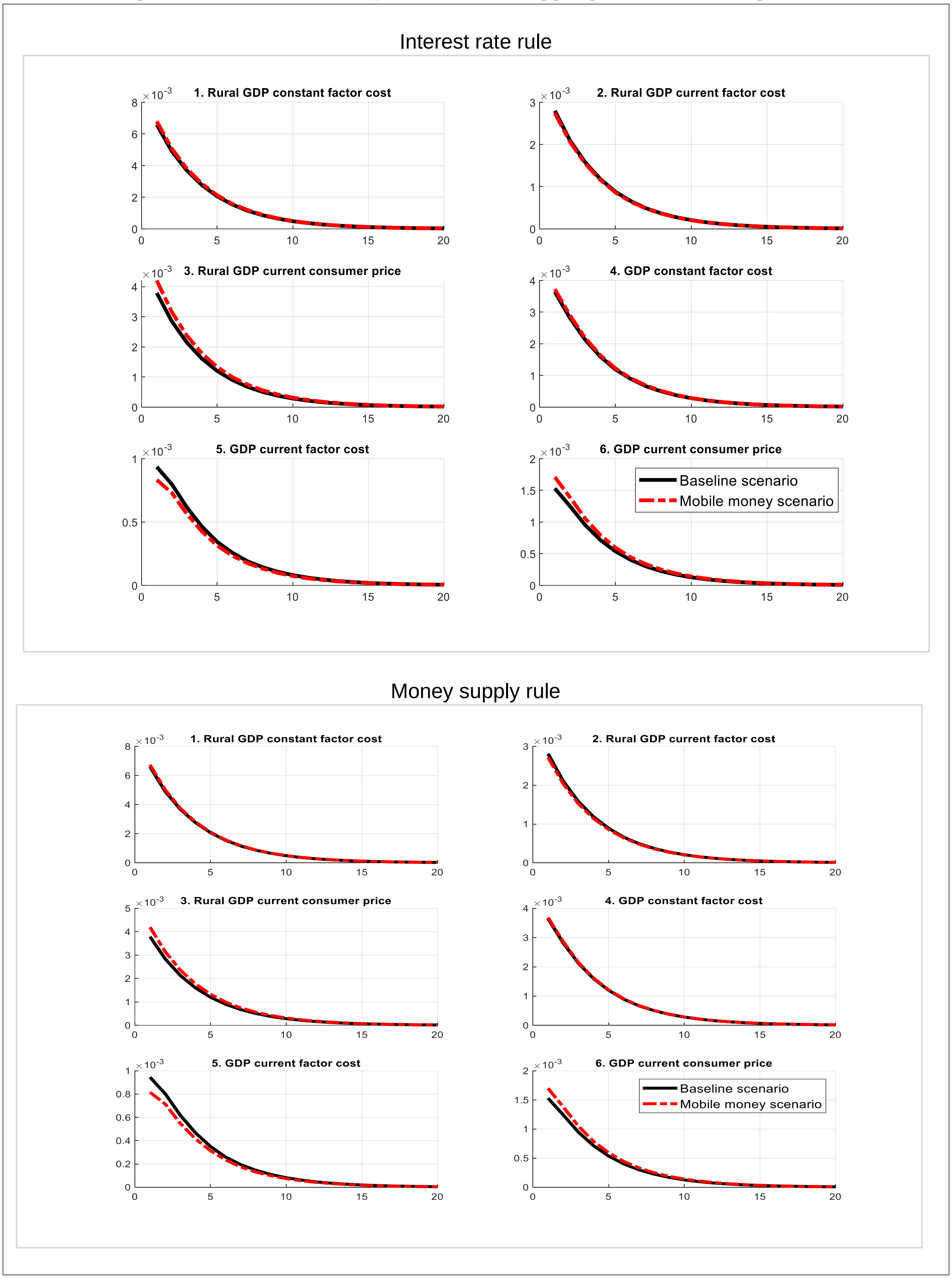


Figure E1D: Model 2 response of household labour quantity to farming shock

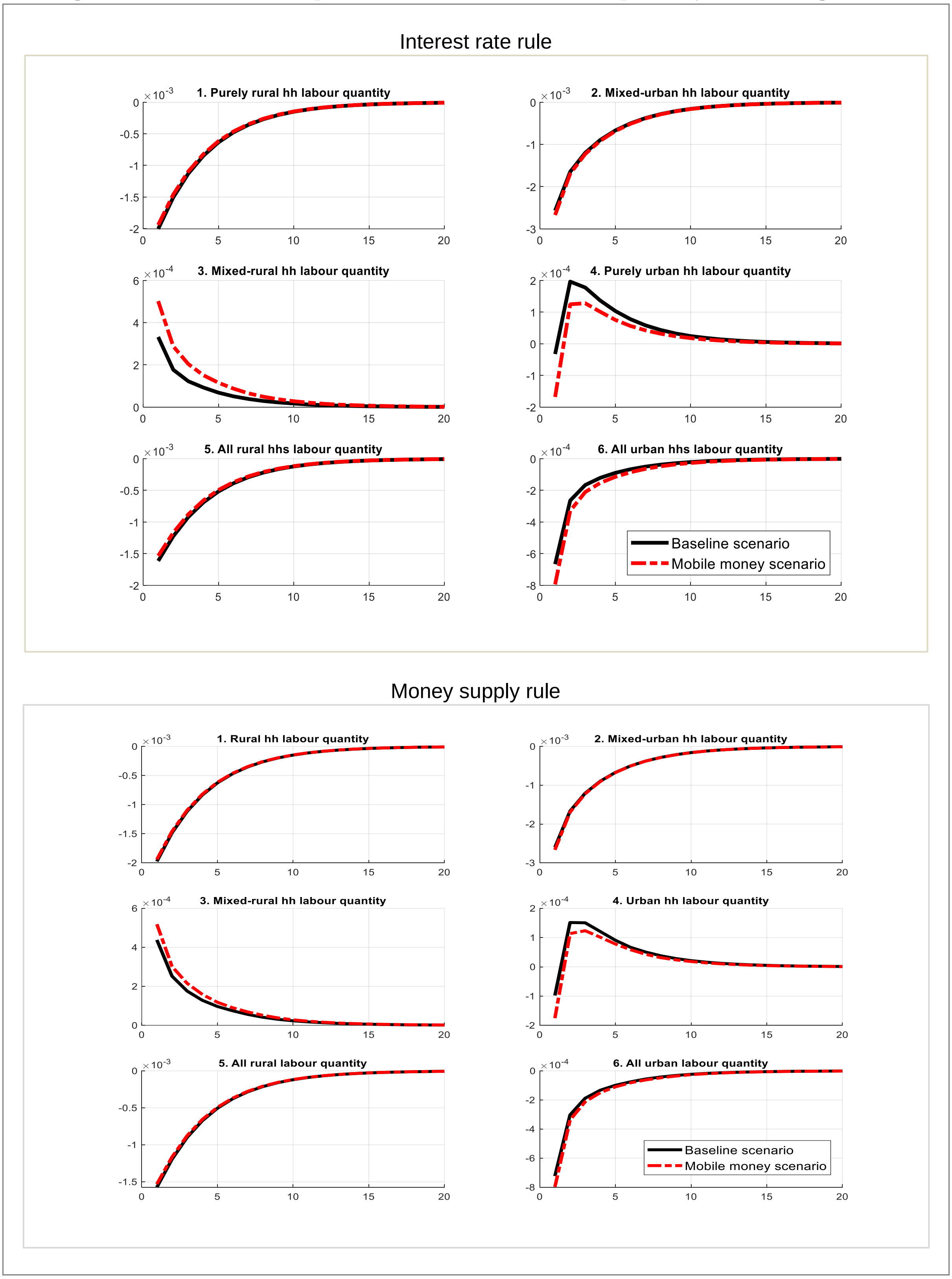


Figure E1E: Model 2 response of household labour value to farming shock

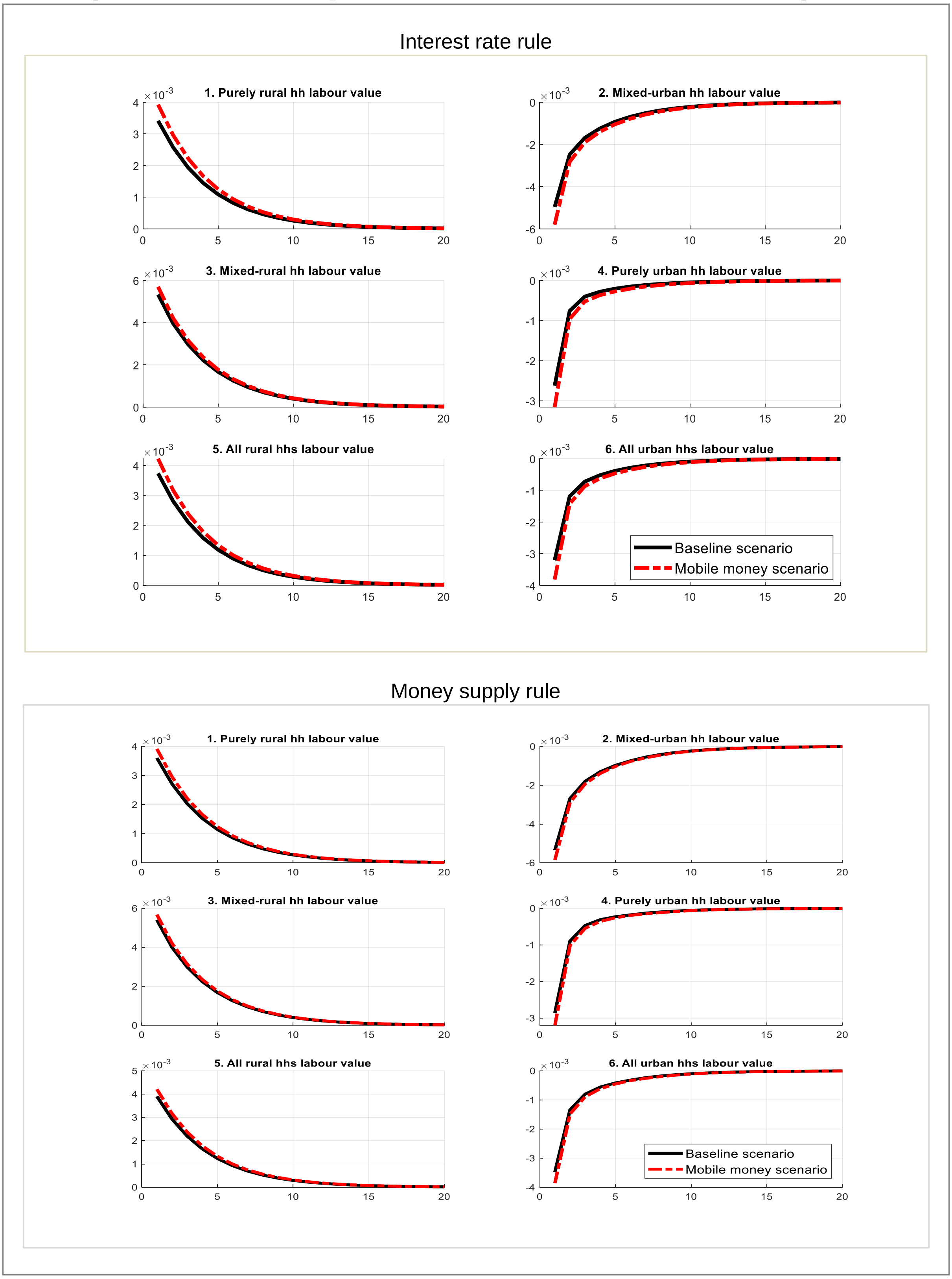


Figure E1F: Model 2 response of labour quantity and value in firms to farming shock

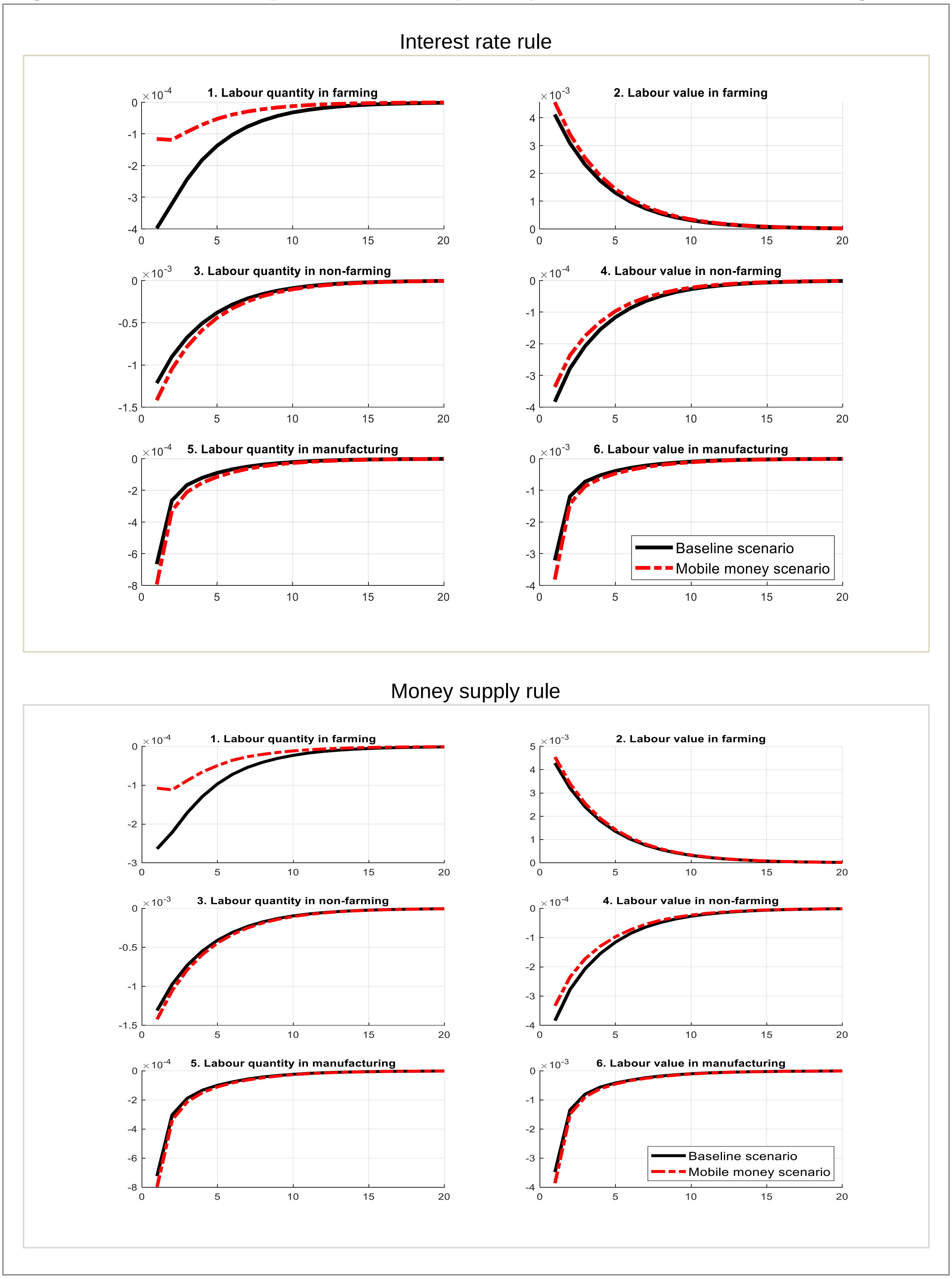


Figure E1G: Model 2 response of consumption to farming shock

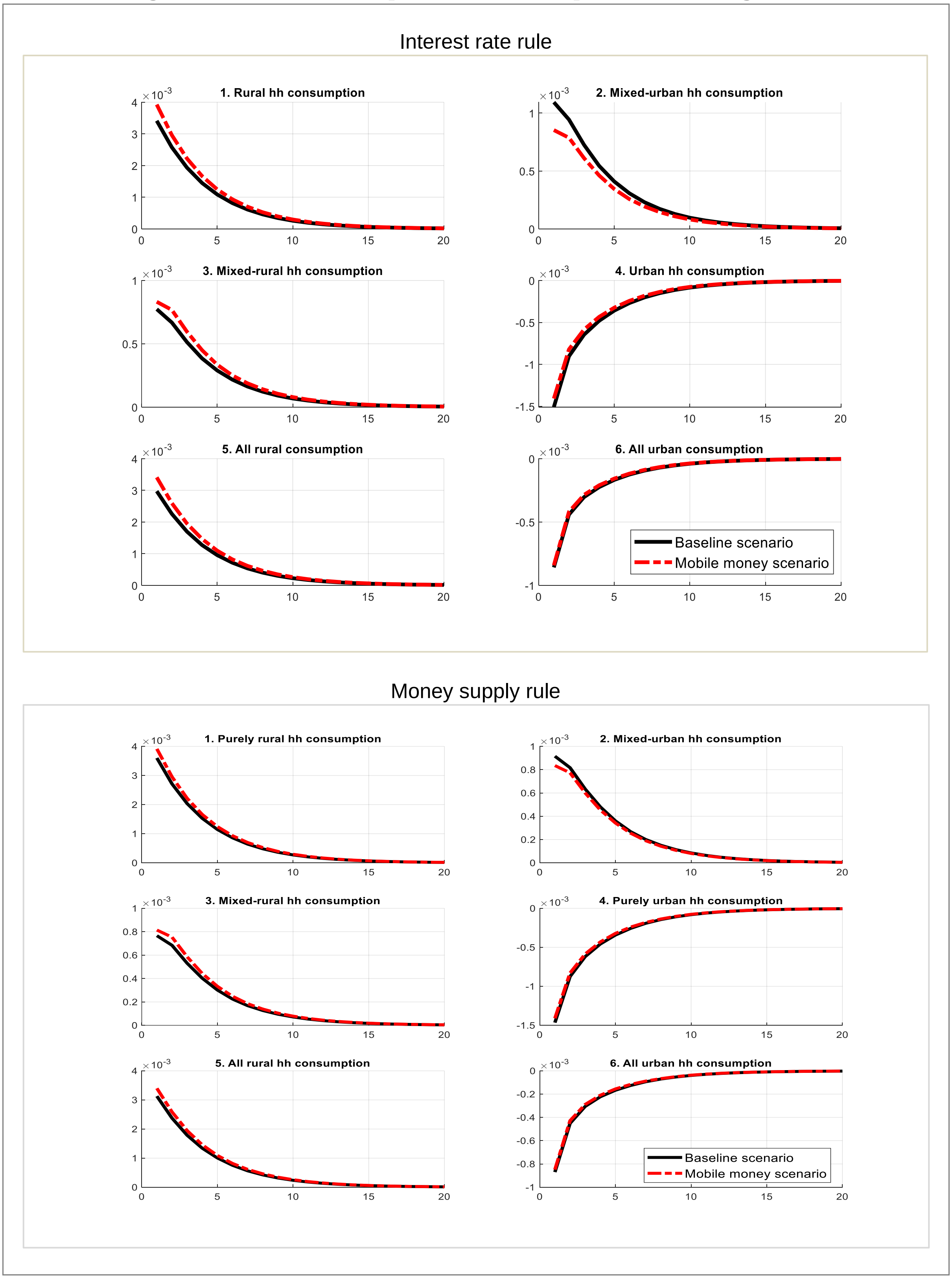


Figure E1H: Model 2 response of welfare to farming shock

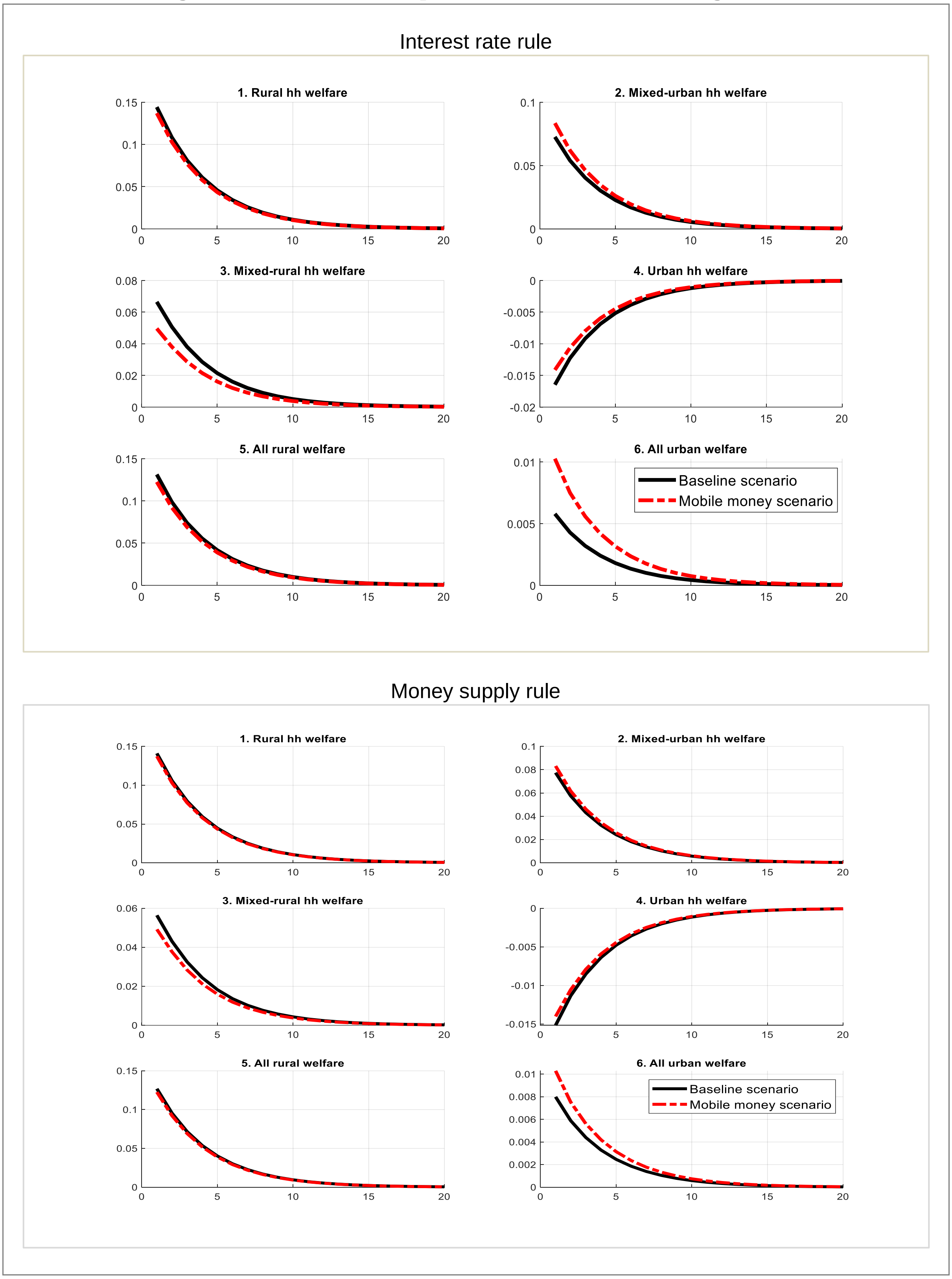
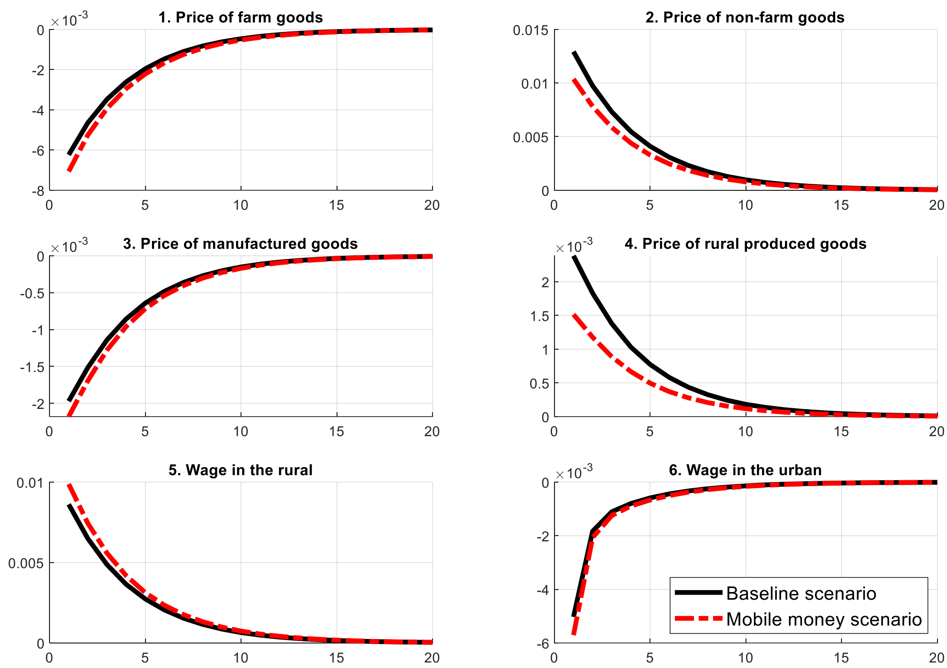


Figure E1I: Model 2 response of relative prices and wages to farming shock

Interest rate rule



Money supply rule

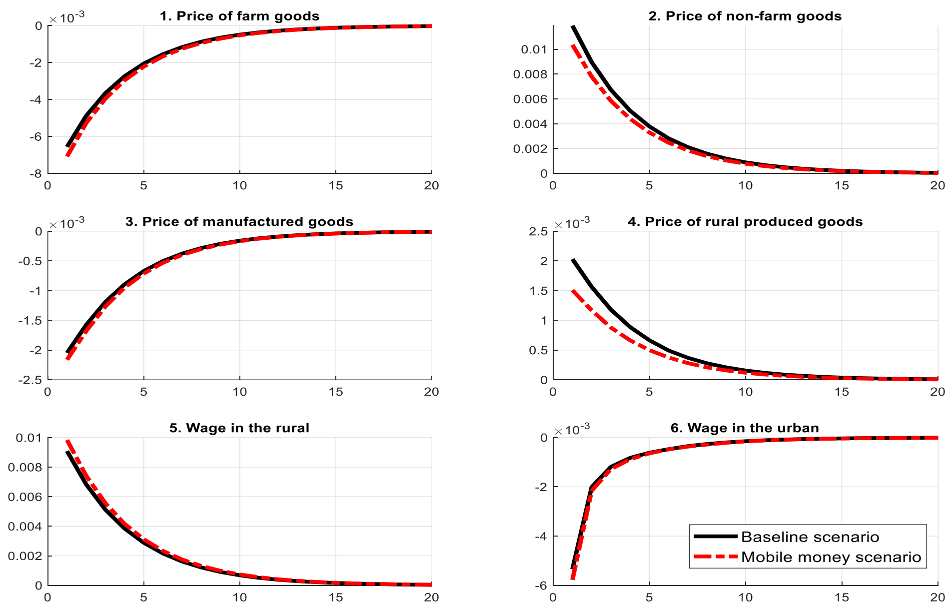
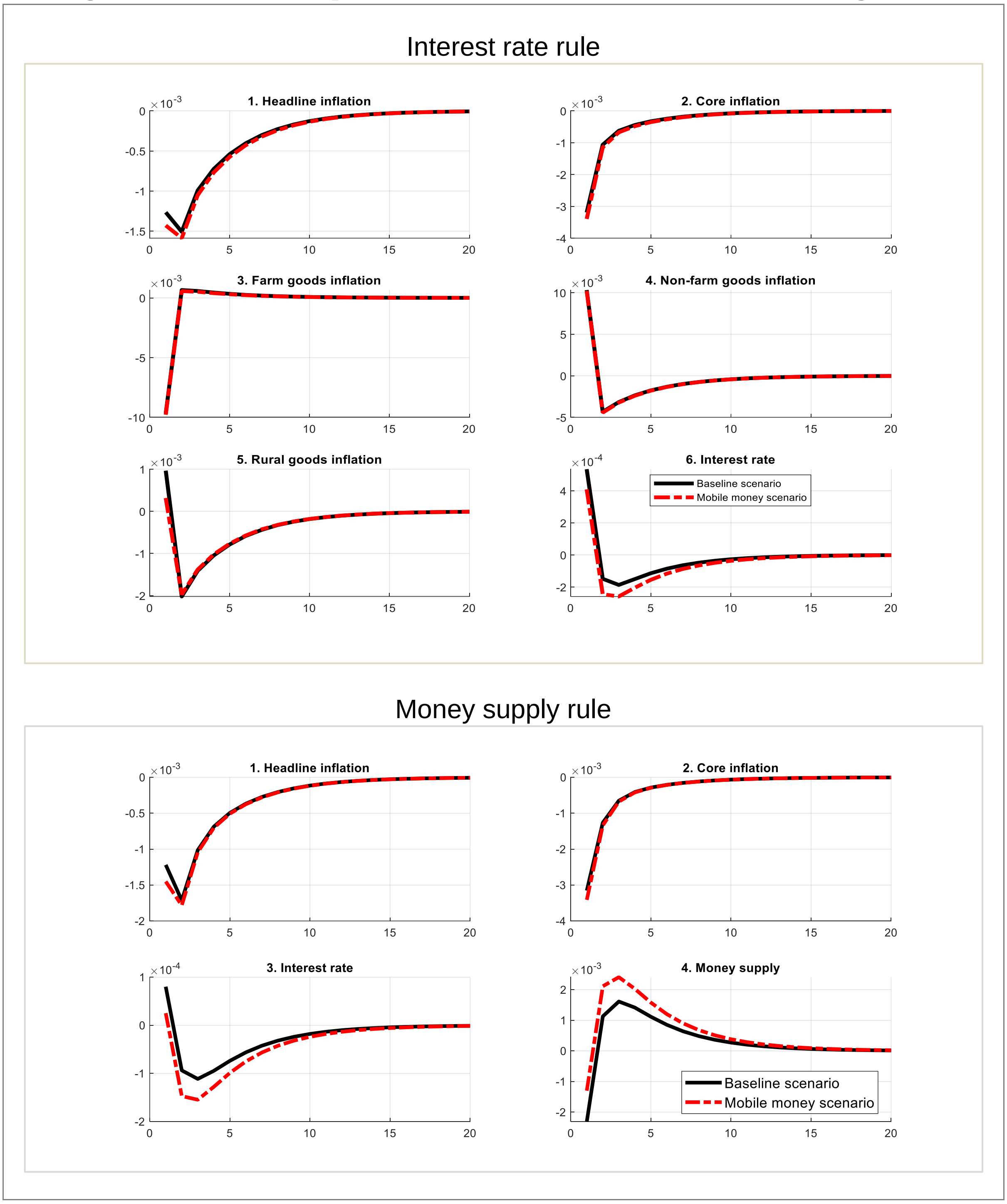


Figure E1J: Model 2 response of inflation and interest rate to farming shock



Model 2 comparison of IRR with MSR non-farming shock IRFs

Figure E2A: Model 2 response of remittances and non-farm goods to non-farming shock

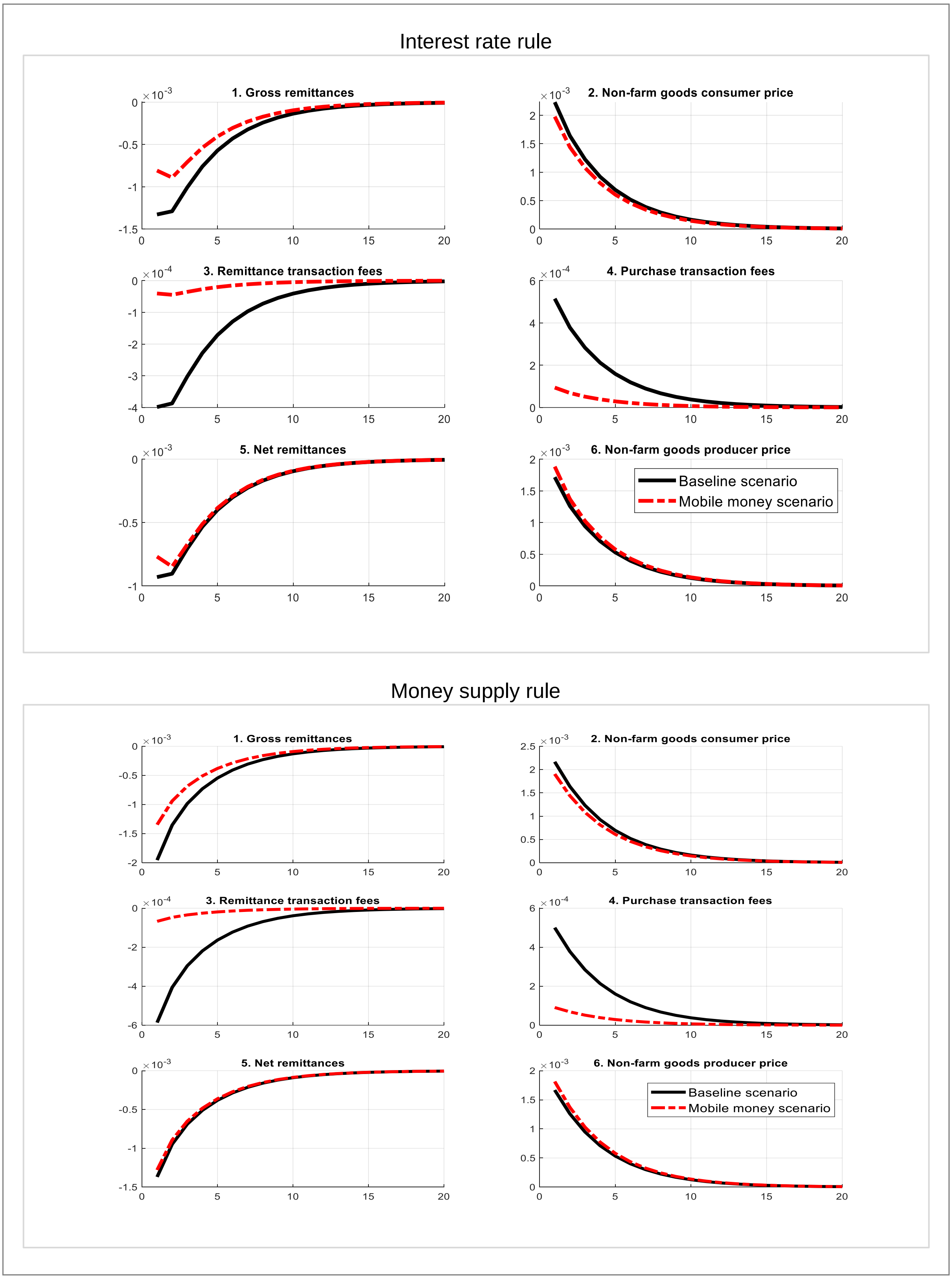


Figure E2B: Model 2 response of quantity and value output to non-farming shock

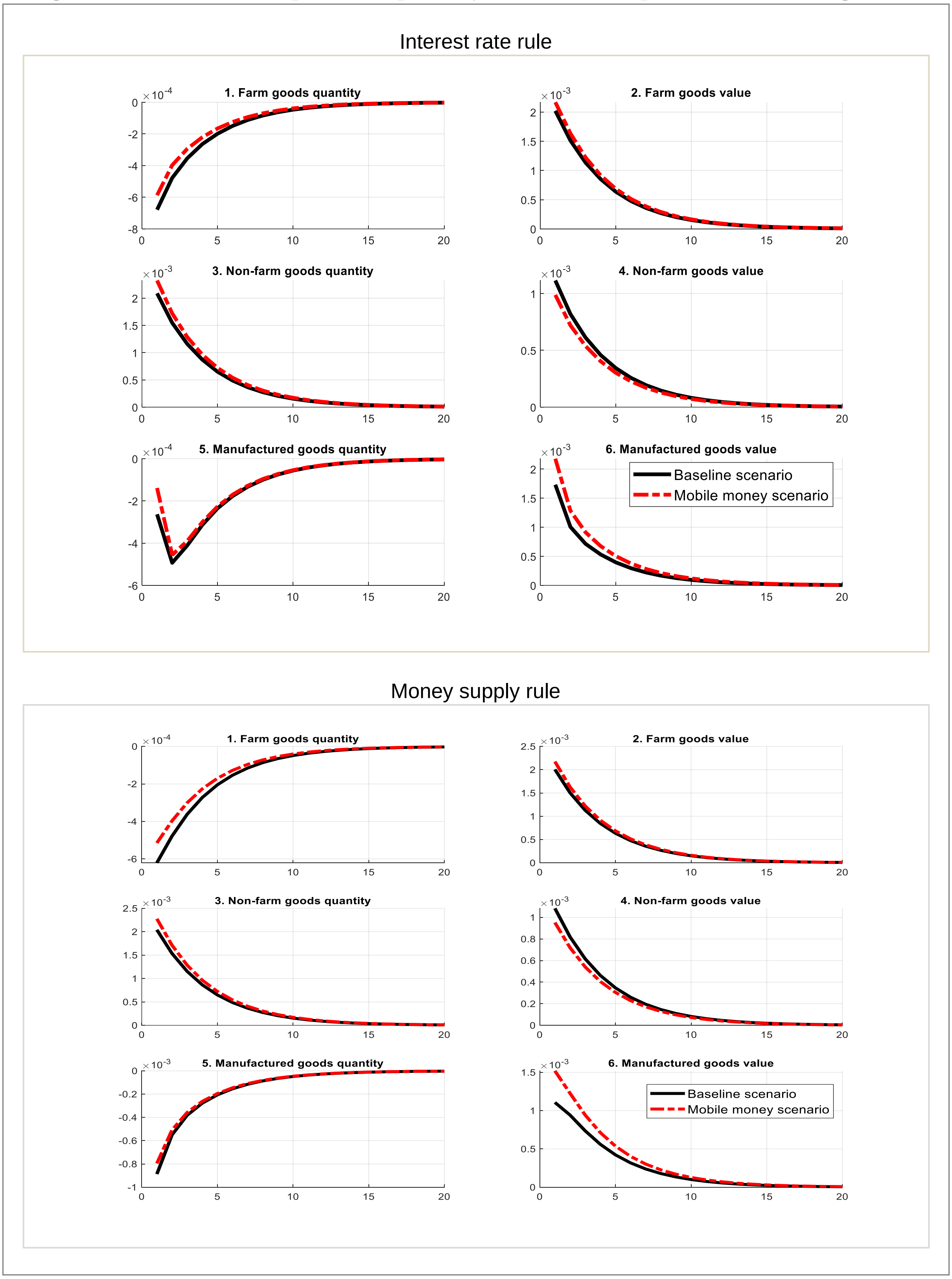


Figure E2C: Model 2 response of GDP aggregates to non-farming shock

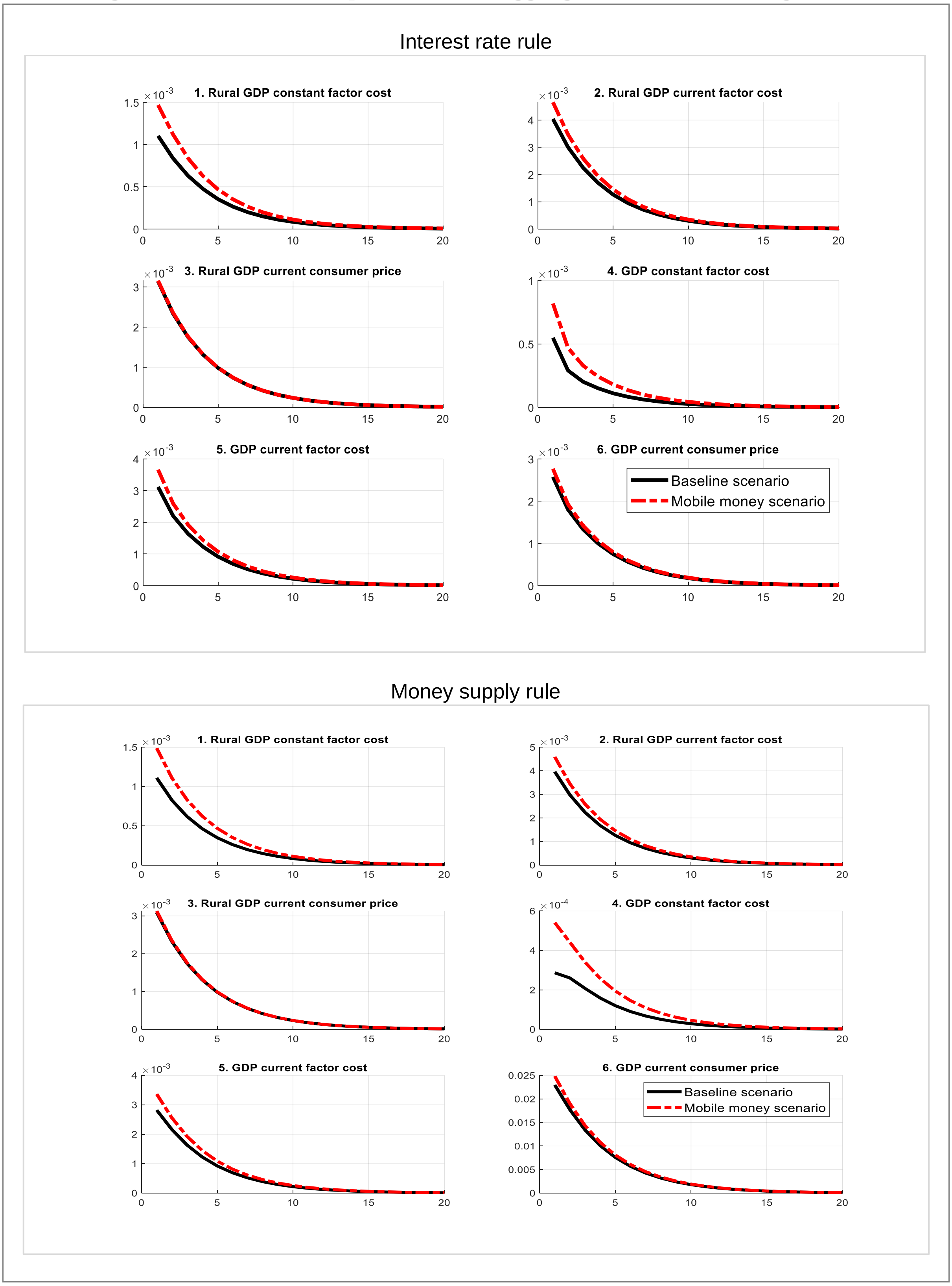


Figure E2D: Model 2 response of household labour quantity to non-farming shock

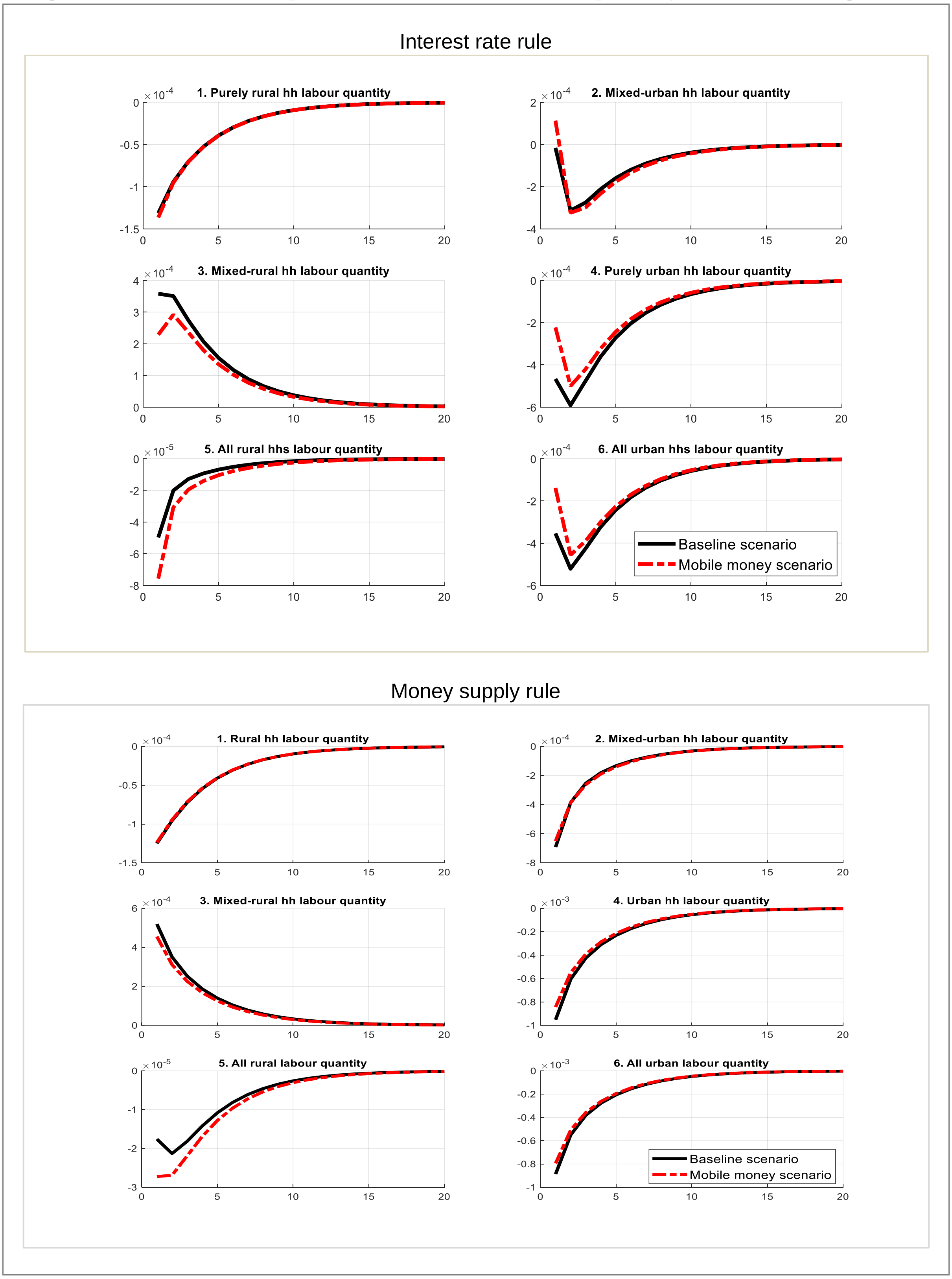


Figure E2E: Model 2 response of household labour value to non-farming shock

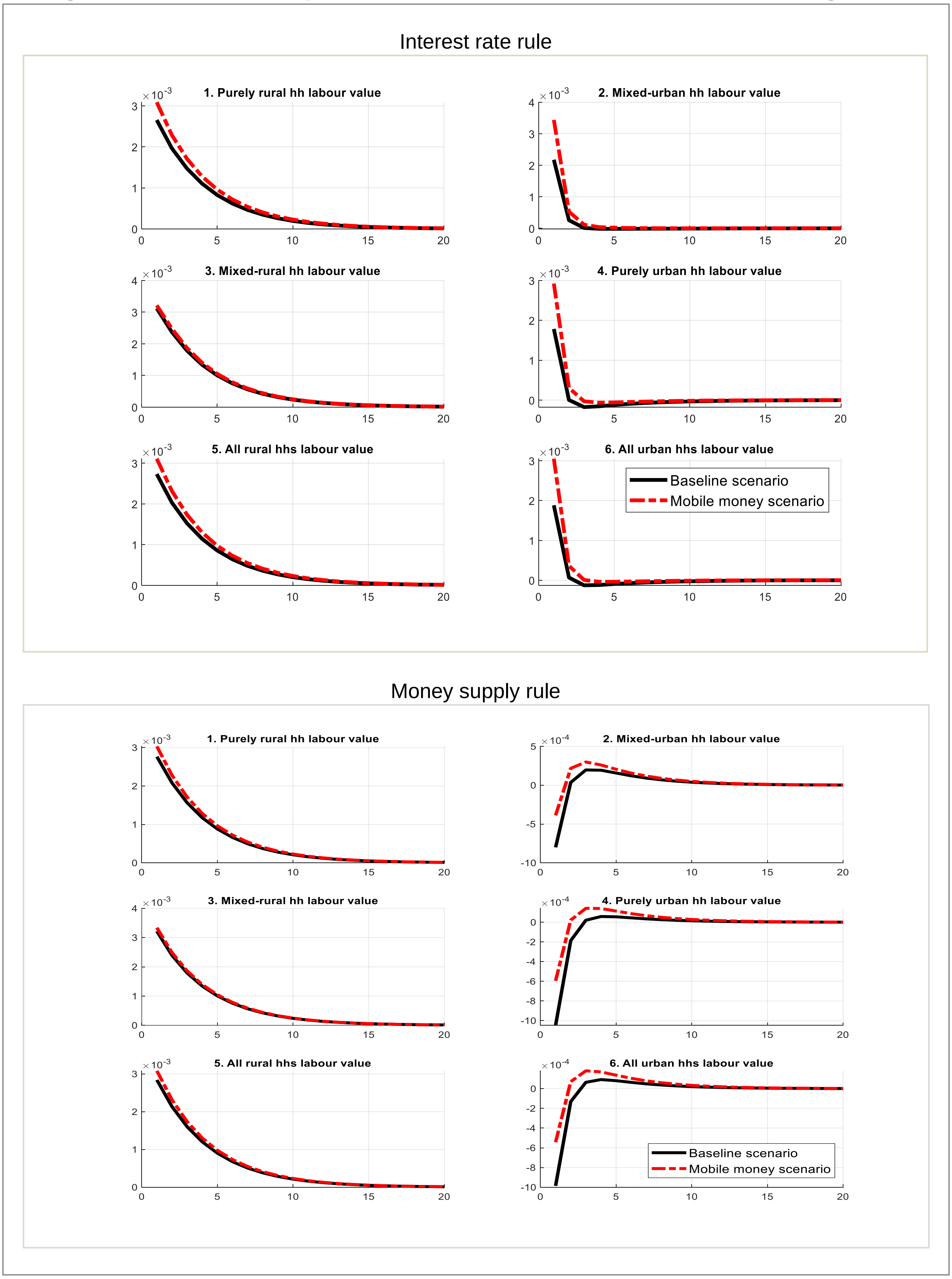


Figure E2F: Model 2 response of labour quantity and value in firms to non-farming shock

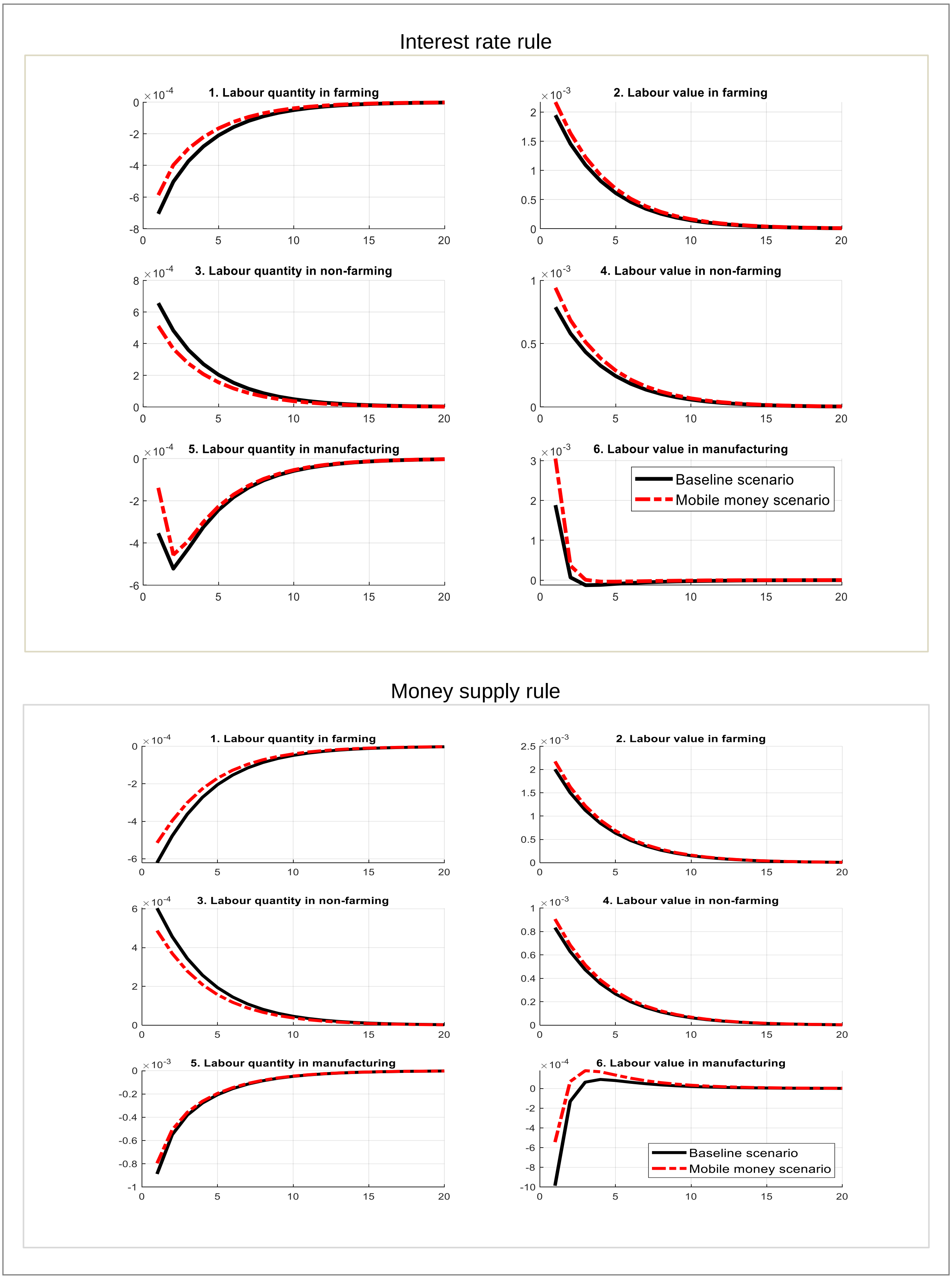


Figure E2G: Model 2 response of consumption to non-farming shock

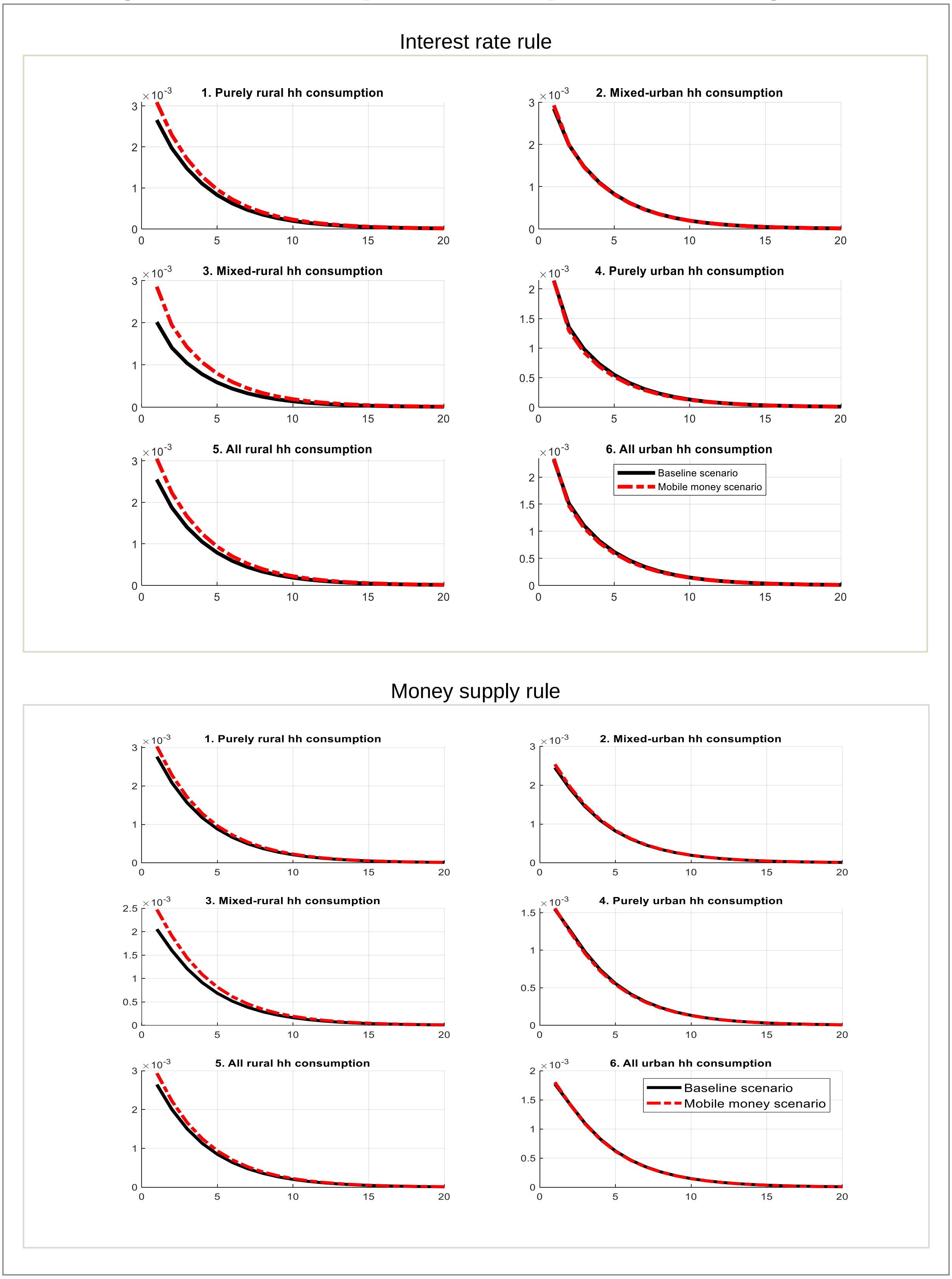


Figure E2H: Model 2 response of welfare to non-farming shock

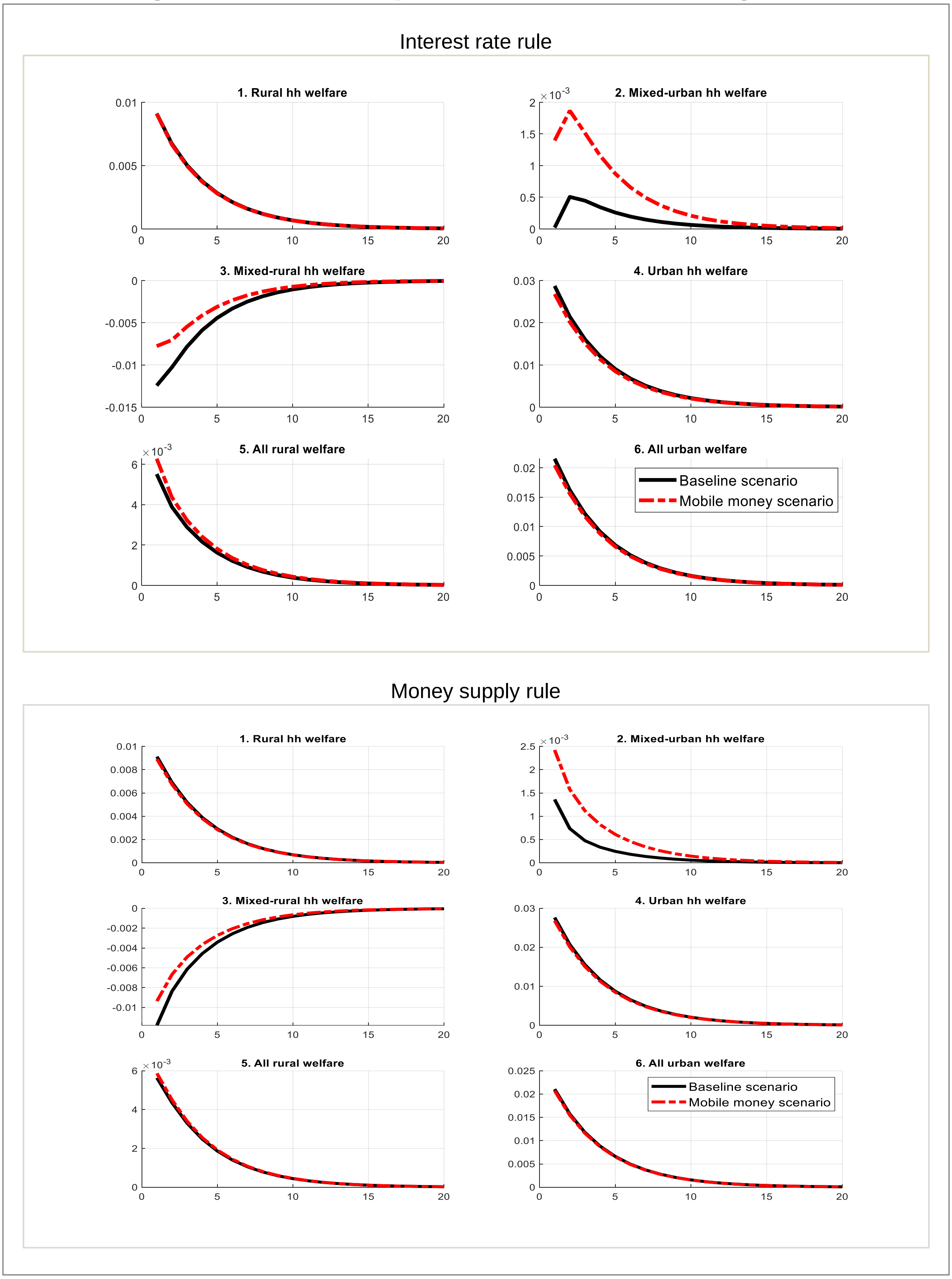


Figure E2I: Model 2 response of relative prices and wages to non-farming shock

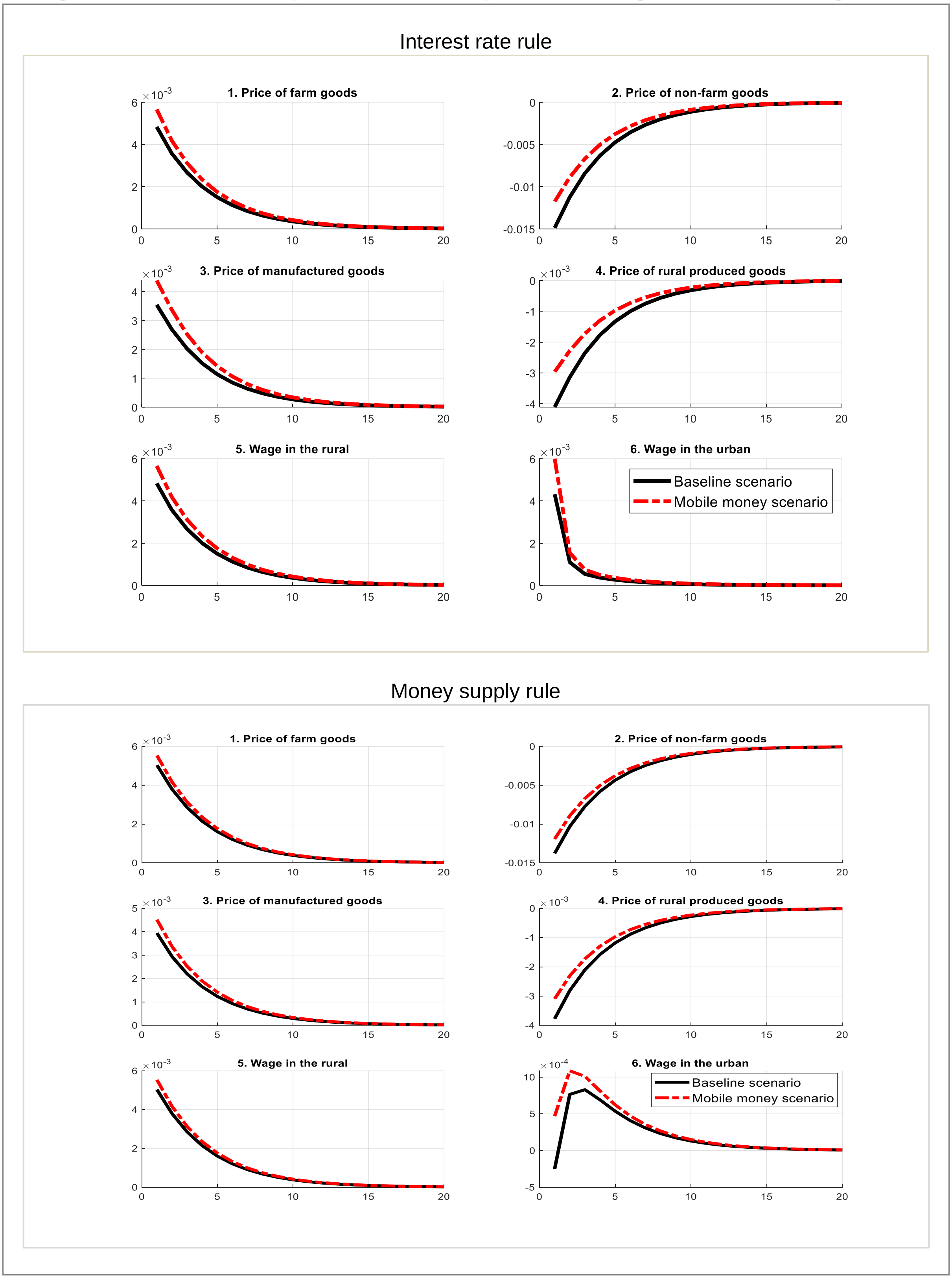
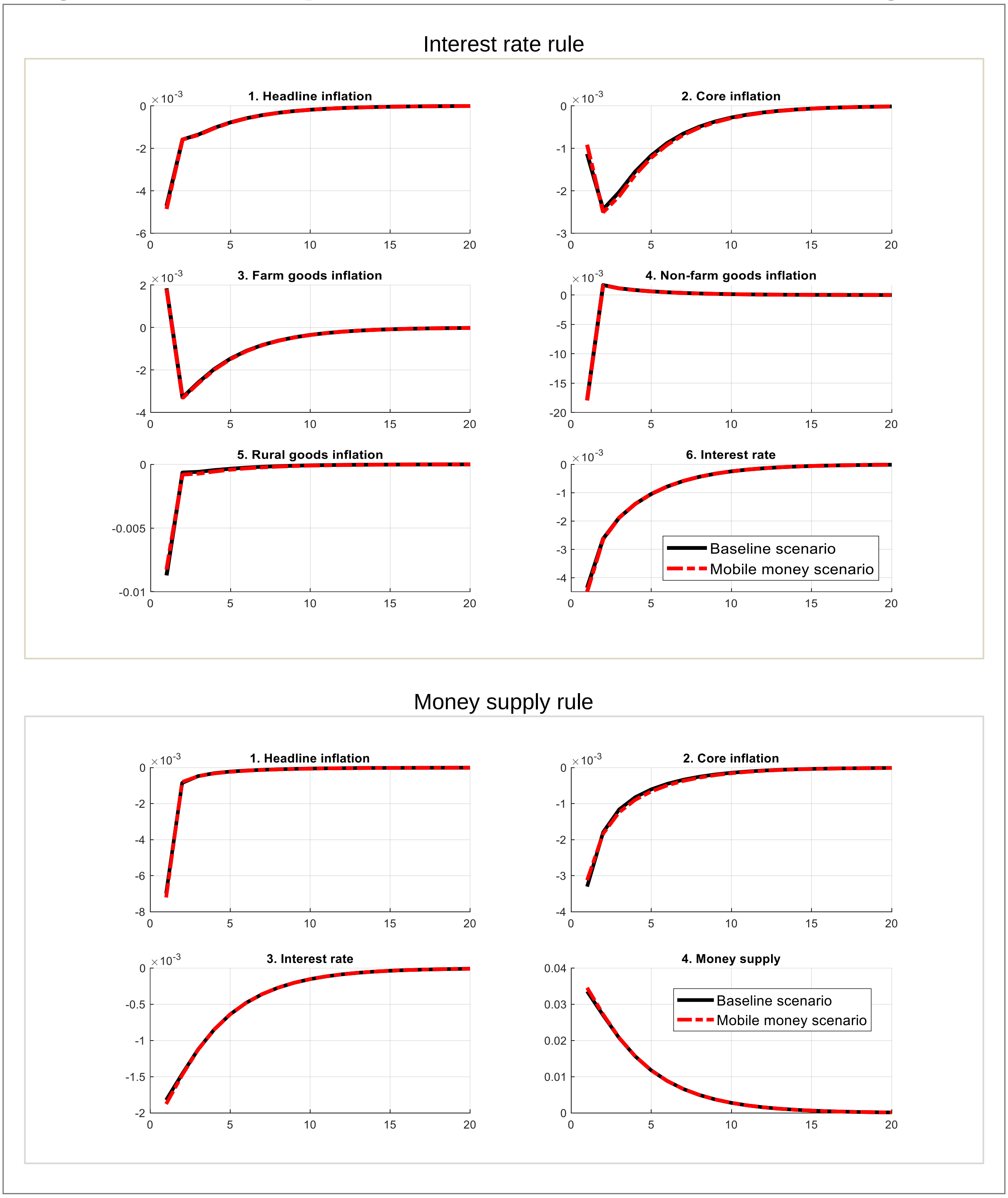


Figure E2J: Model 2 response of inflation and interest rate to non-farming shock



Model 2 comparison of IRR with MSR manufacturing shock IRFs

Figure E3A: Model 2 response of remittances and non-farm goods to manufacturing shock

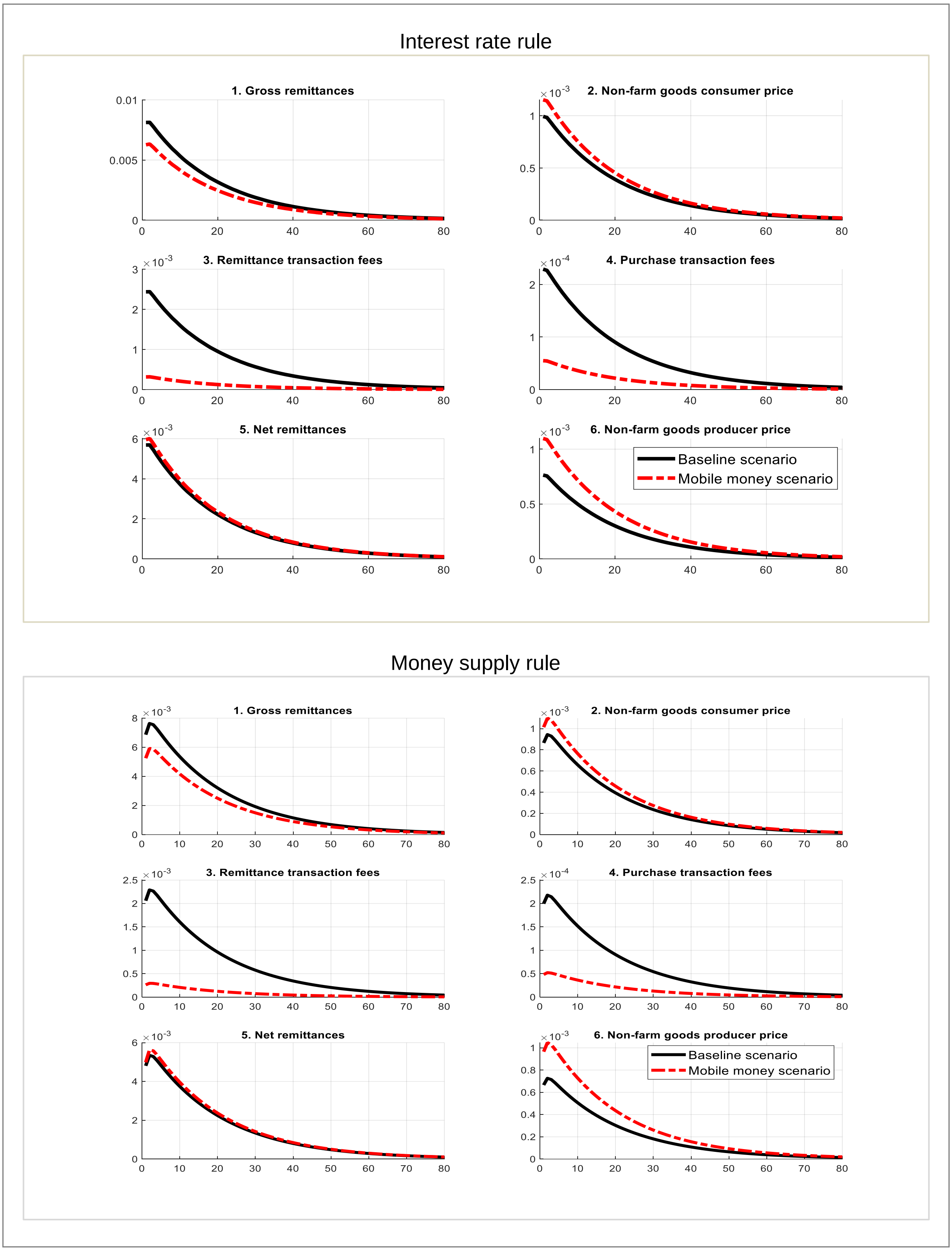
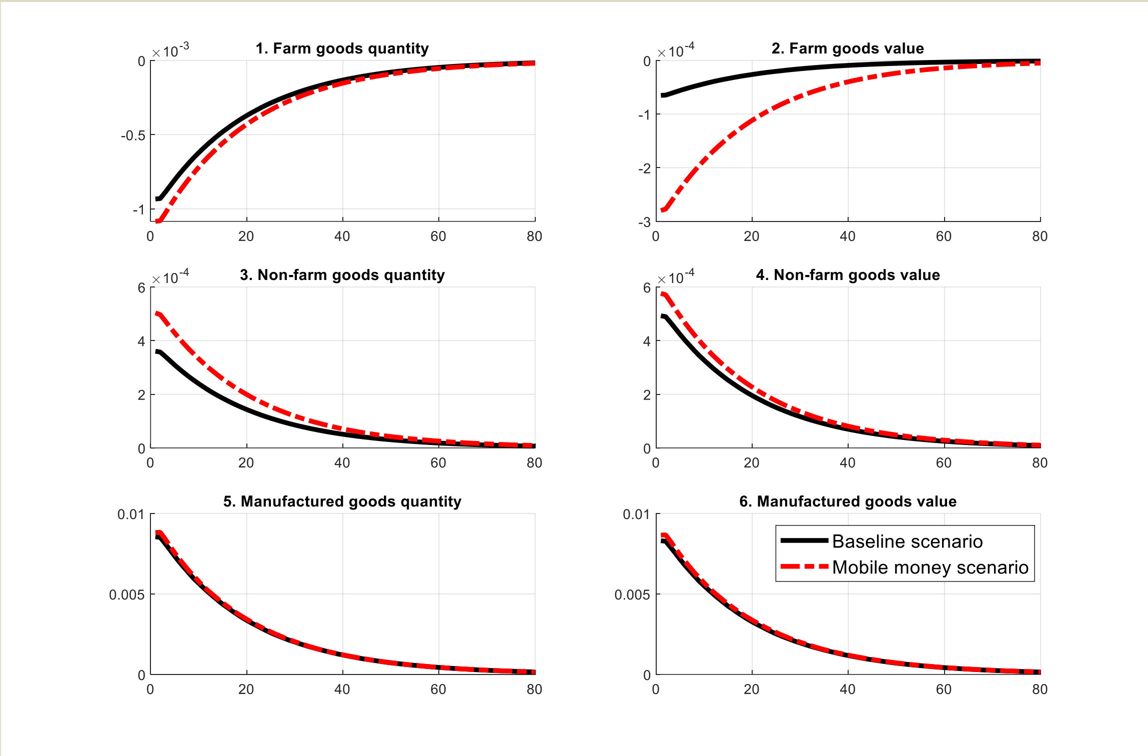


Figure E3B: Model 2 response of quantity and value of output to manufacturing shock

Interest rate rule



Money supply rule

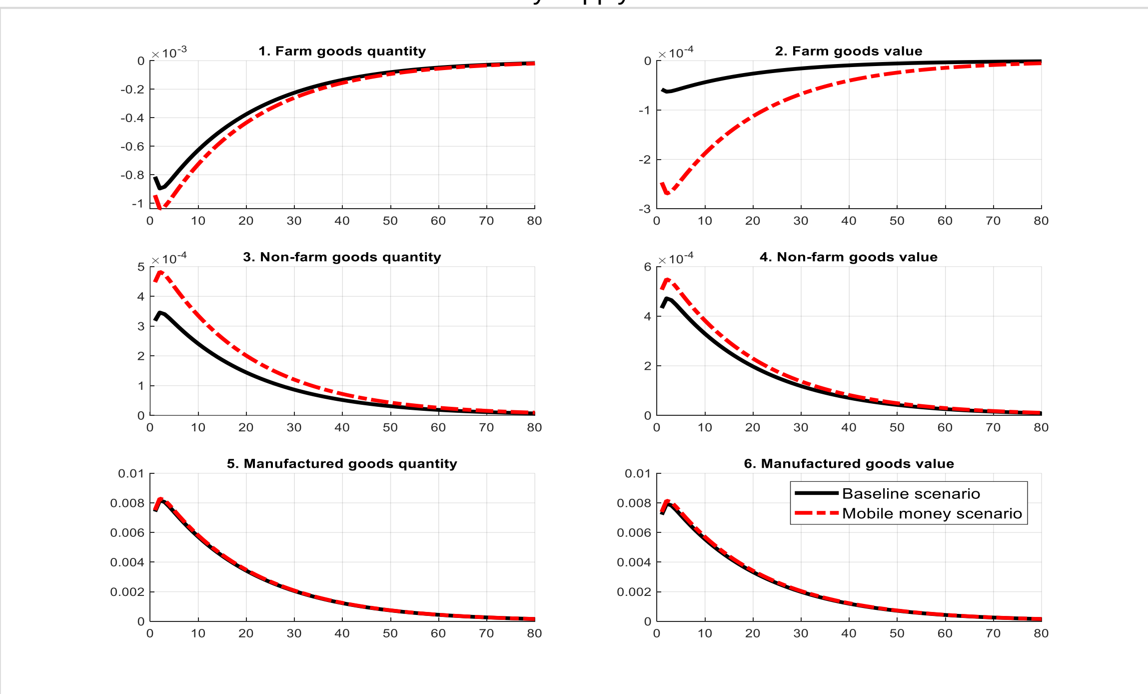


Figure E3C: Model 2 response of GDP aggregates to manufacturing shock

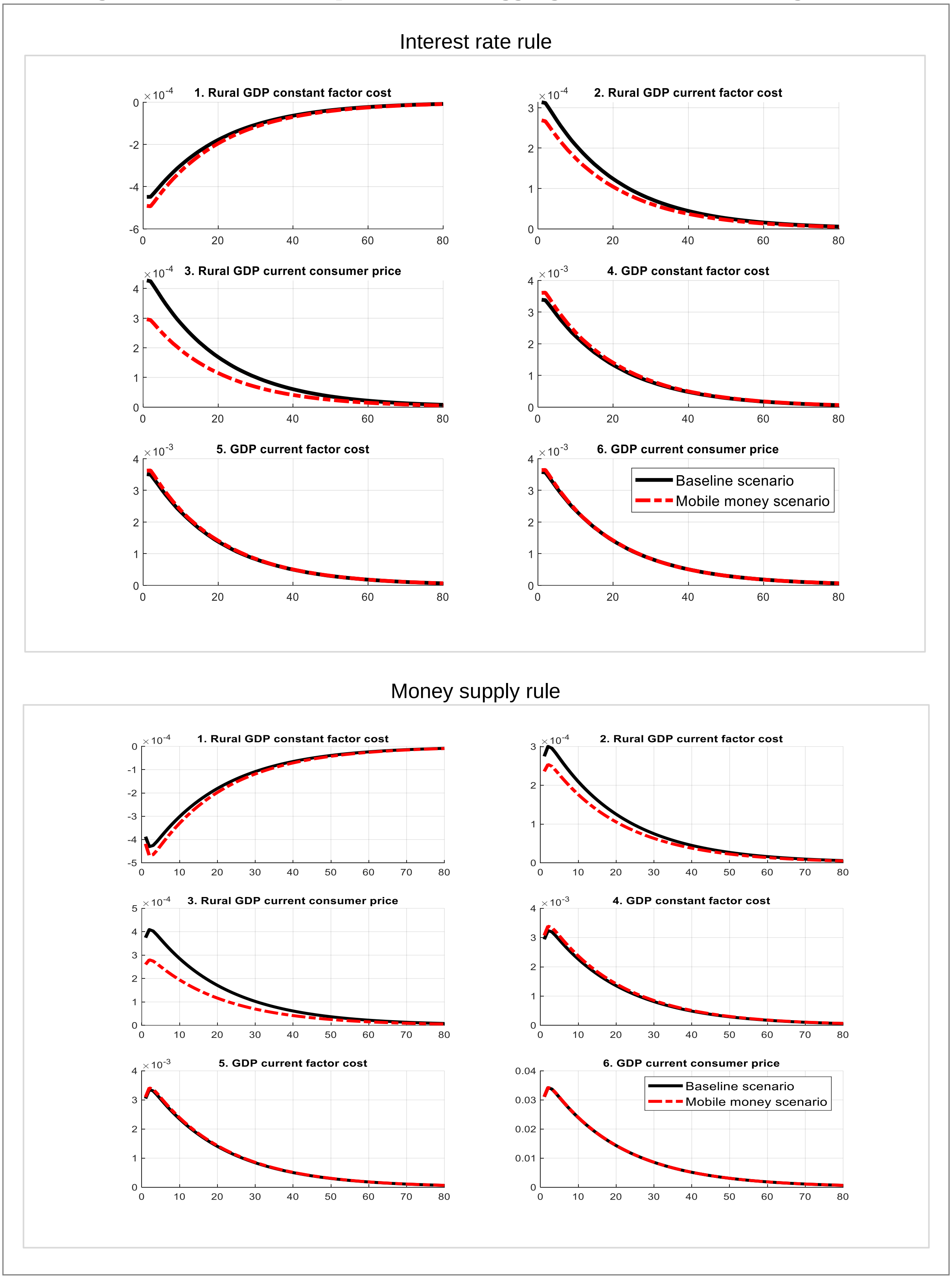


Figure E3D: Model 2 response of household labour quantity to manufacturing shock

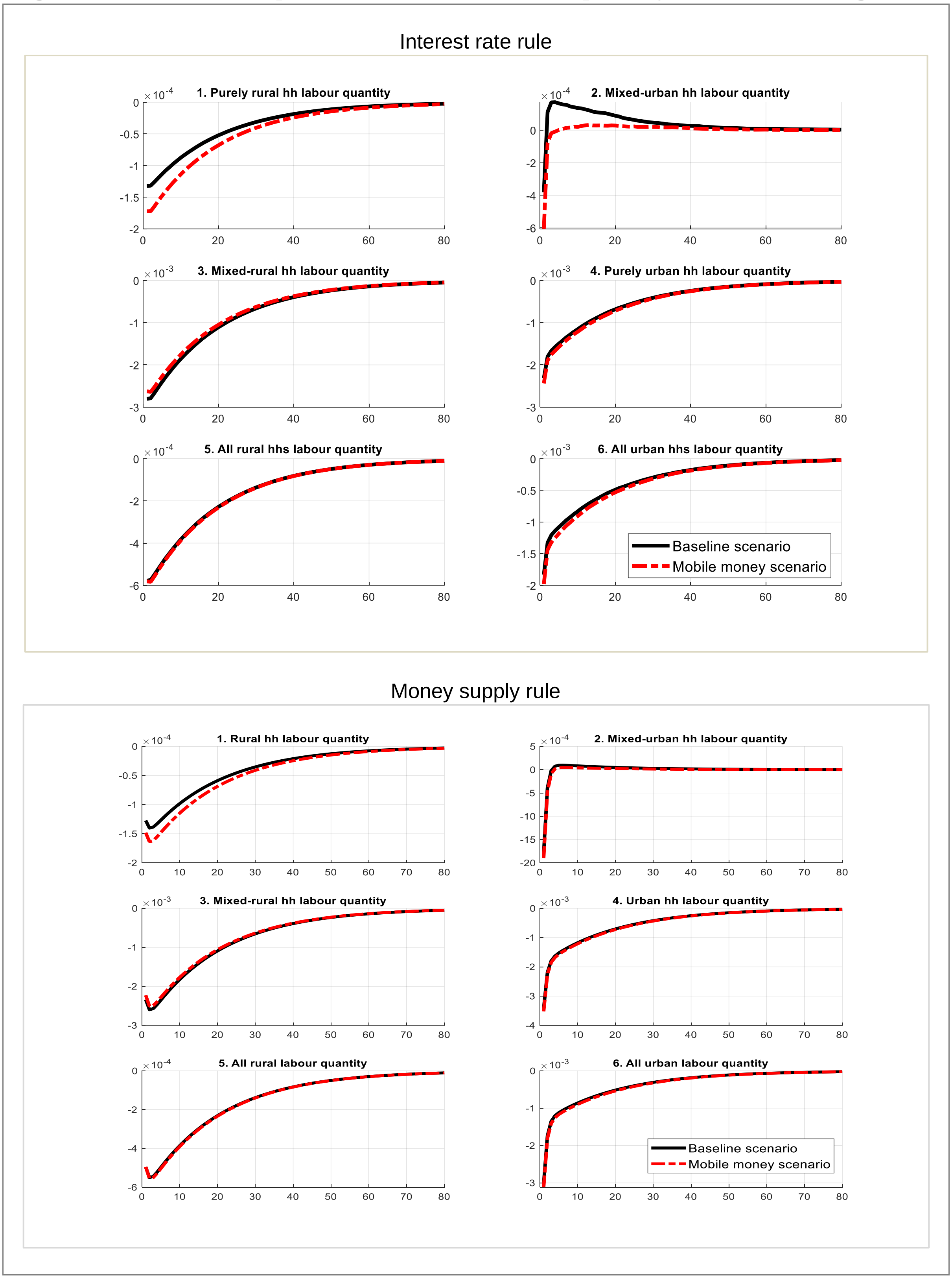


Figure E3E: Model 2 response of household labour value to manufacturing shock

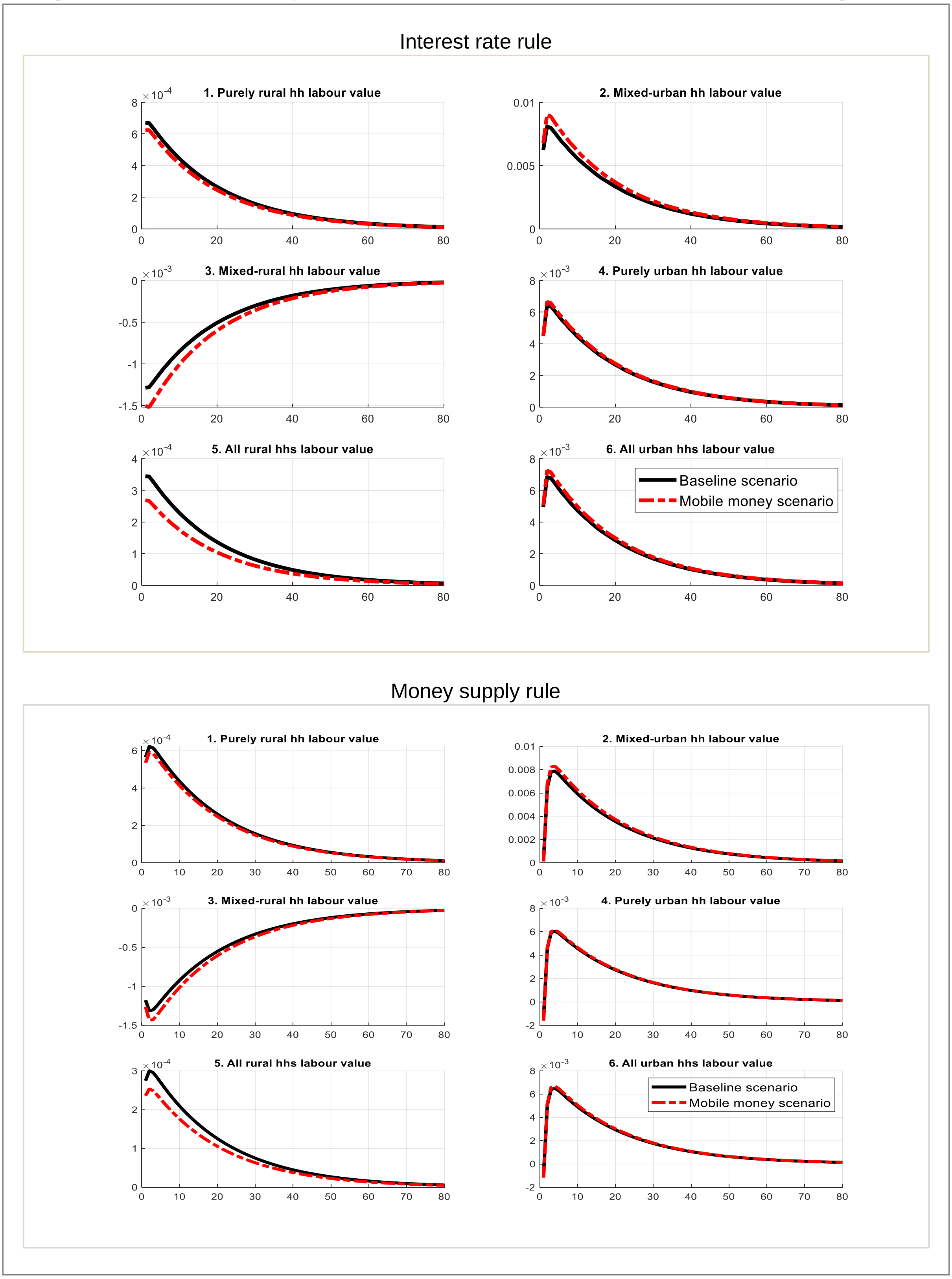


Figure E3F: Model 2 response of labour quantity and value in firms to manufacturing shock

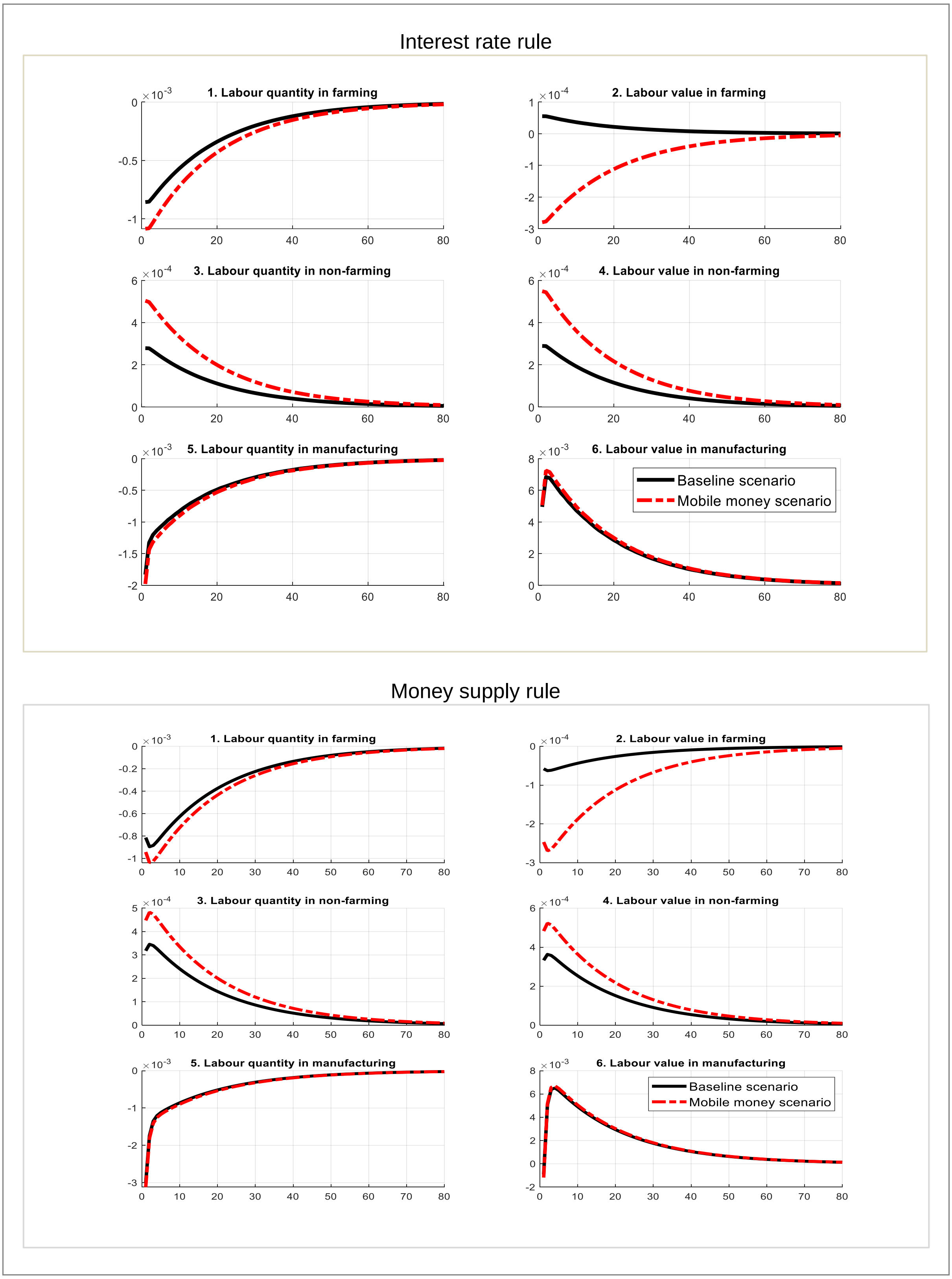


Figure E3G: Model 2 response of consumption to manufacturing shock

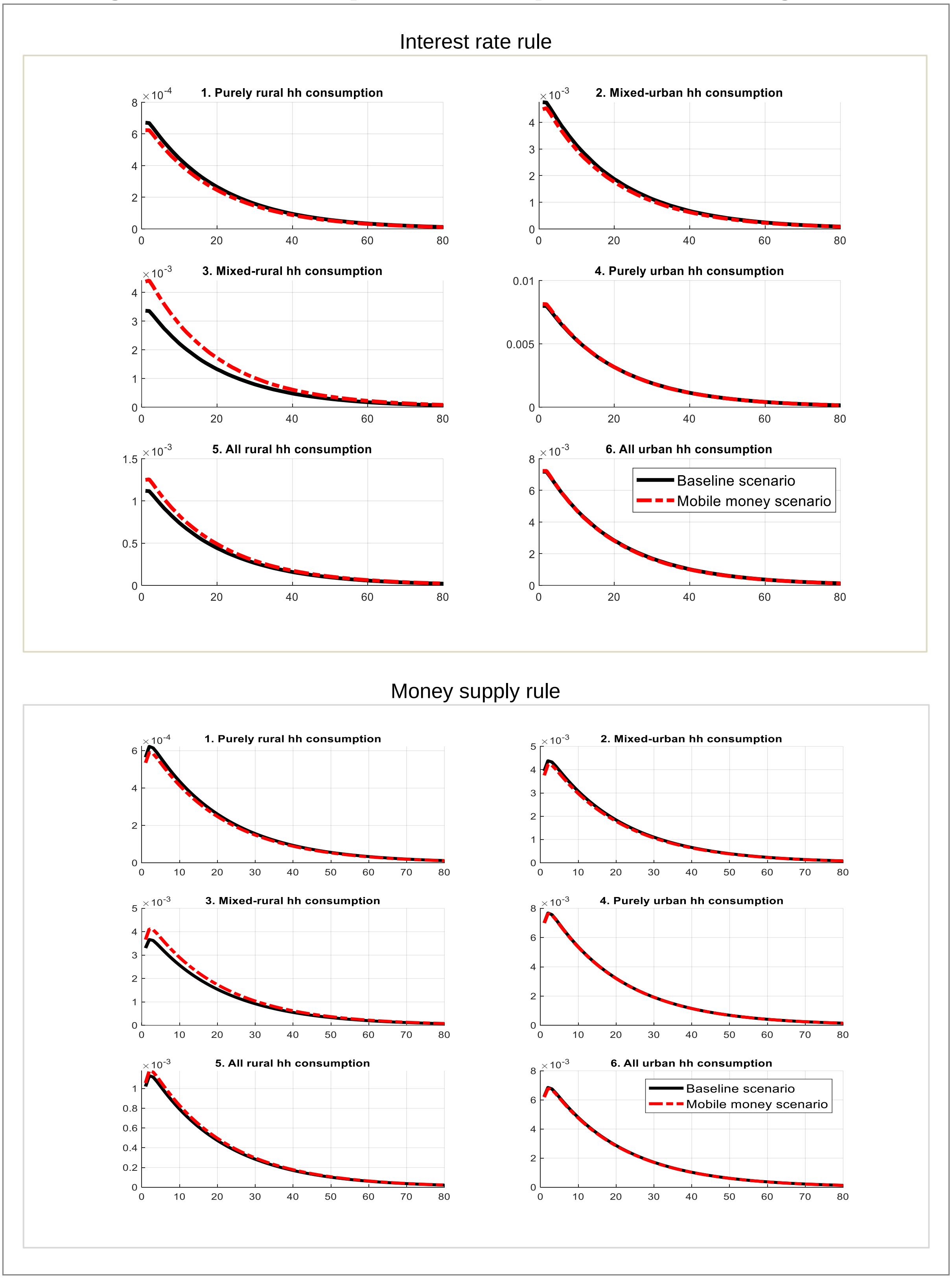


Figure E3H: Model 2 response of welfare to manufacturing shock

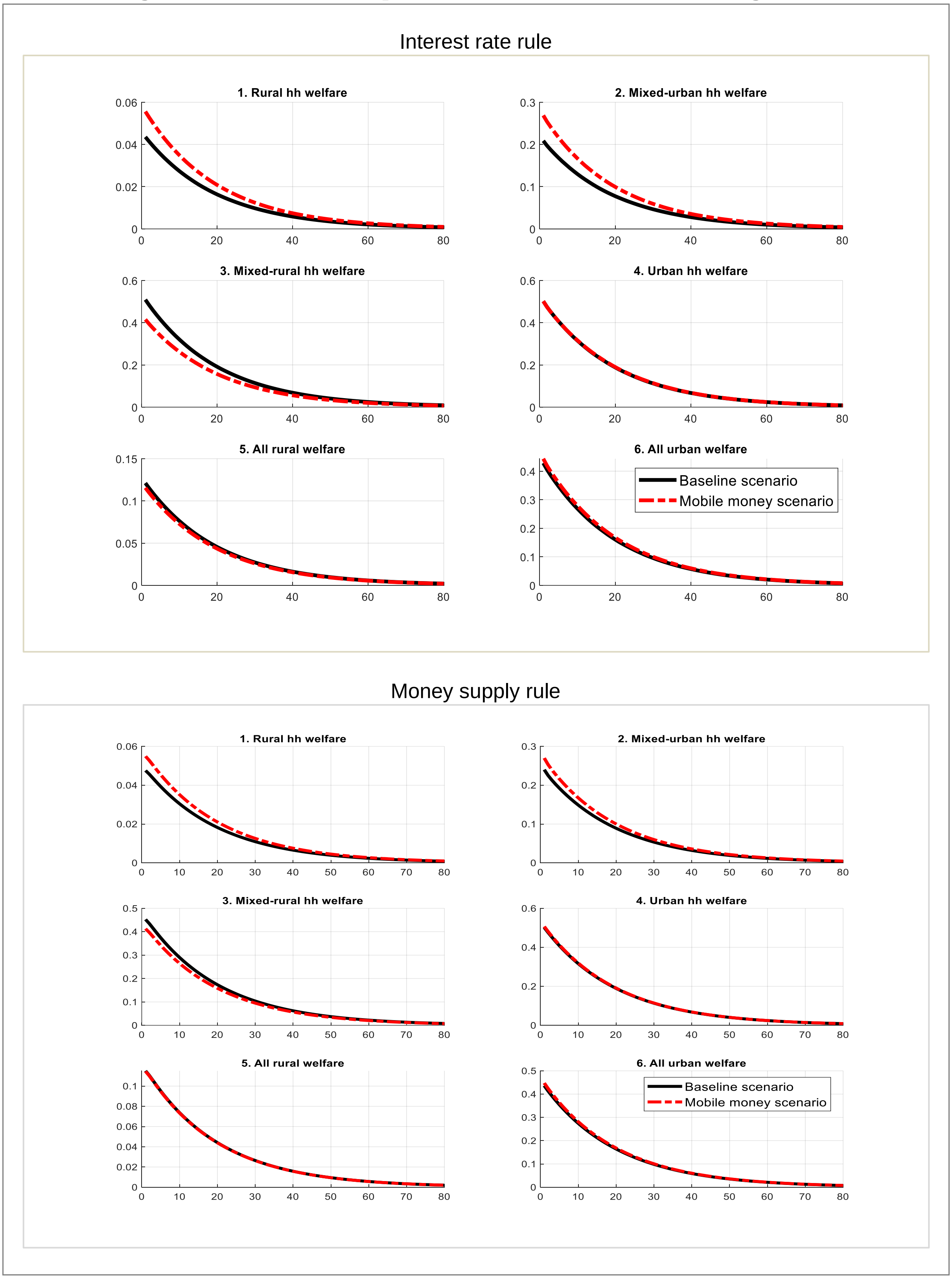
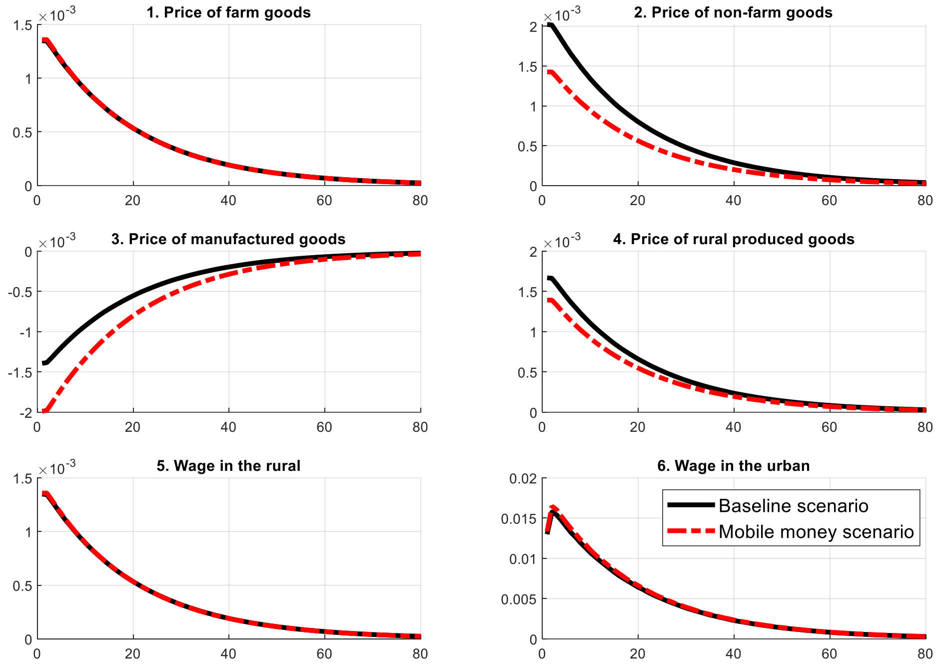


Figure E3I: Model 2 response of relative prices and wages to manufacturing shock

Interest rate rule



Money supply rule

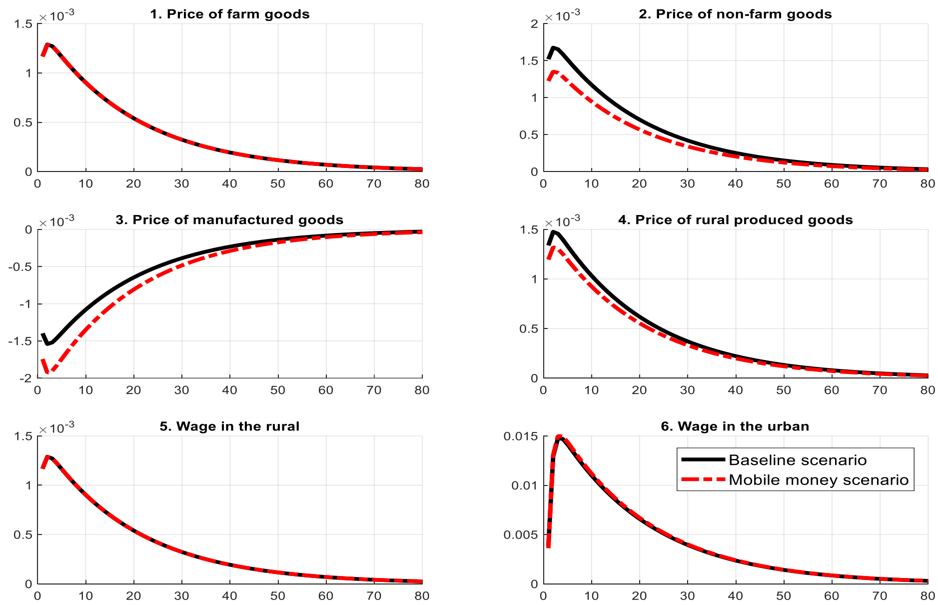
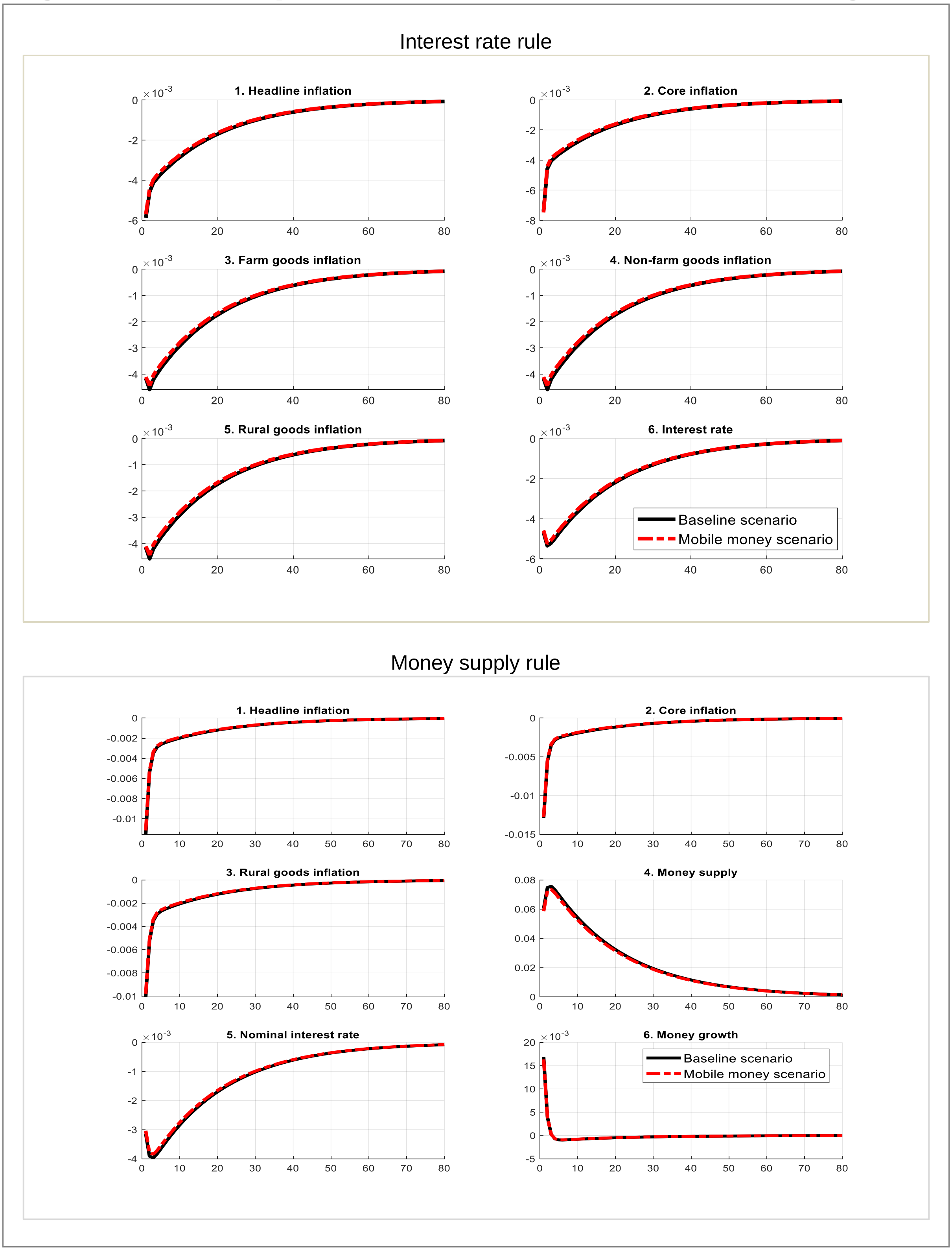


Figure E3J: Model 2 response of inflation and interest rate to manufacturing shock



Model 2 impulse responses to policy shock

Figure E4A: Model 2 response of remittances and non-farm goods to policy shock

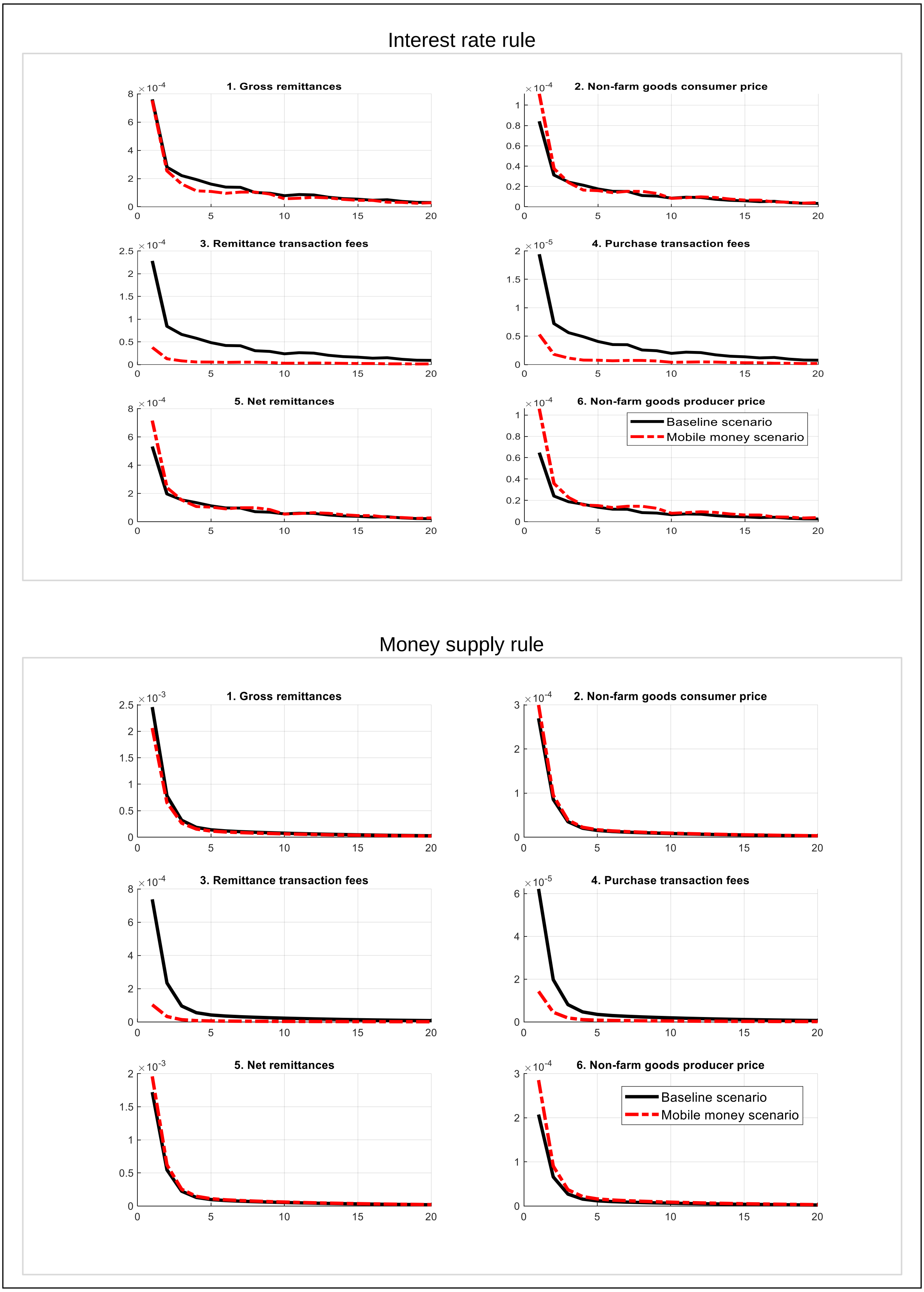


Figure E4B: Model 2 response of quantity and value output to policy shock

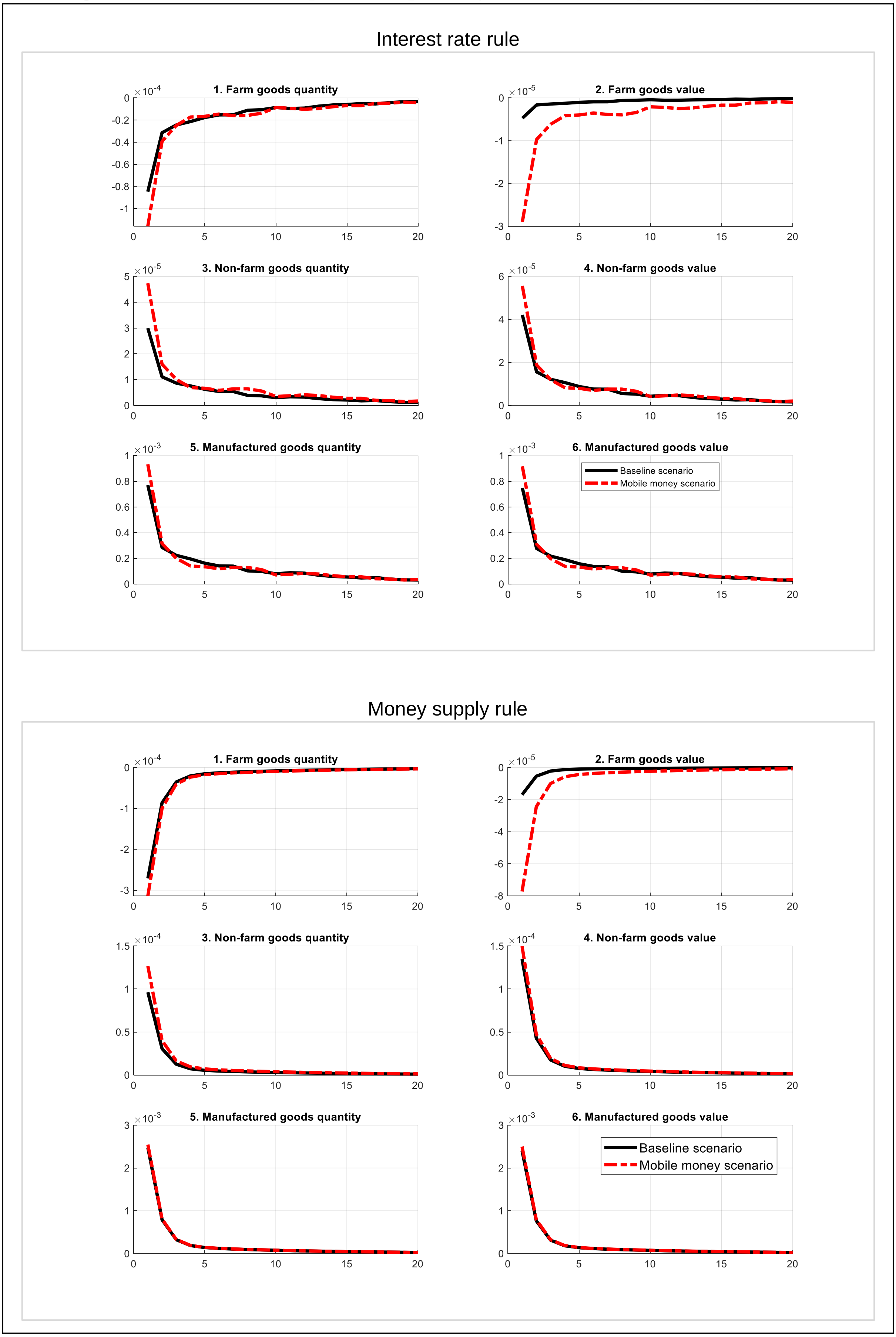


Figure E4C: Model 2 response of GDP aggregates to policy shock

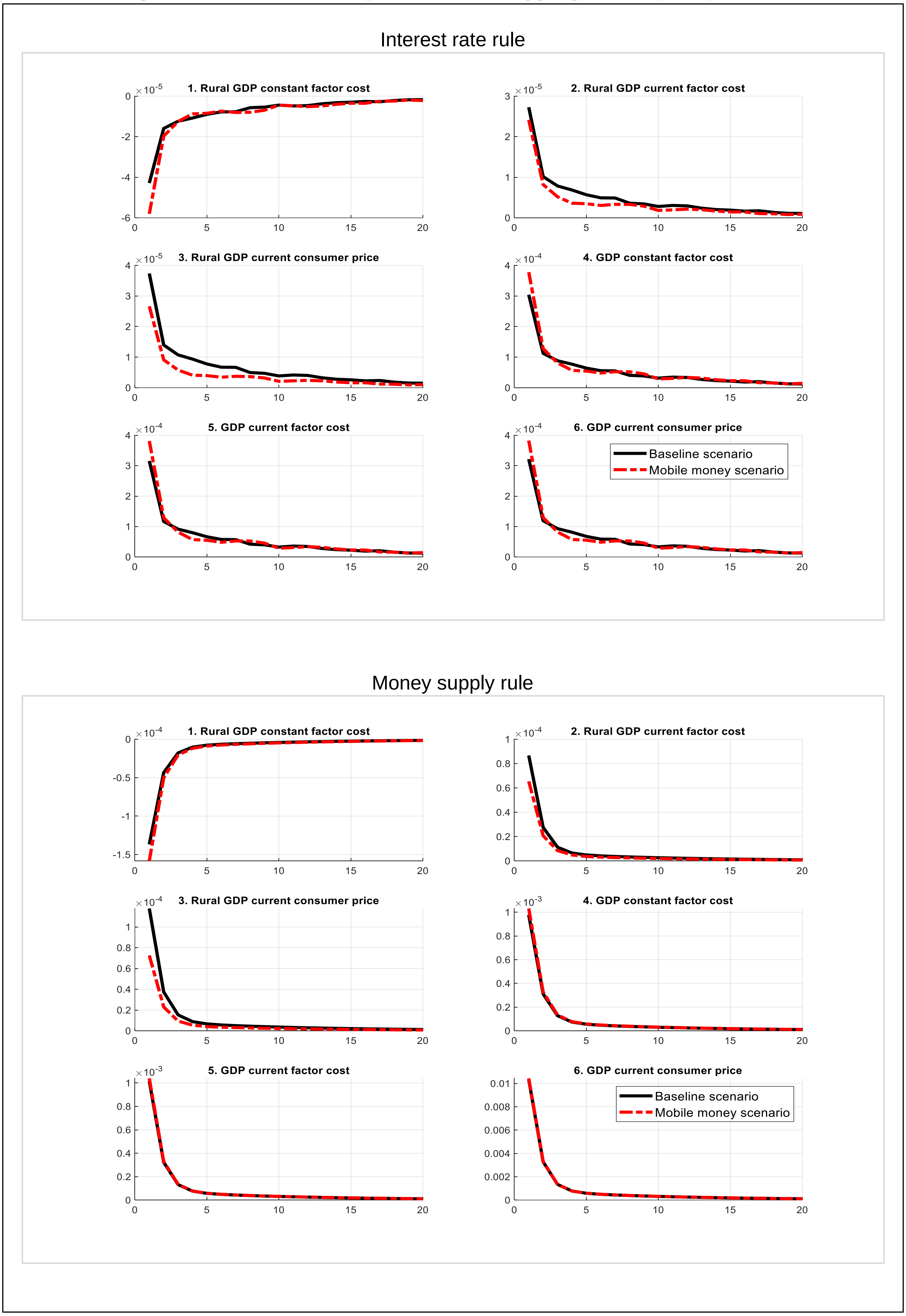


Figure E4D: **Model 2 r**esponse of household labour quantity to policy shock

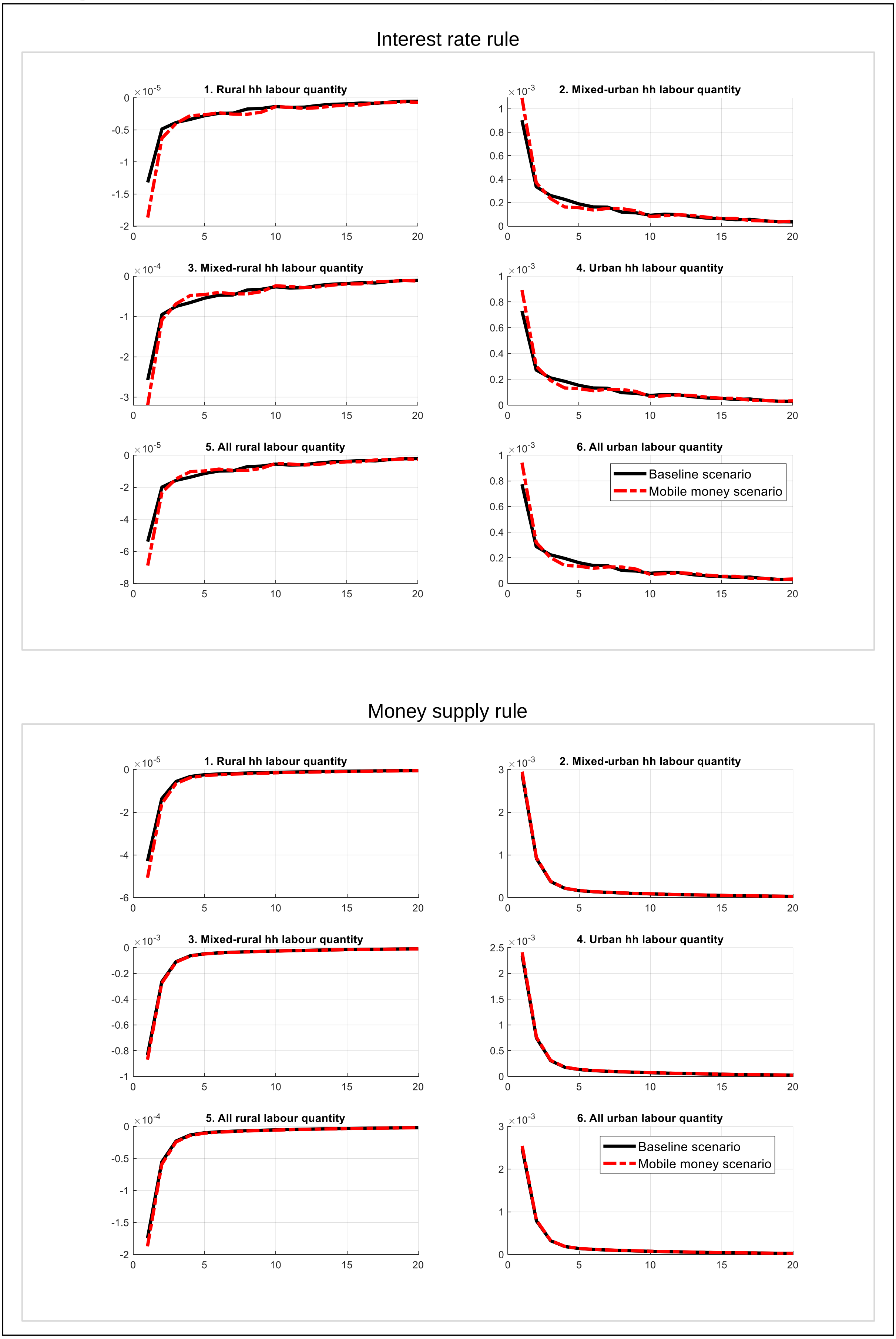


Figure E4E: Model 2 response of household labour value to policy shock

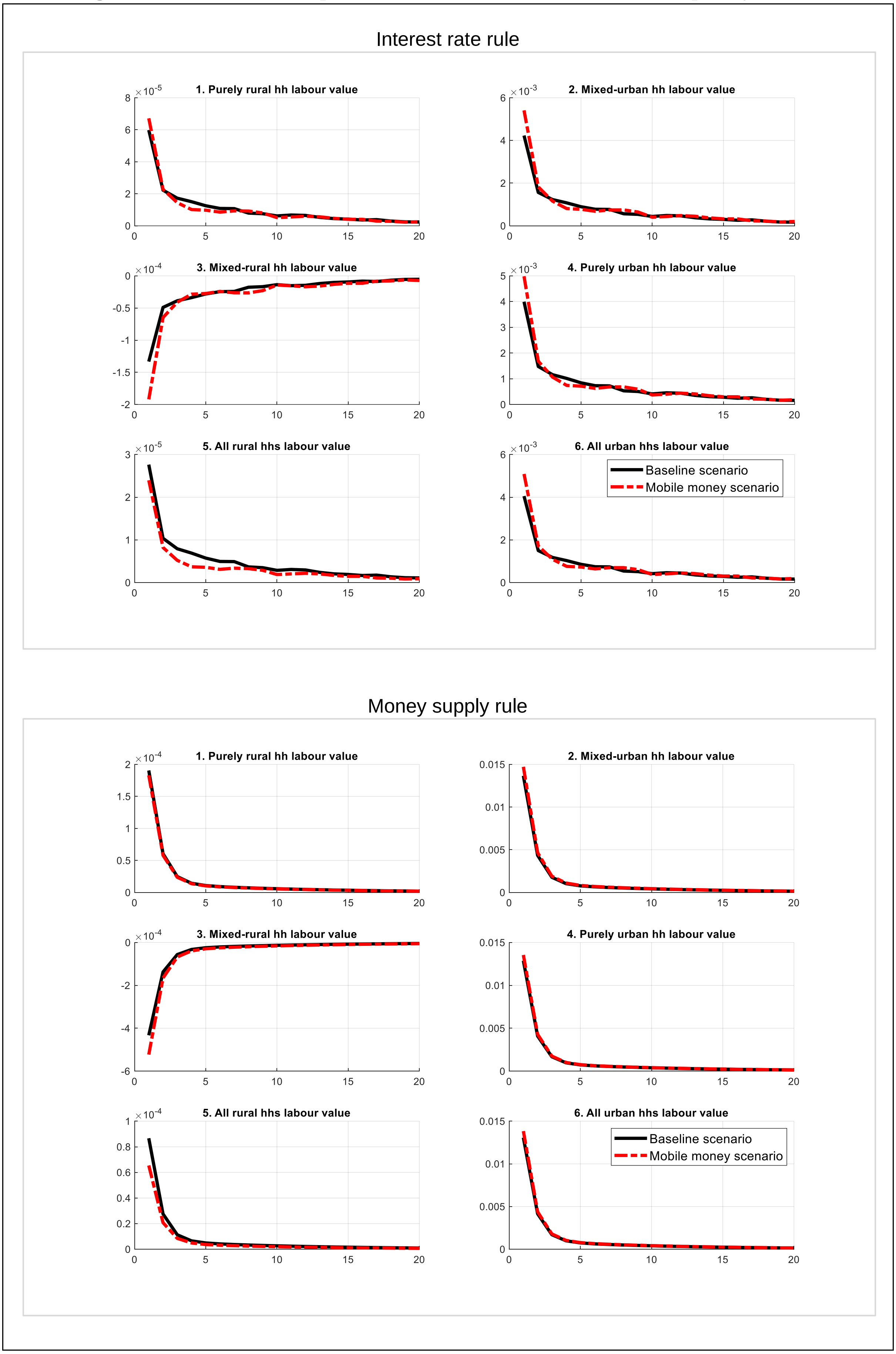


Figure E4F: Model 2 response of labour quantity and value in firms to policy shock

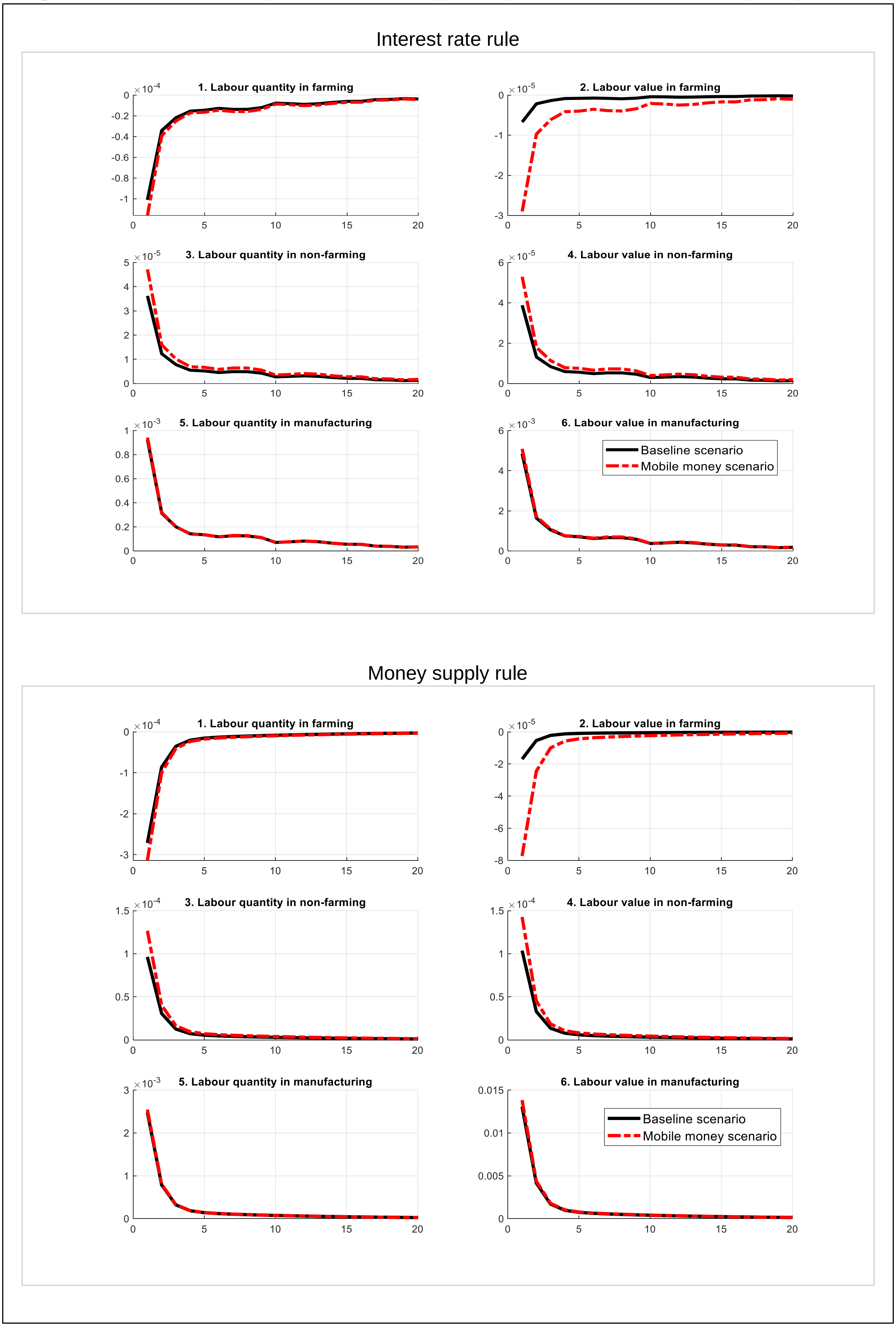


Figure E4G: Model 2 response of consumption to policy shock

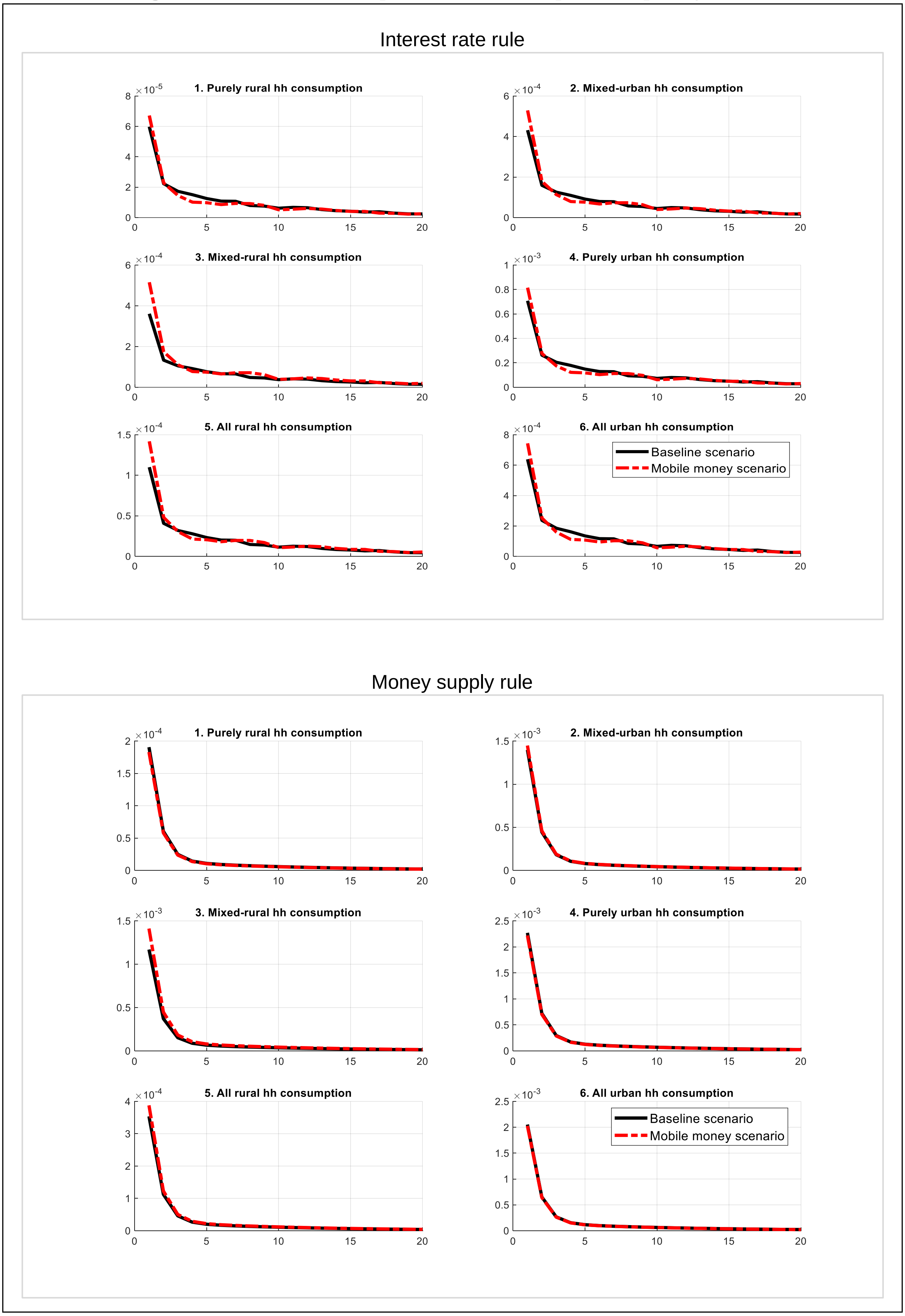


Figure E4H: **Model 2 r**esponse of welfare to policy shock

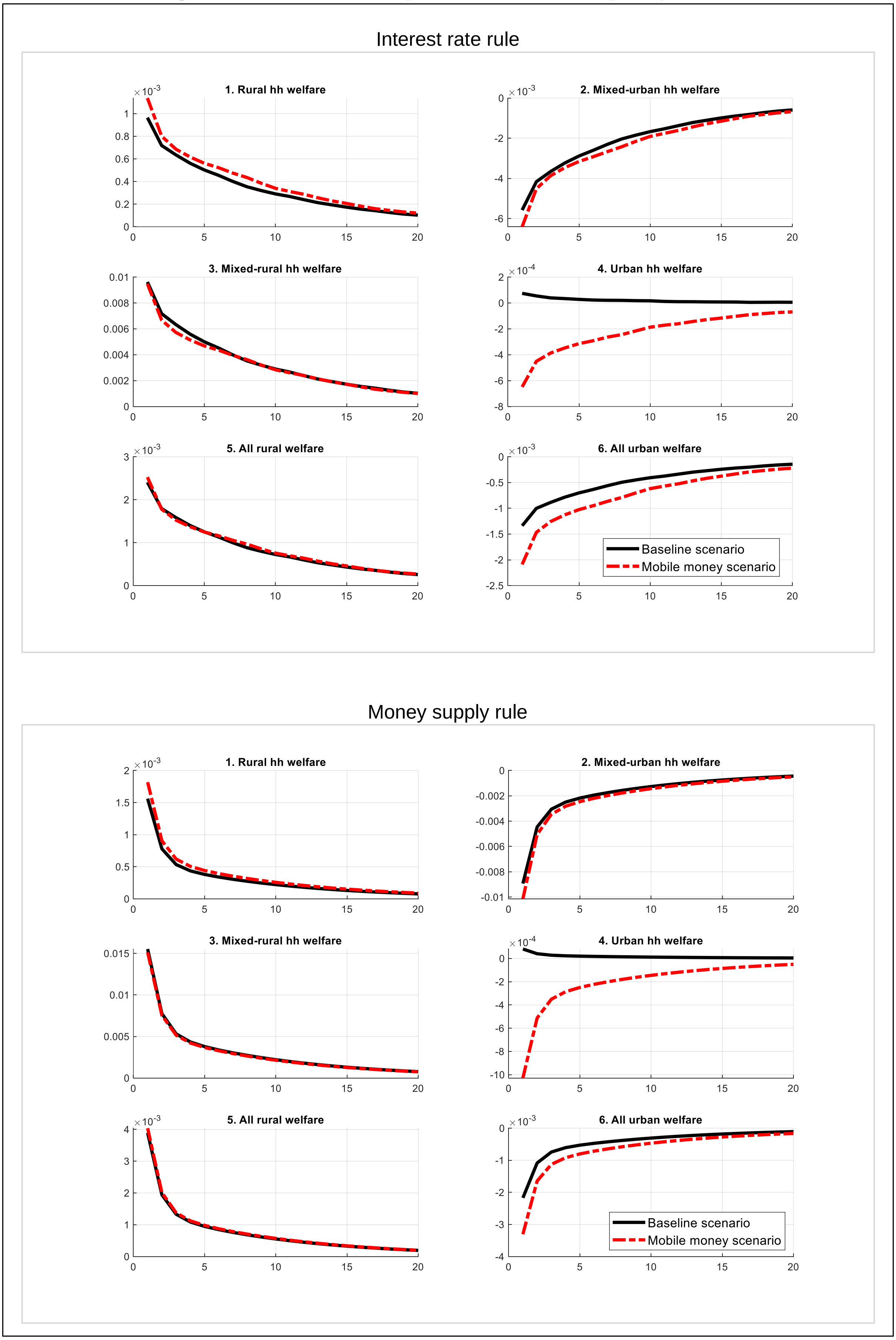
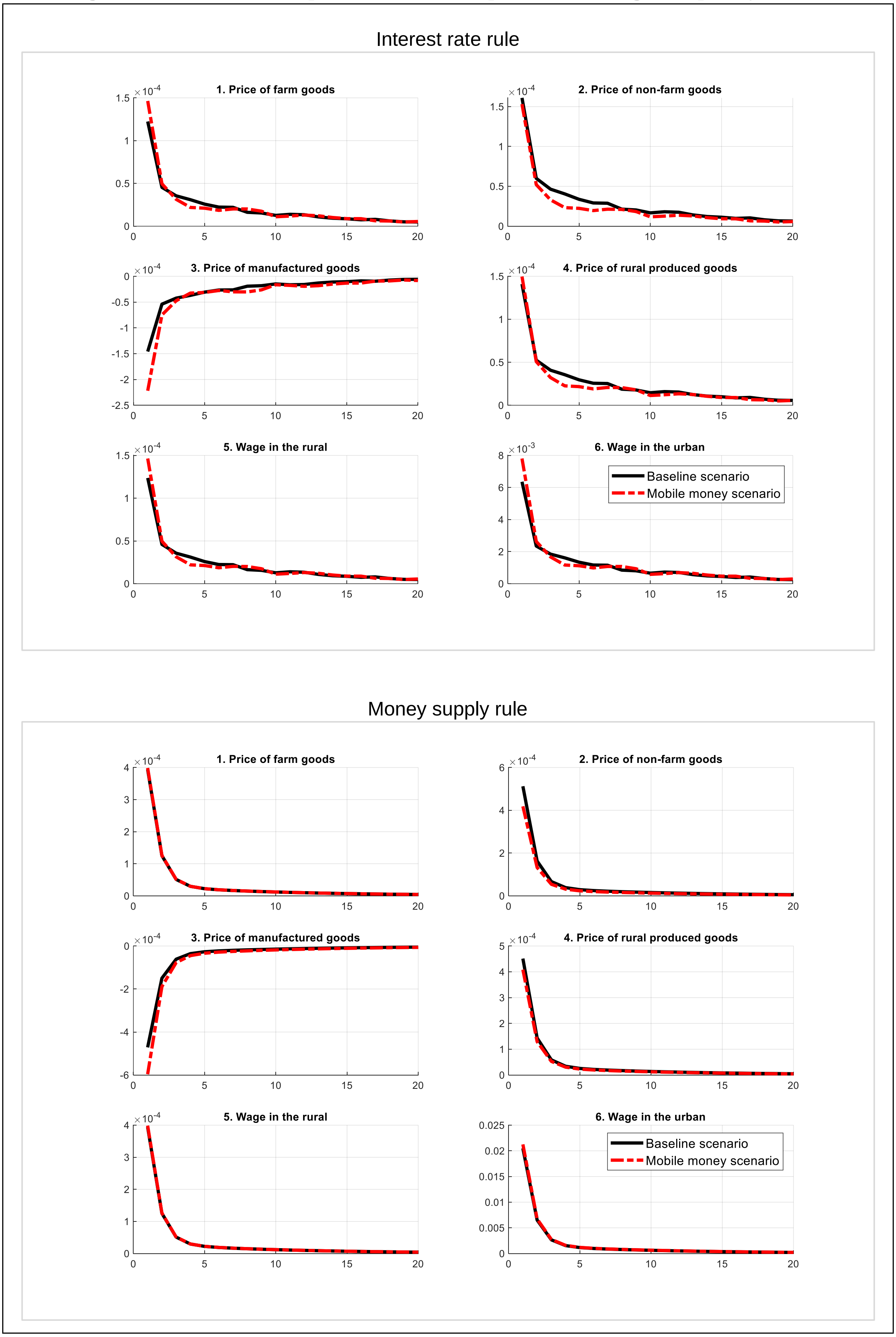


Figure E4I: Model 2 response of relative prices and wages to policy shock



Model 3 comparison of IRR with MSR farming shock IRFs

Figure E5A: Model 3 response of remittances and non-farm goods to farming shock

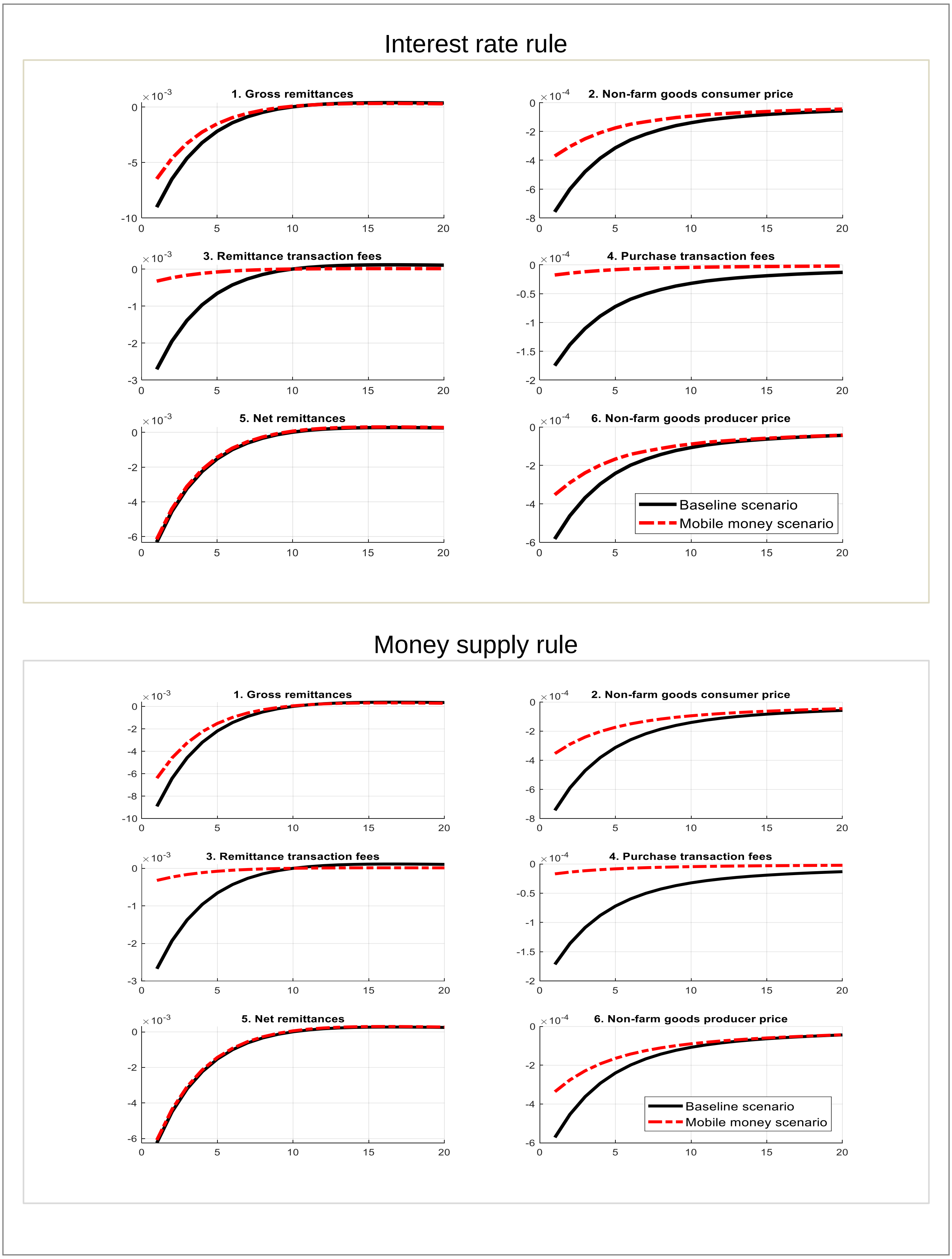


Figure E5B: Model 3 response of quantity and value output to farming shock

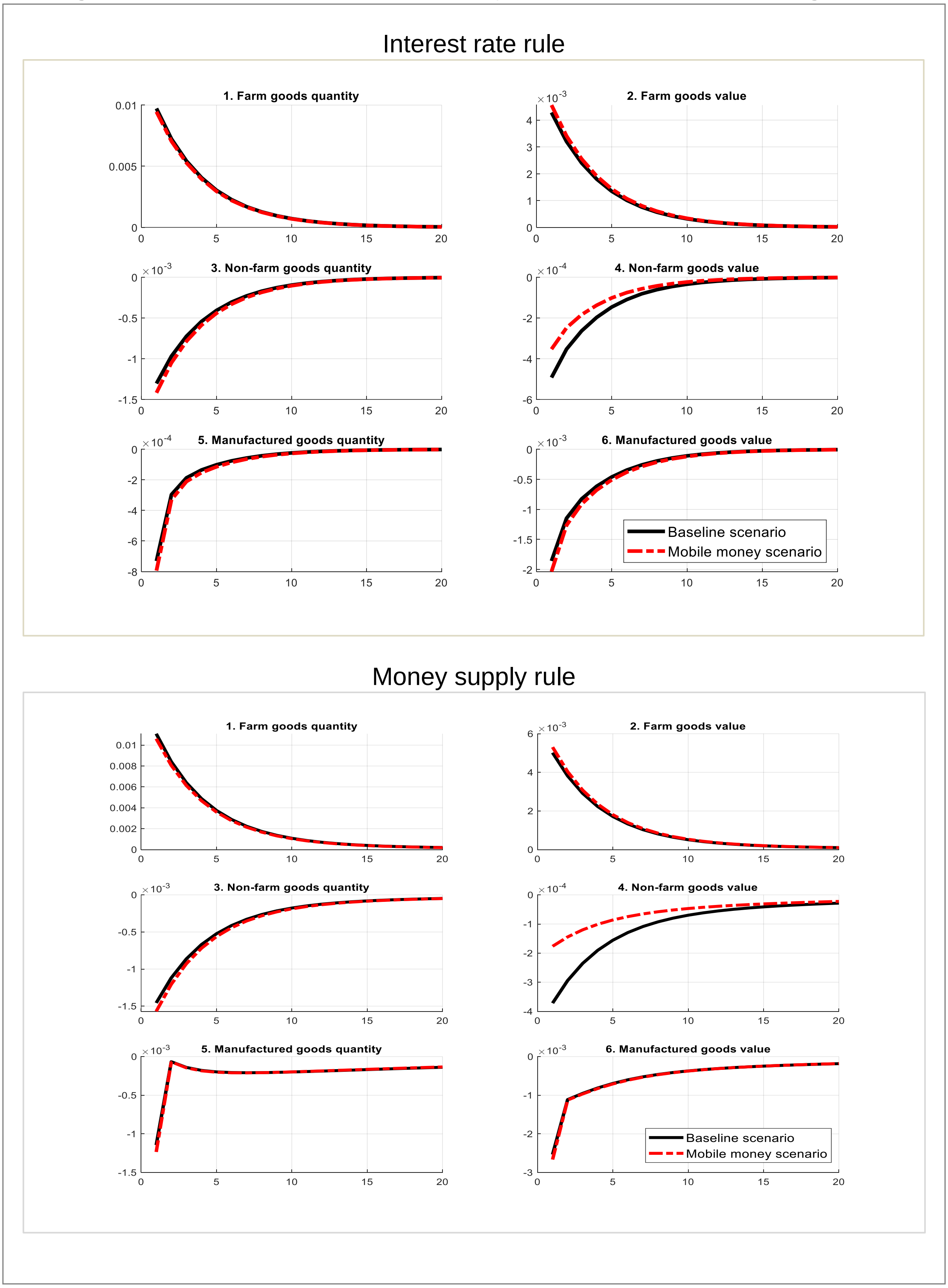


Figure E5C: Model 3 response of GDP aggregates to farming shock

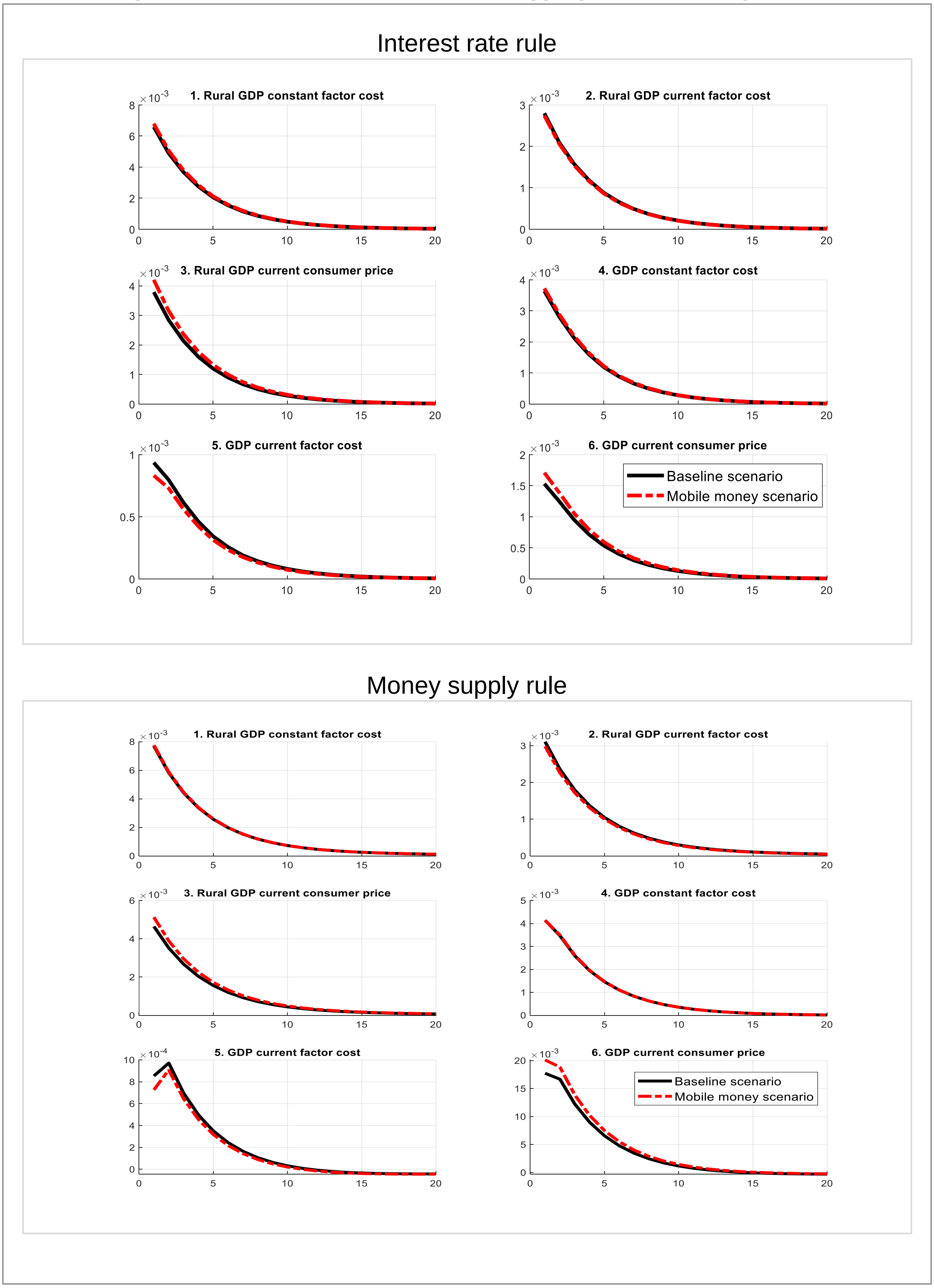


Figure E5D: Model 3 response of household labour quantity to farming shock

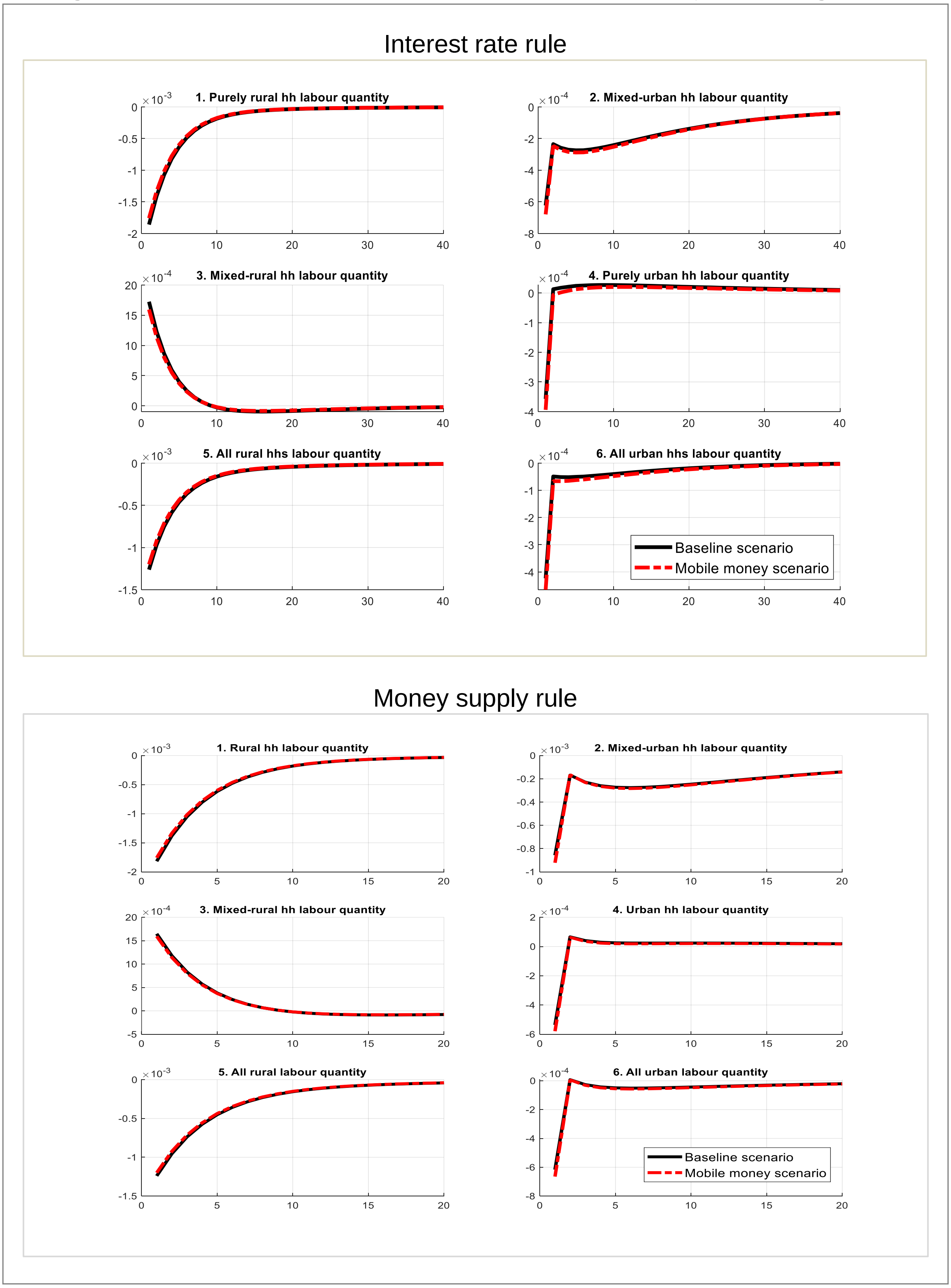


Figure E5E: Model 3 response of household labour value to farming shock

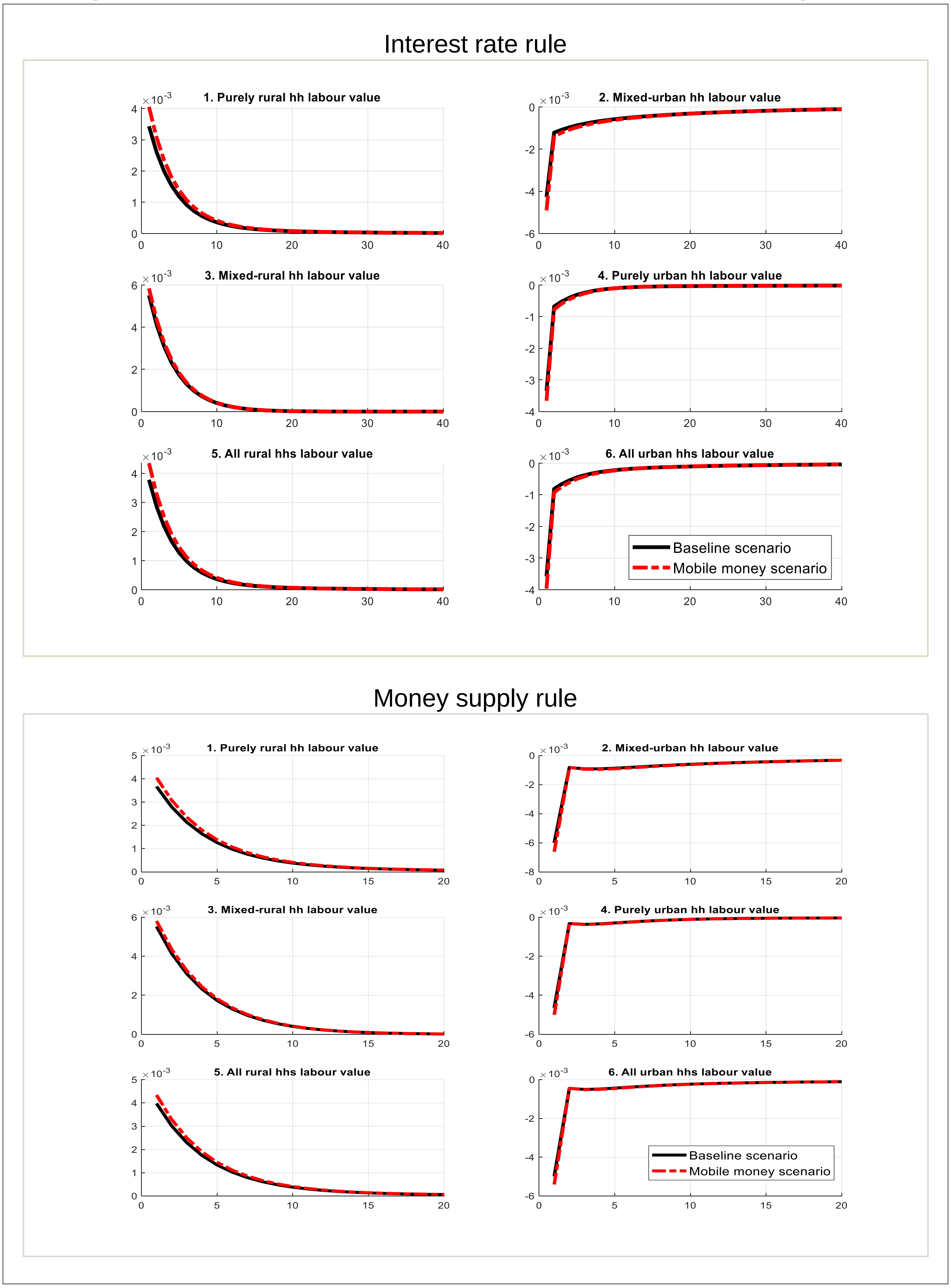


Figure E5F: Model 3 response of labour quantity and value in firms to farming shock

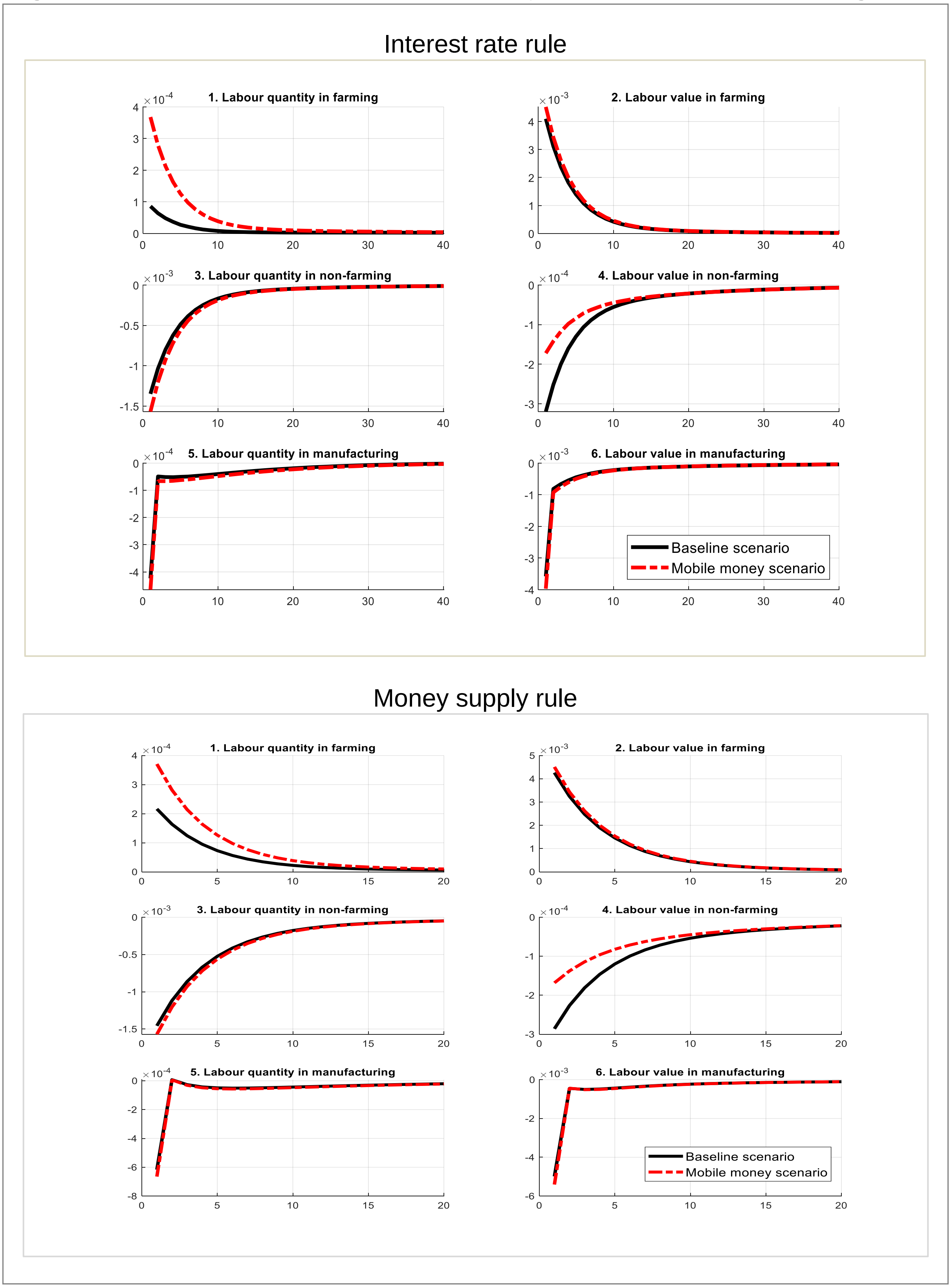


Figure E5G: Model 3 response of consumption to farming shock

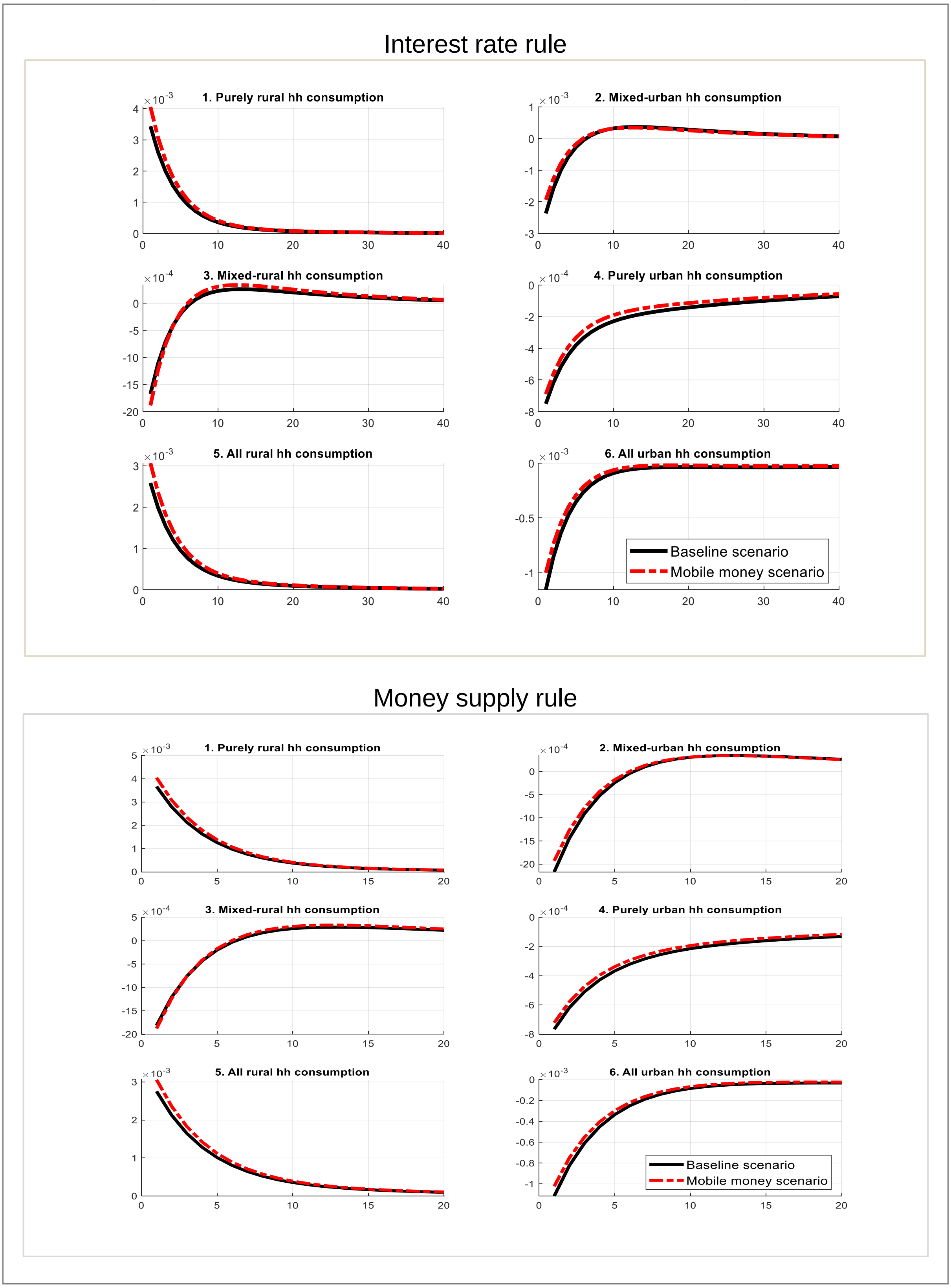


Figure E5H: Model 3 response of welfare to farming shock

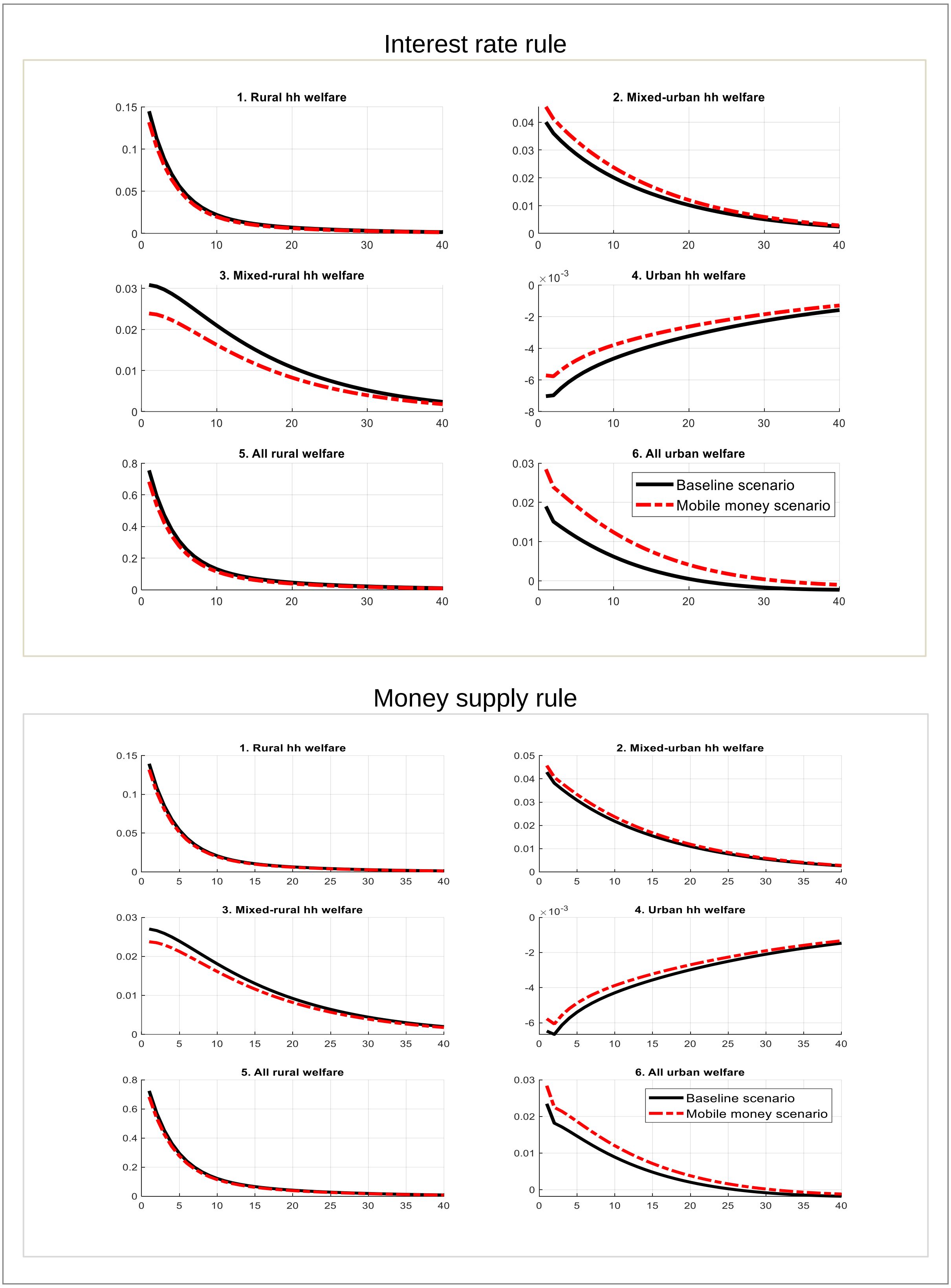


Figure E5I: Model 3 response of relative prices and wages to farming shock

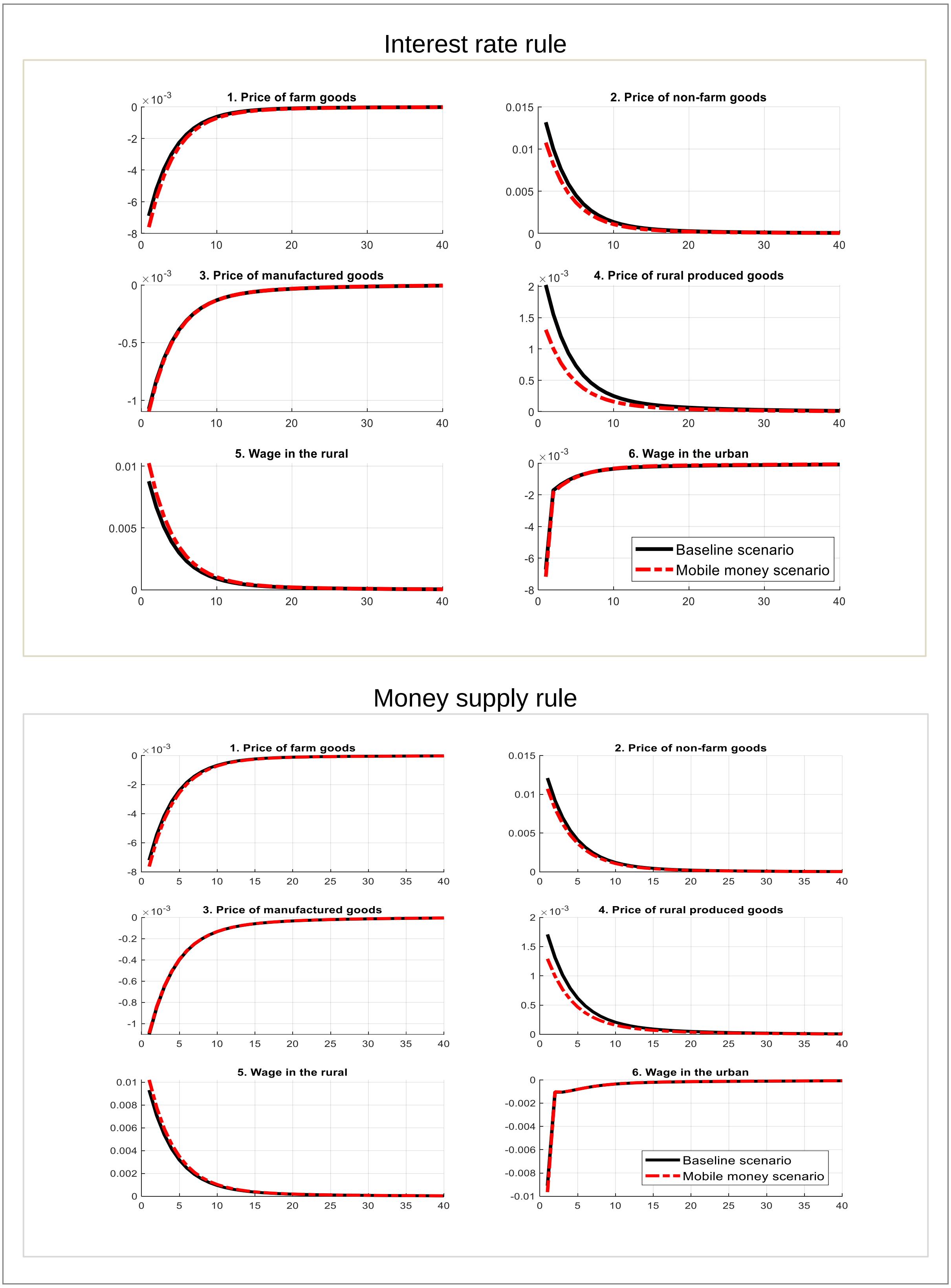


Figure E5J: Model 3 response of inflation and interest rate to farming shock

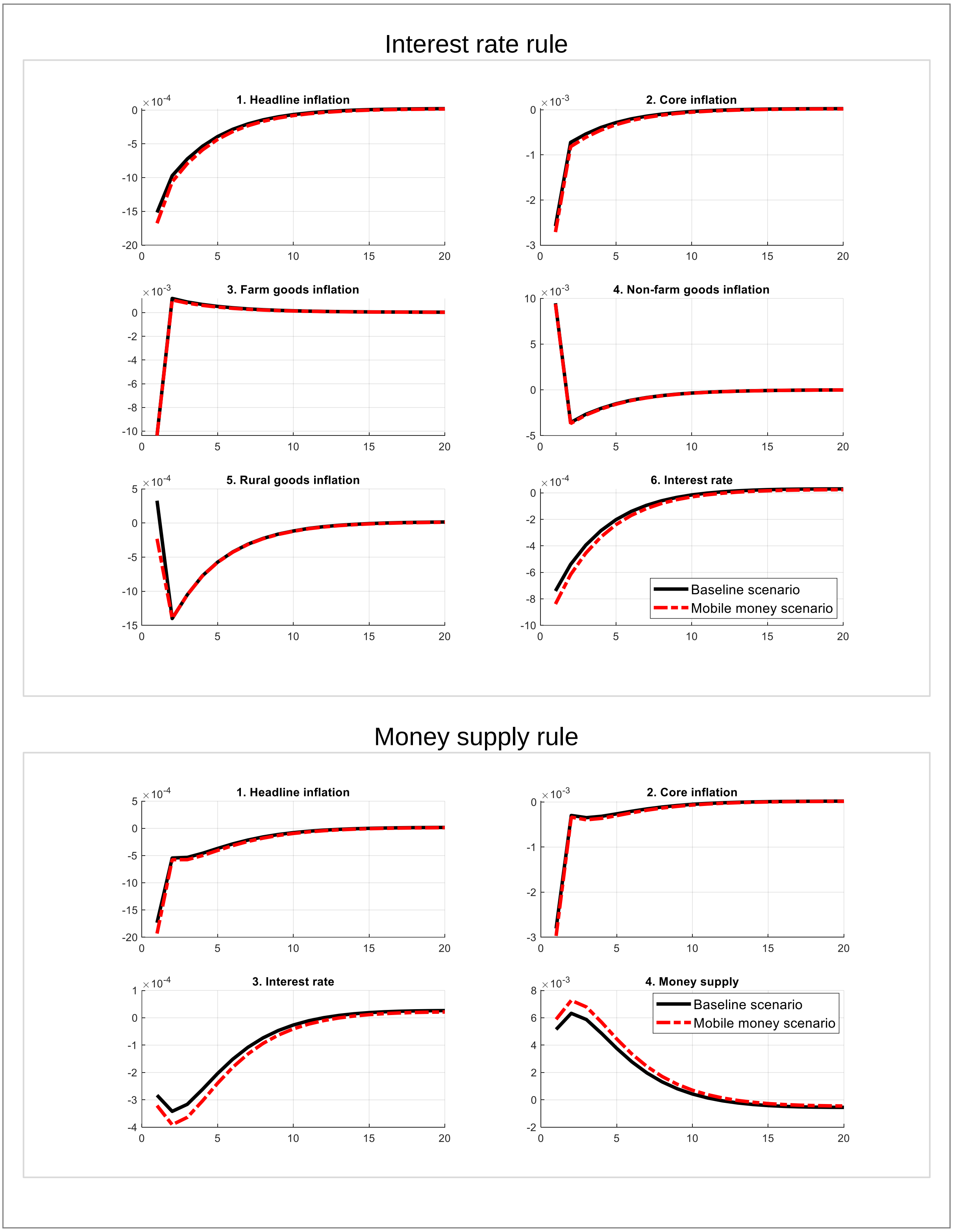


Figure E5K: Optimal policy response of inflation and interest rate to farming shock

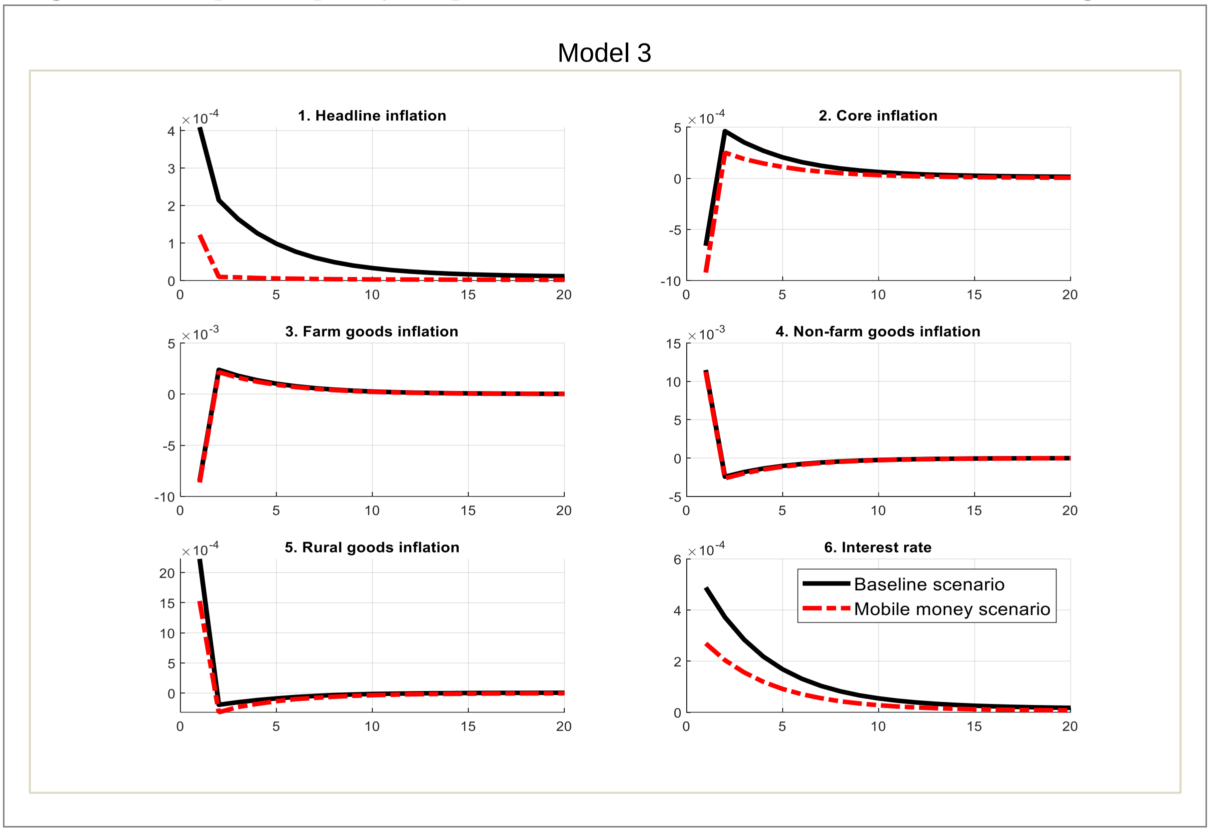
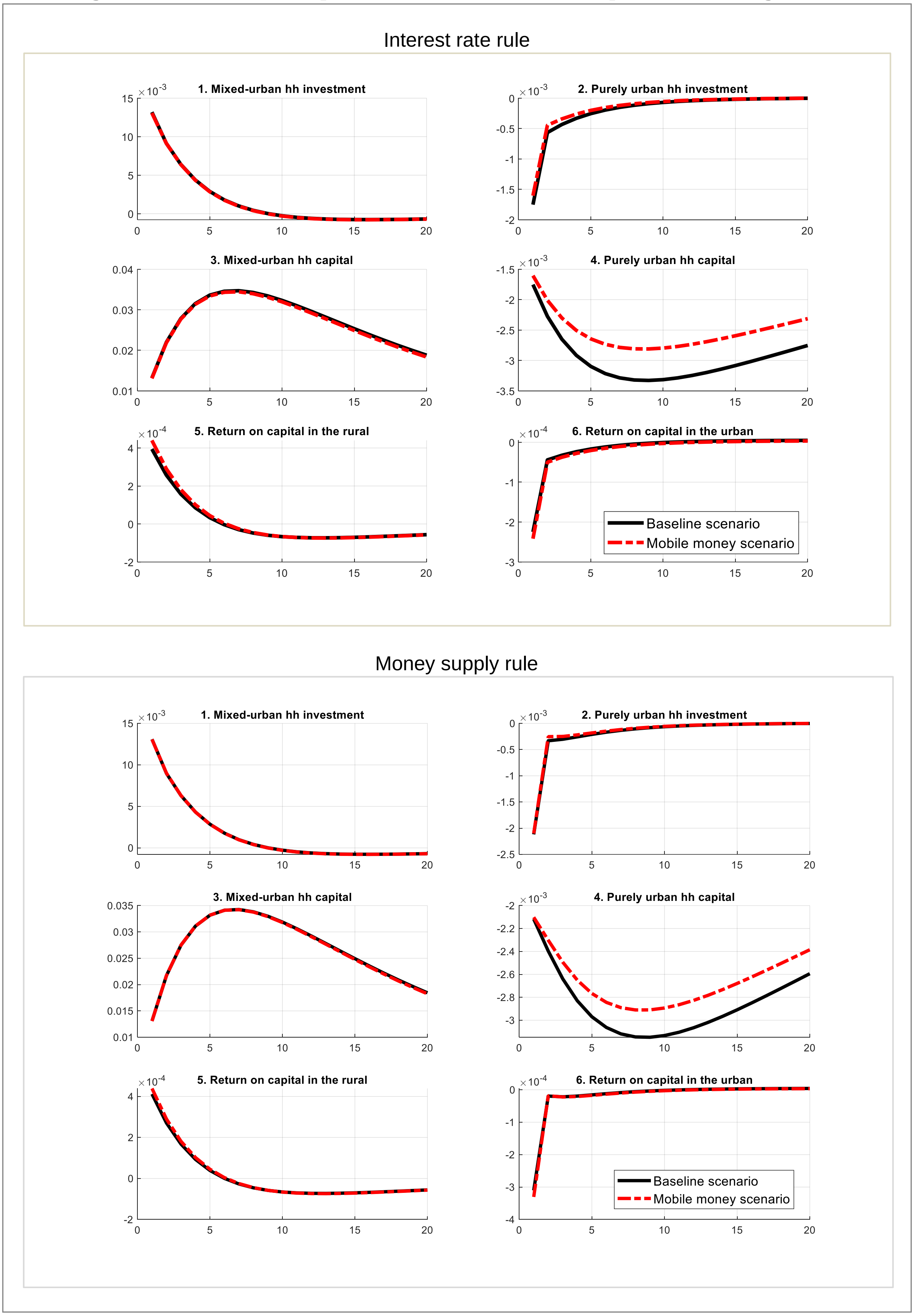


Figure E5L: Model 3 response of investment and capital to farming shock



Model 3 comparison of IRR with MSR non-farming shock IRFs

Figure E6A: Model 3 response of remittances and non-farm goods to non-farming shock

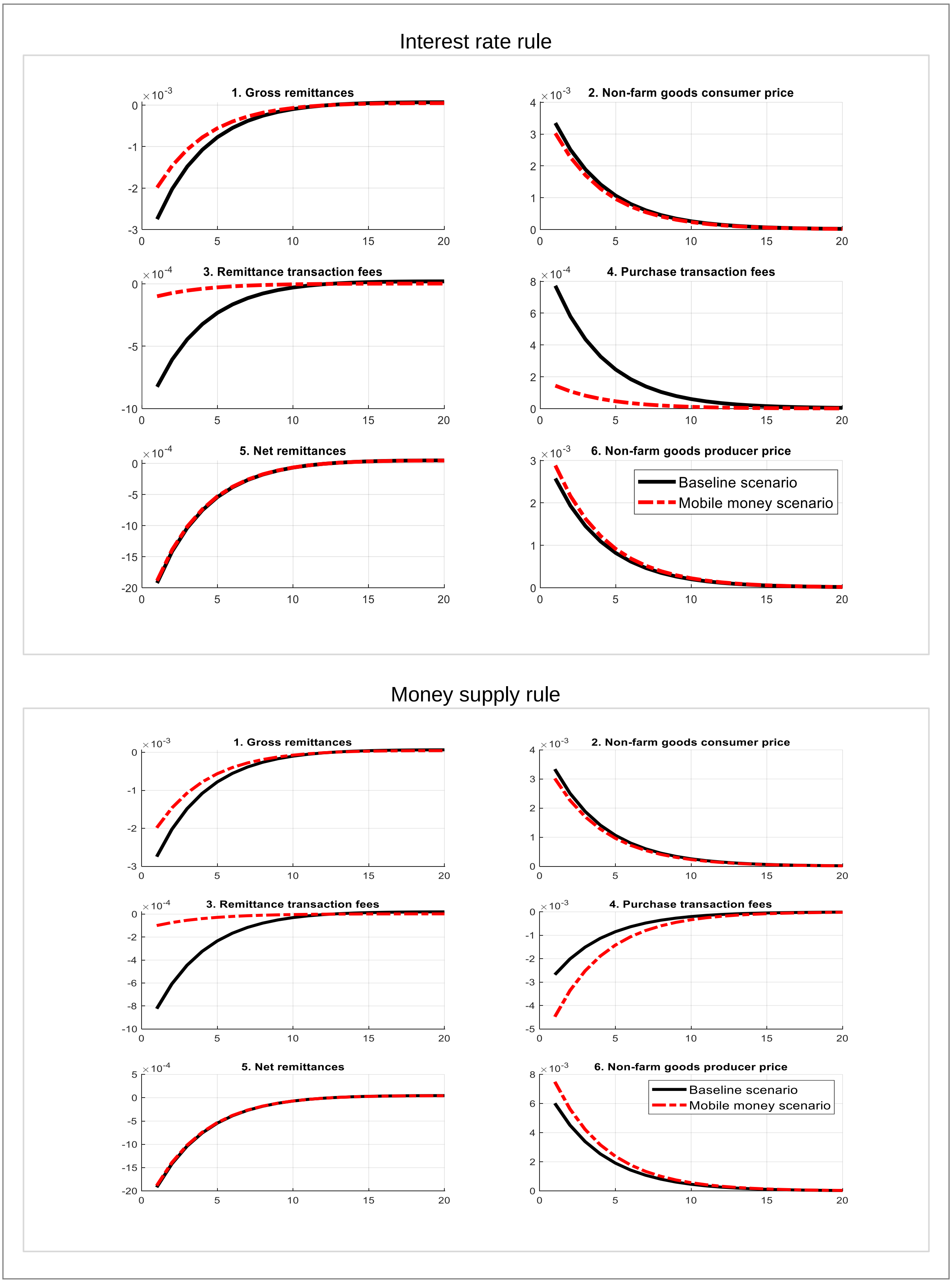


Figure E6B: Model 3 response of quantity and value output to non-farming shock

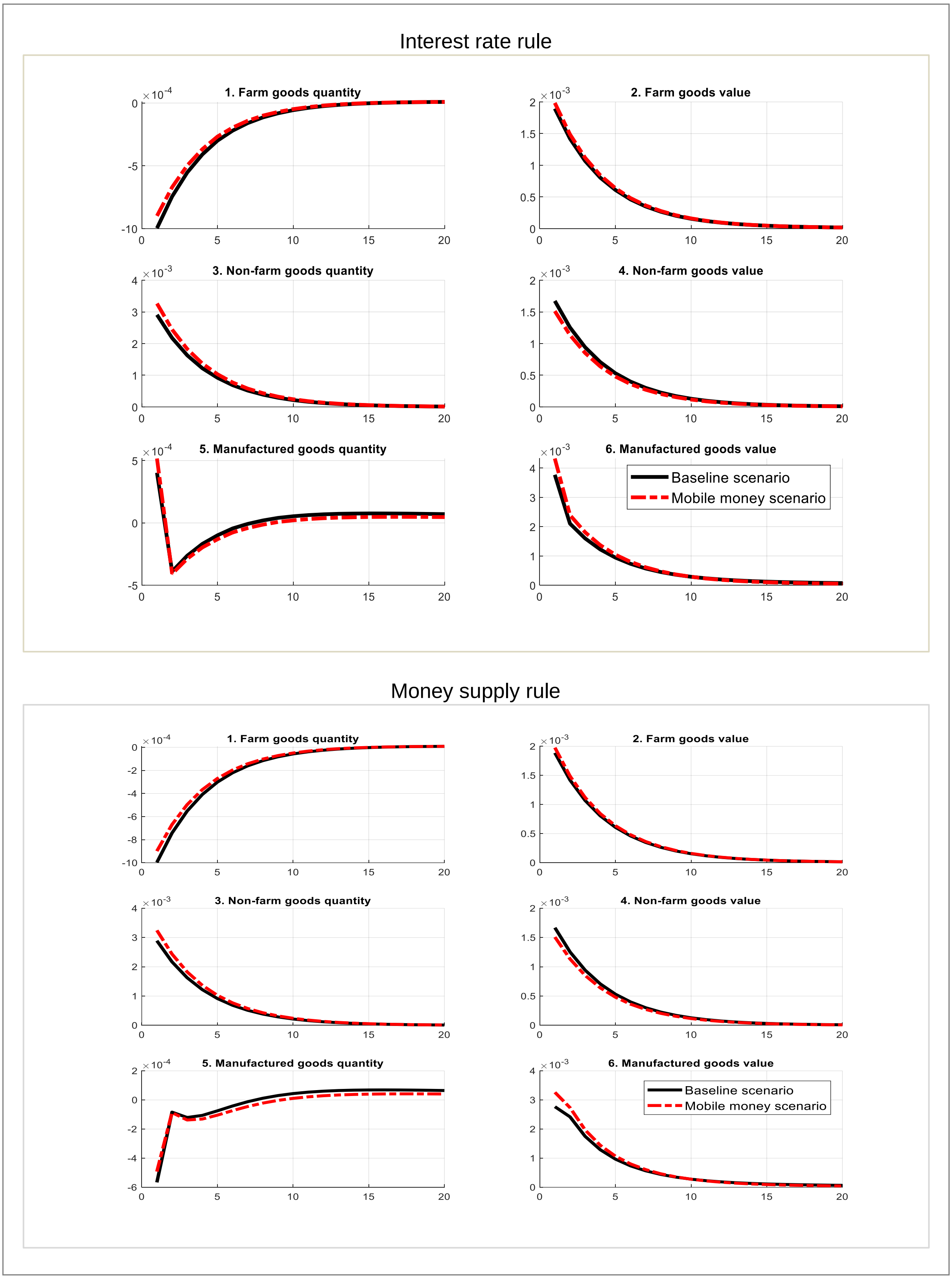


Figure E6C: Model 3 response of GDP aggregates to non-farming shock

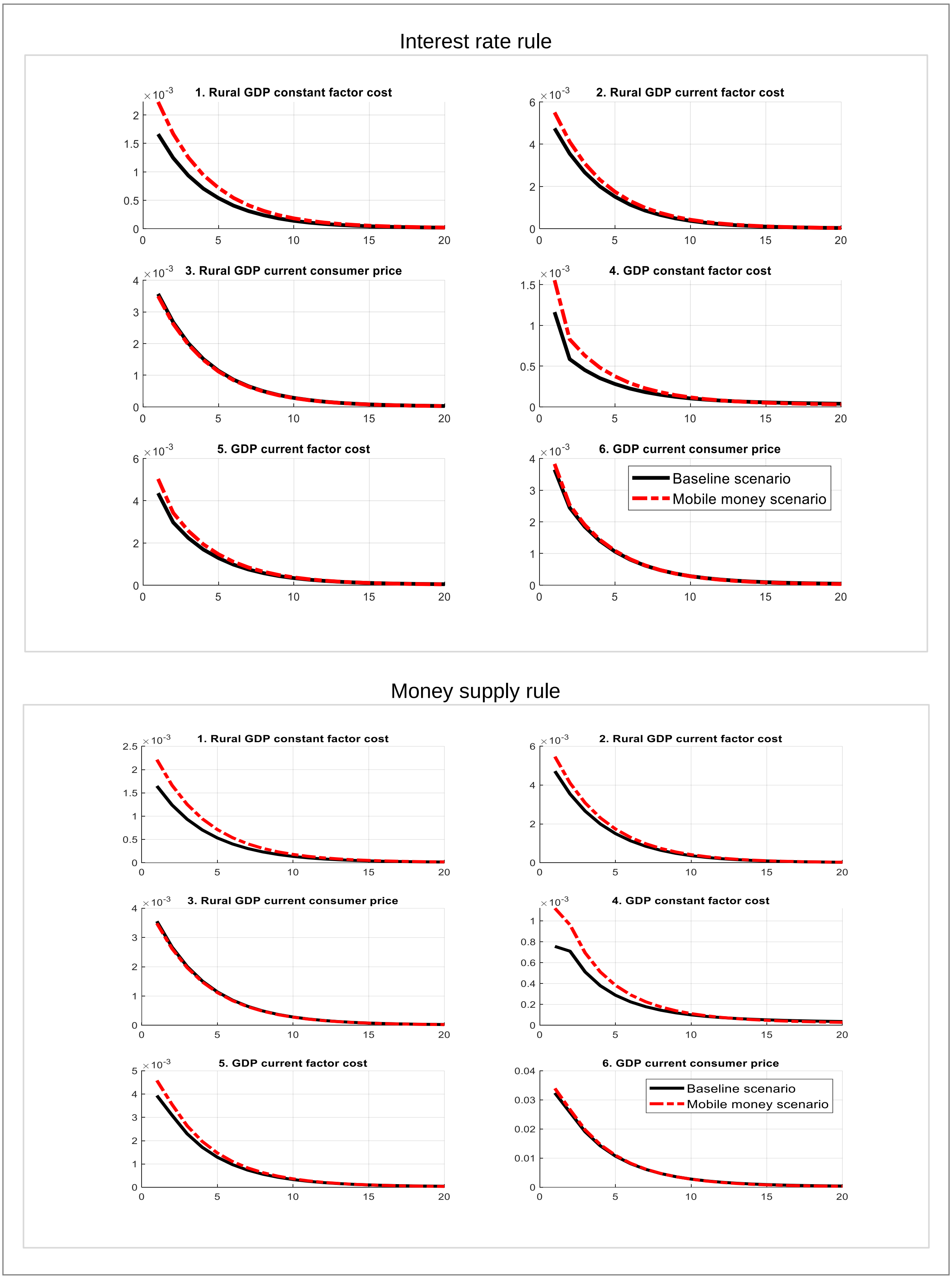


Figure E6D: Model 3 response of household labour quantity to non-farming shock

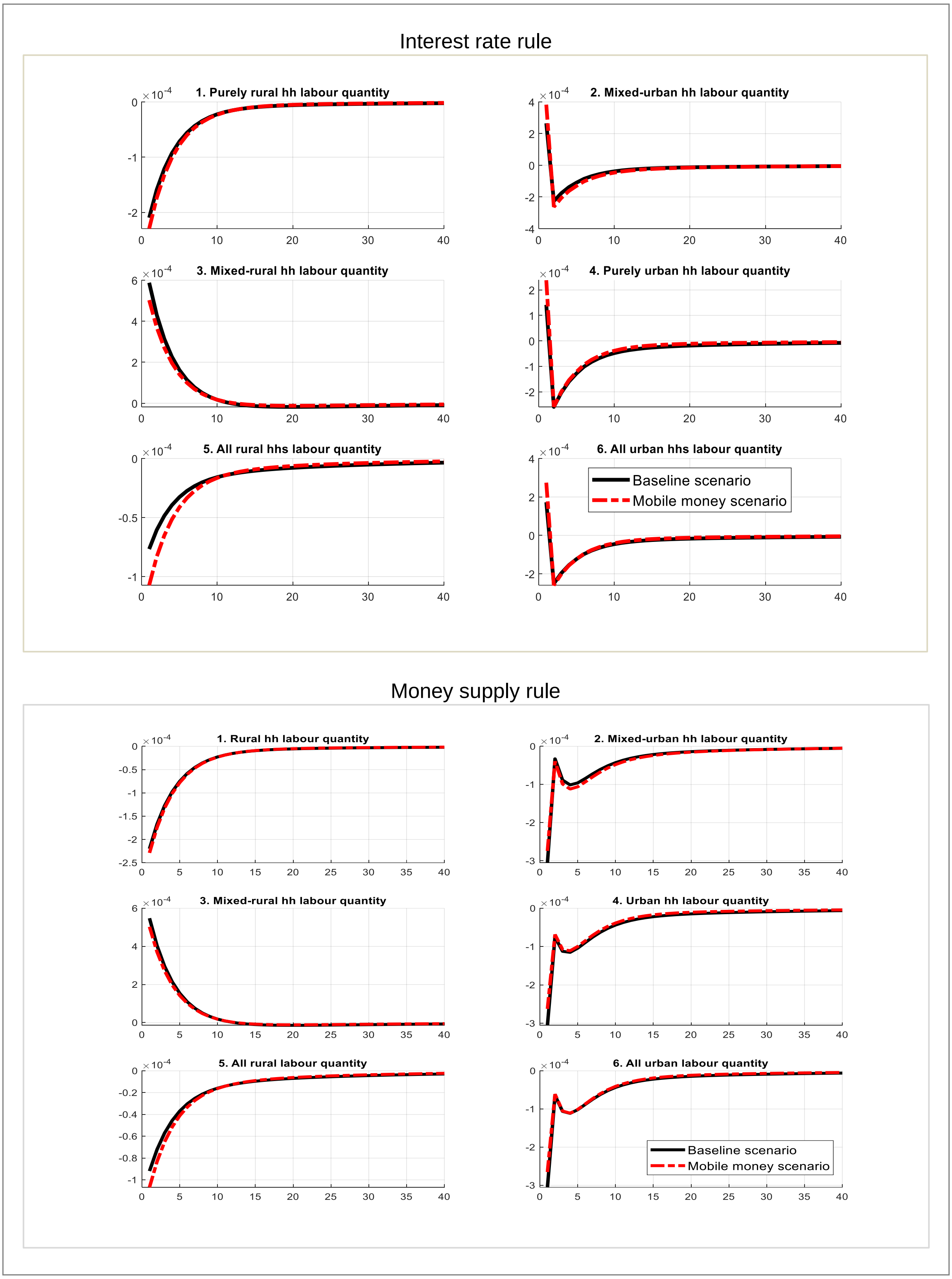


Figure E6E: Model 3 response of household labour value to non-farming shock

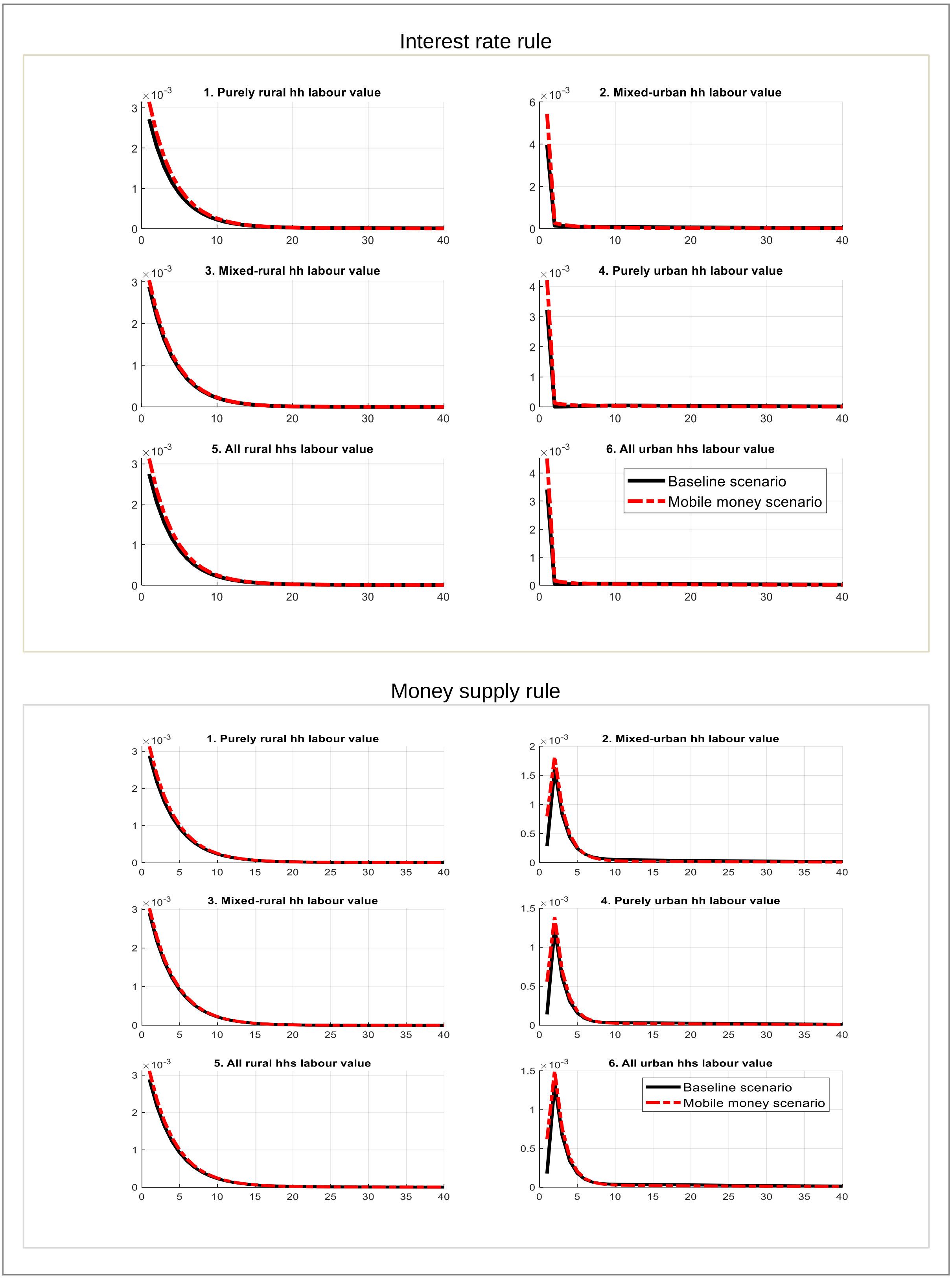


Figure E6F: Model 3 response of labour quantity and value in firms to non-farming shock

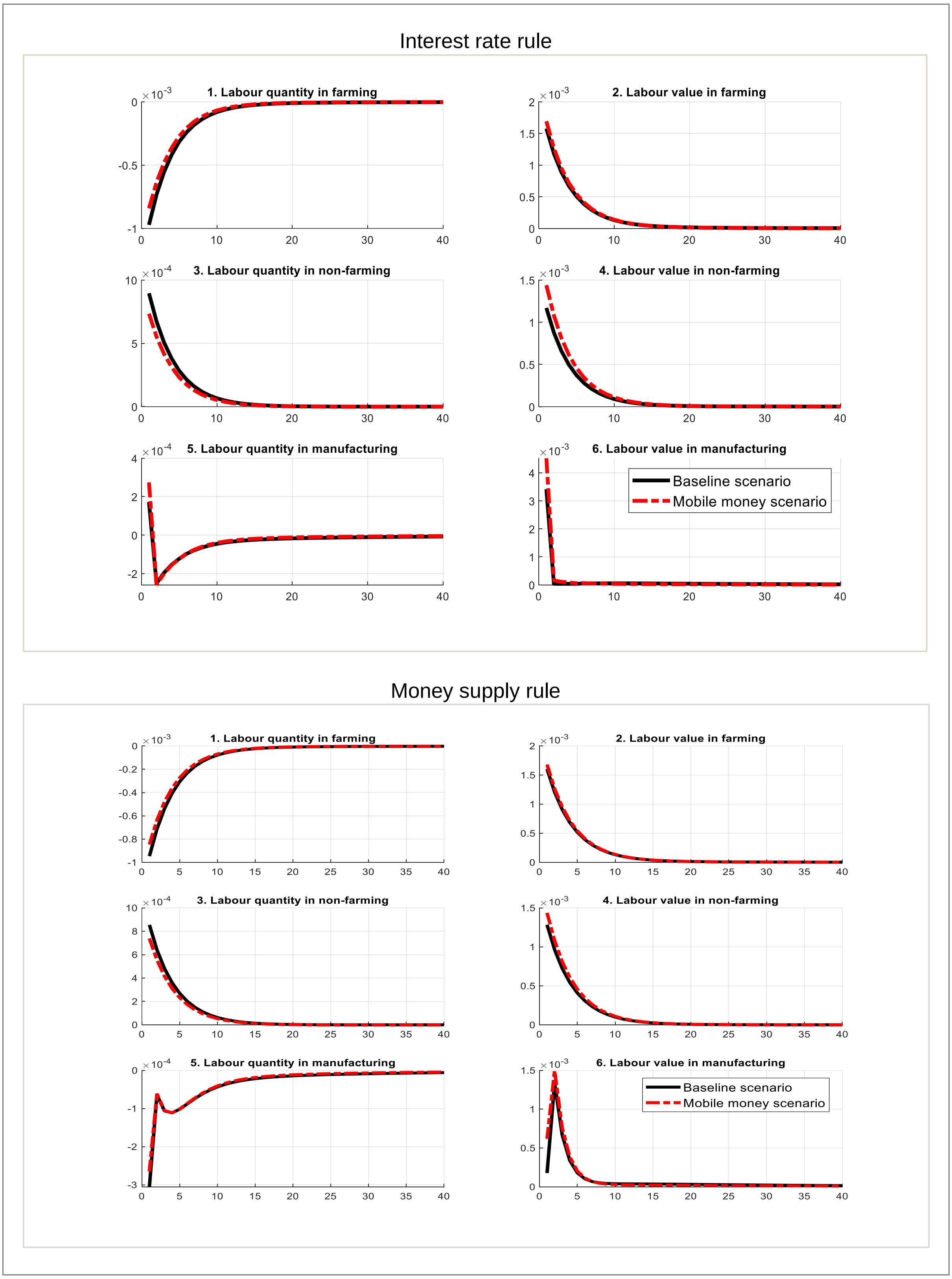


Figure E6G: Model 3 response of consumption to non-farming shock

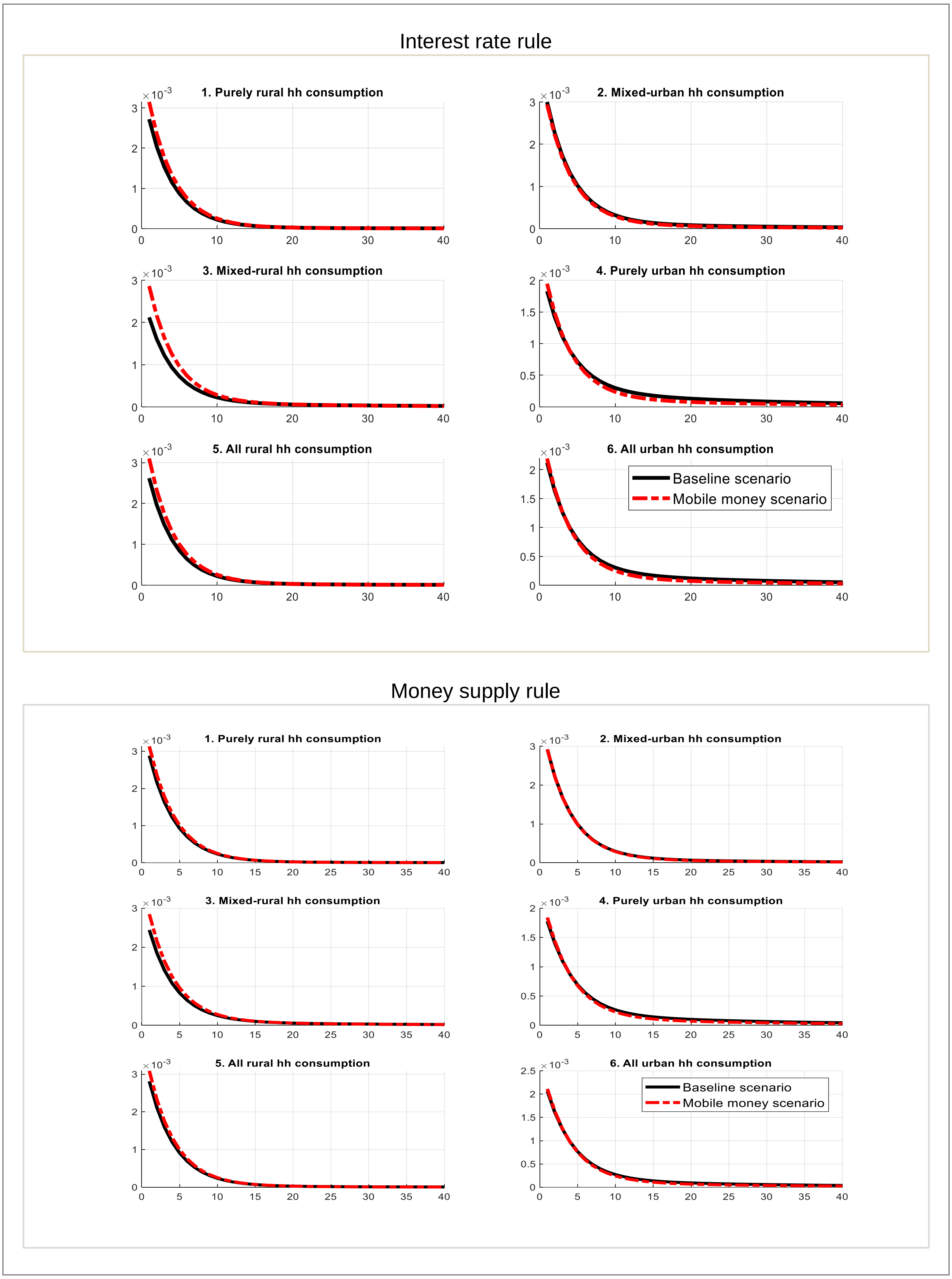


Figure E6H: Model 3 response of welfare to non-farming shock

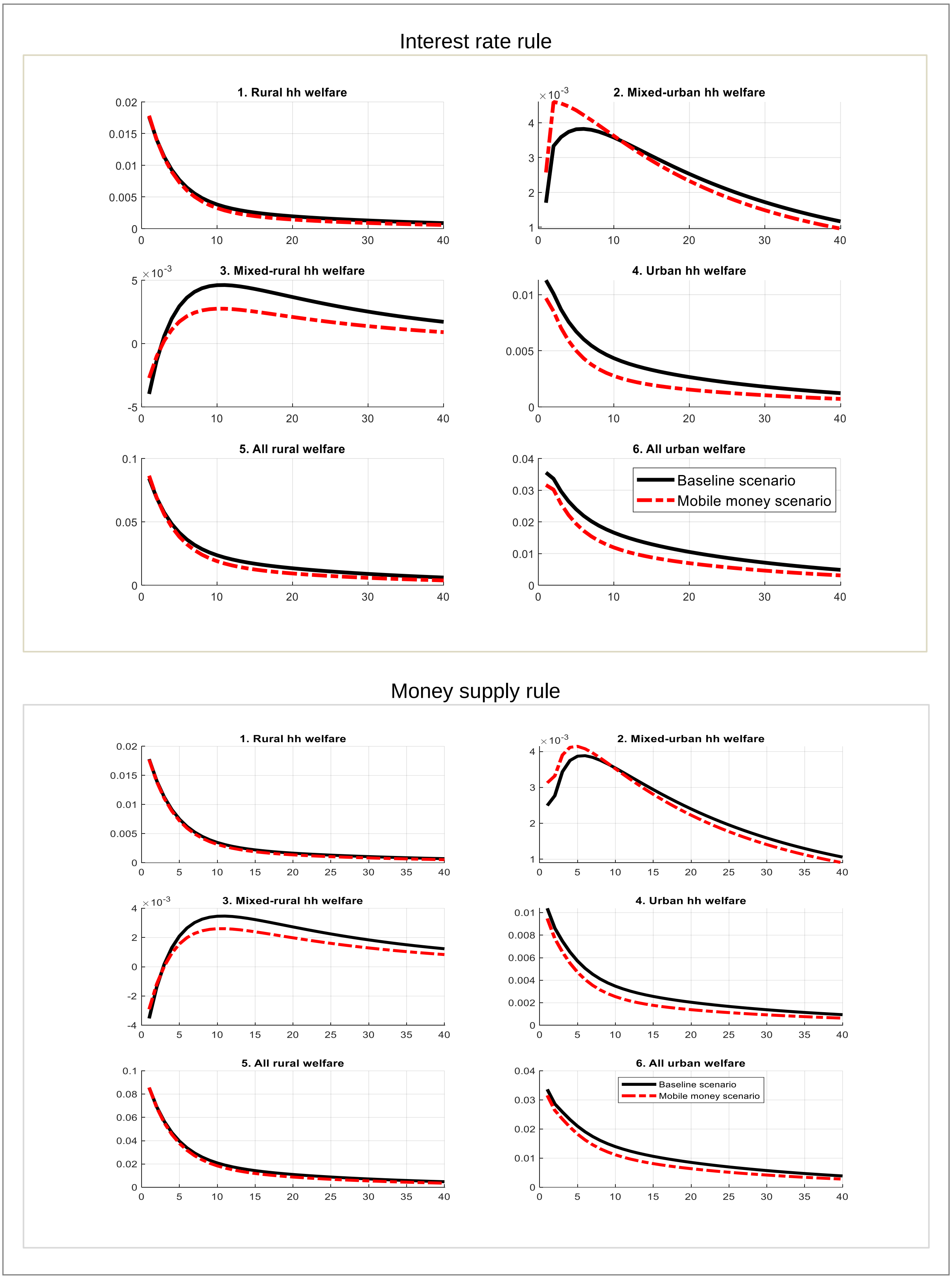


Figure E6I: Model 3 response of relative prices and wages to non-farming shock

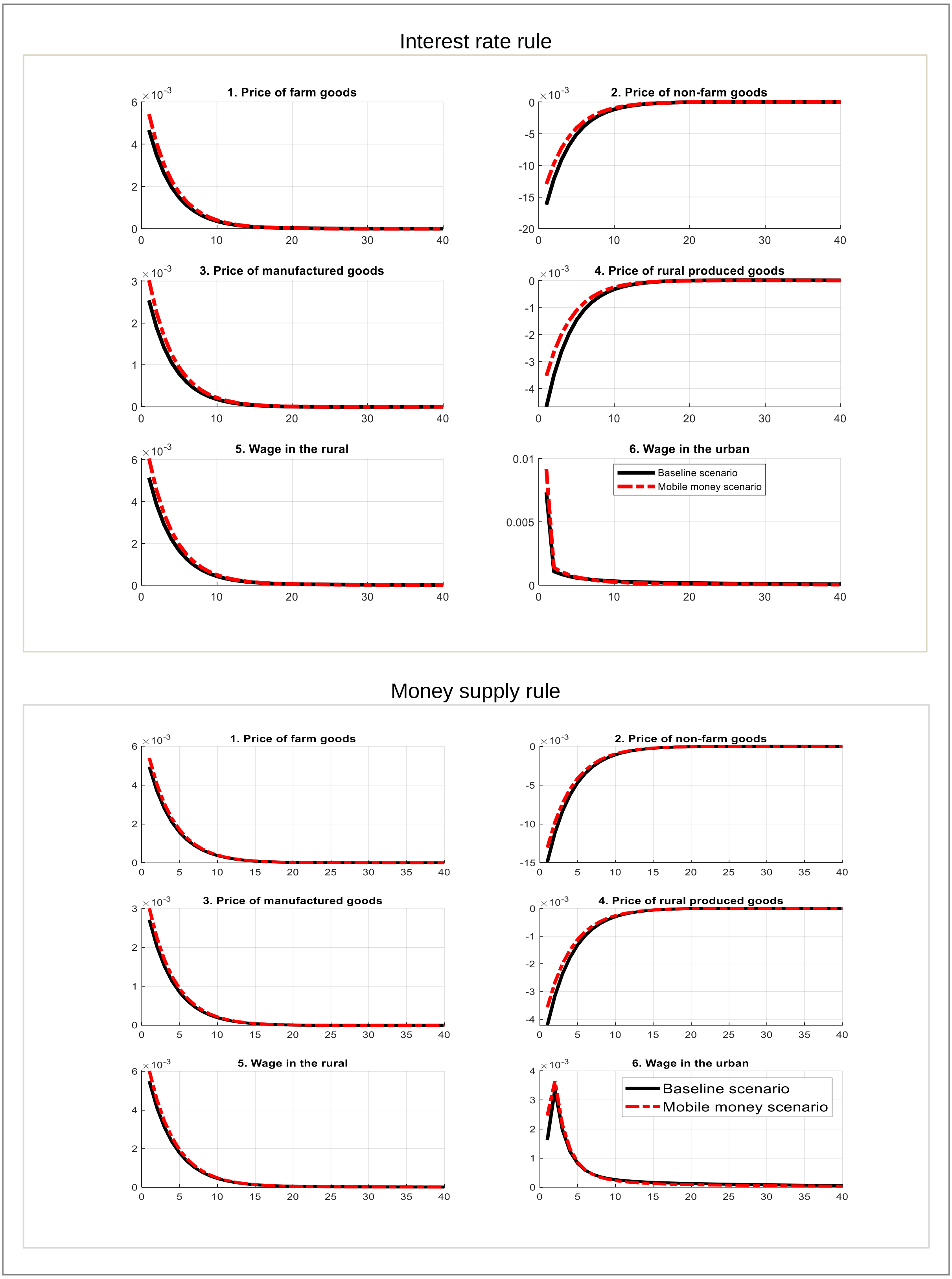


Figure E6J: Model 3 response of inflation and interest rate to non-farming shock

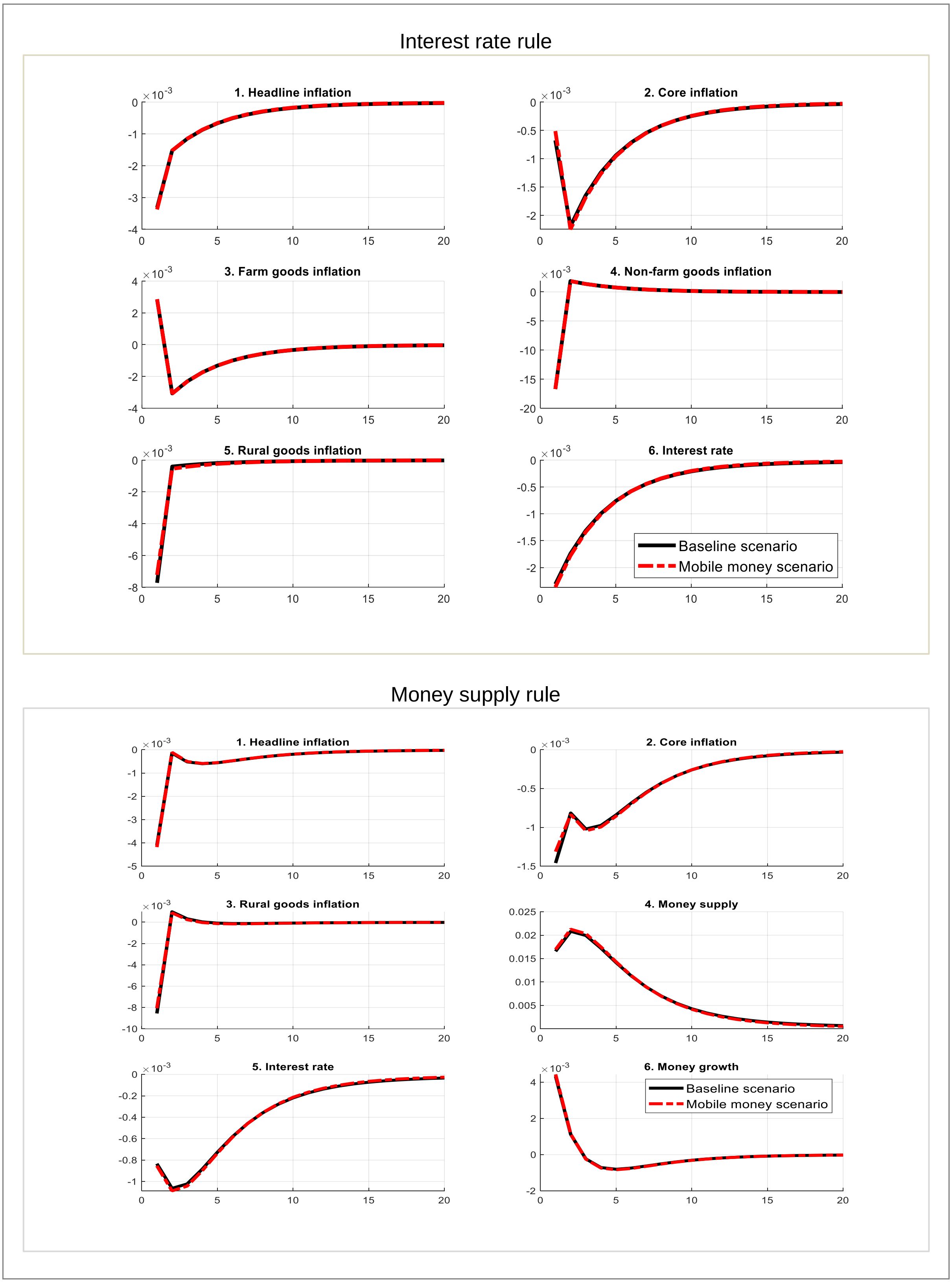


Figure E6K: Optimal policy response of inflation and interest rate to non-farming shock

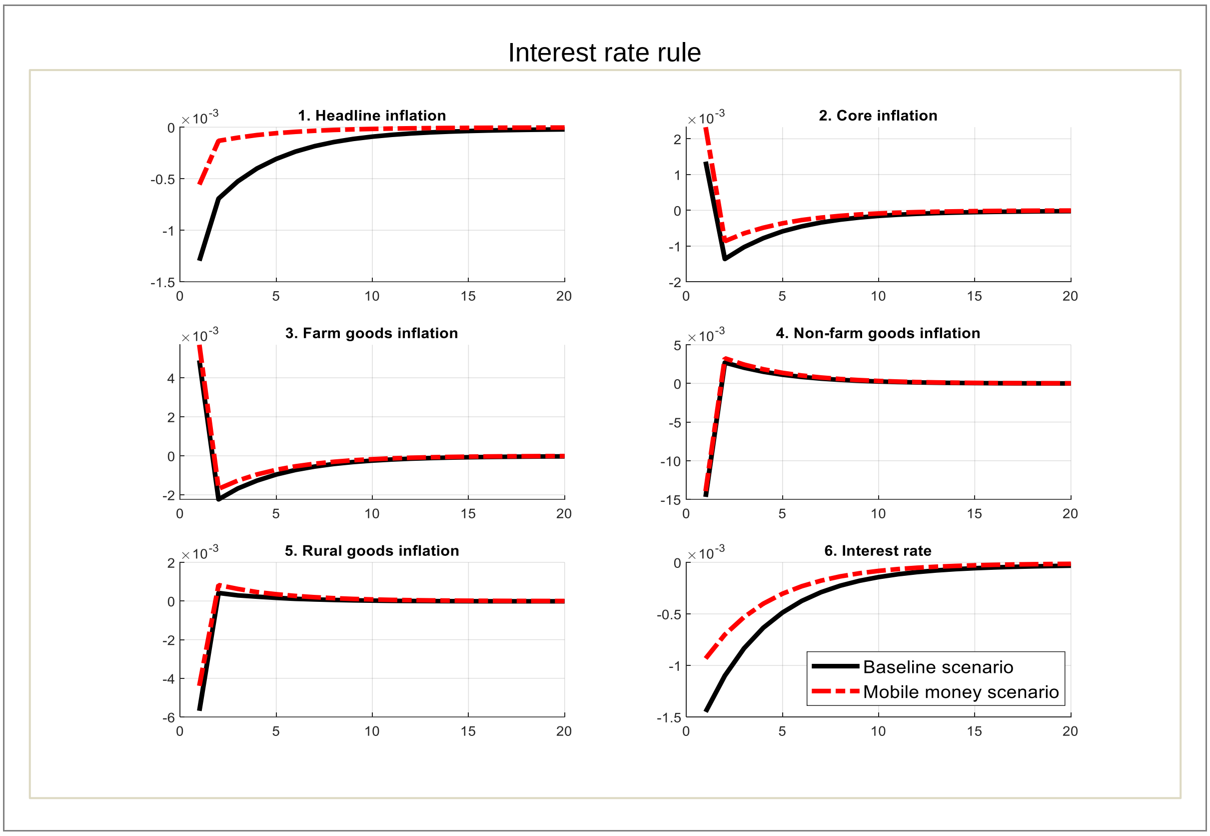
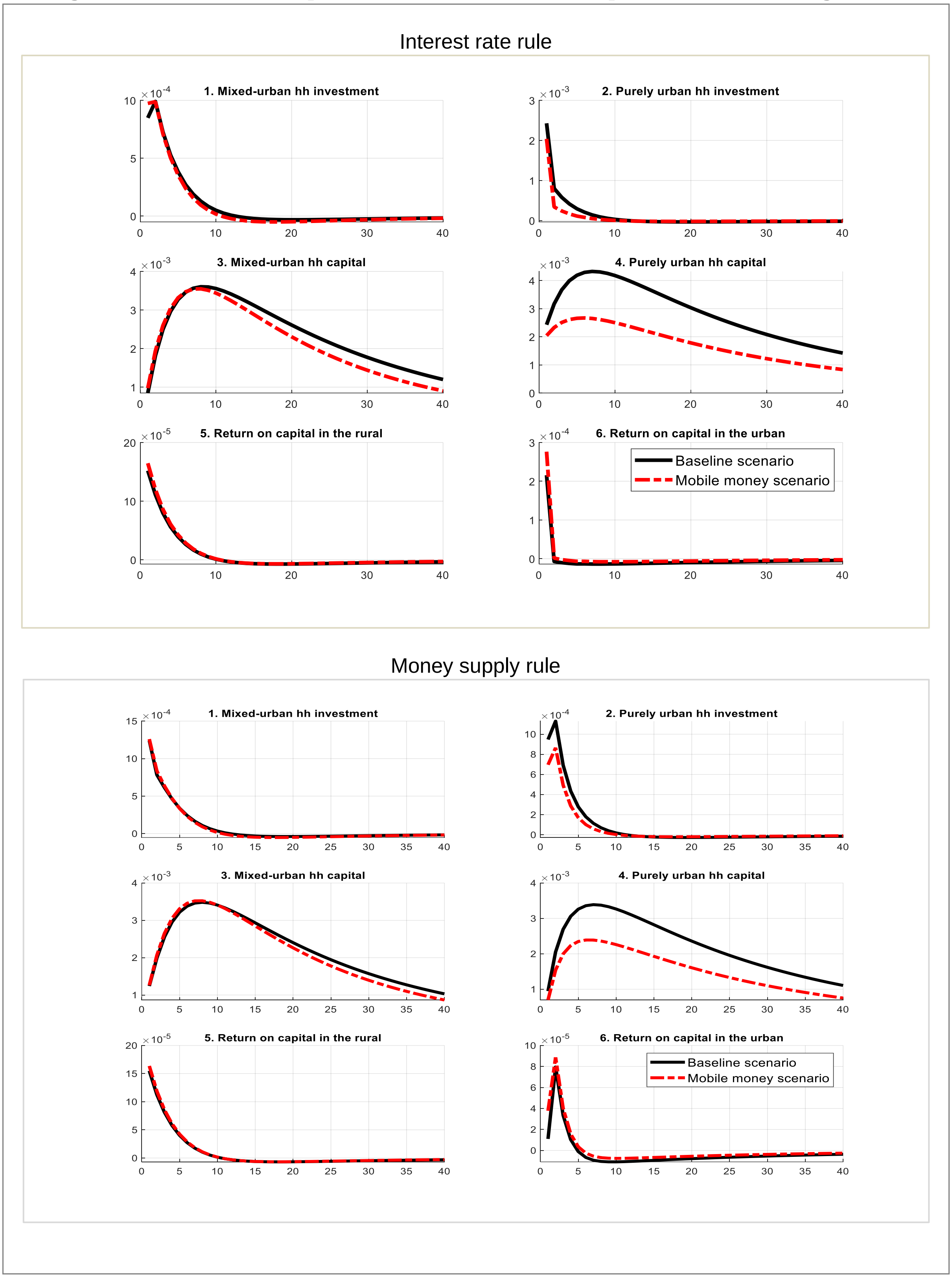


Figure E6L: Model 3 response of investment and capital to non-farming shock



Model 3 comparison of IRR with MSR manufacturing shock IRFs

Figure E7A: Model 3 response of remittances and non-farm goods to manufacturing shock

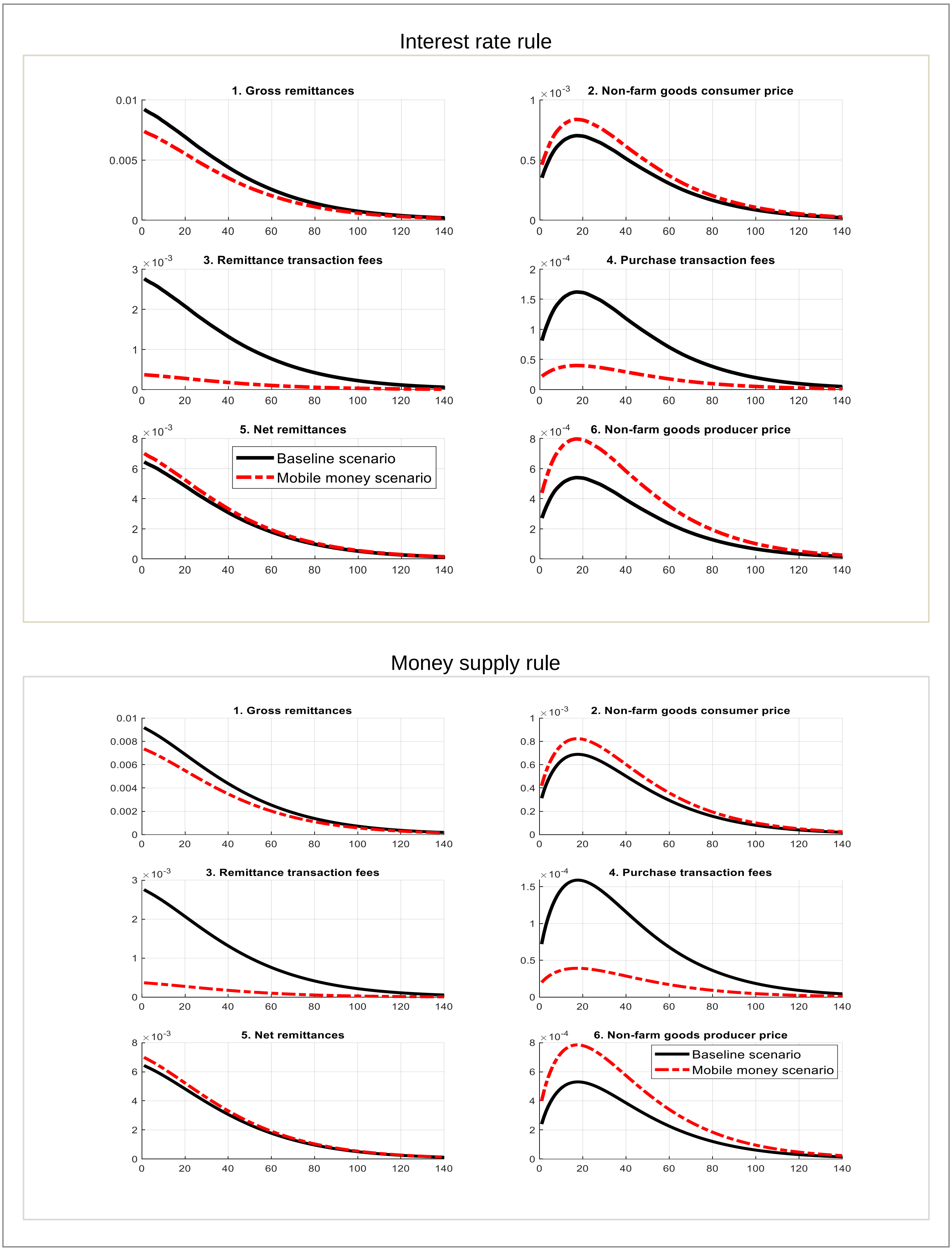


Figure E7B: Model 3 response of quantity and value of output to manufacturing shock

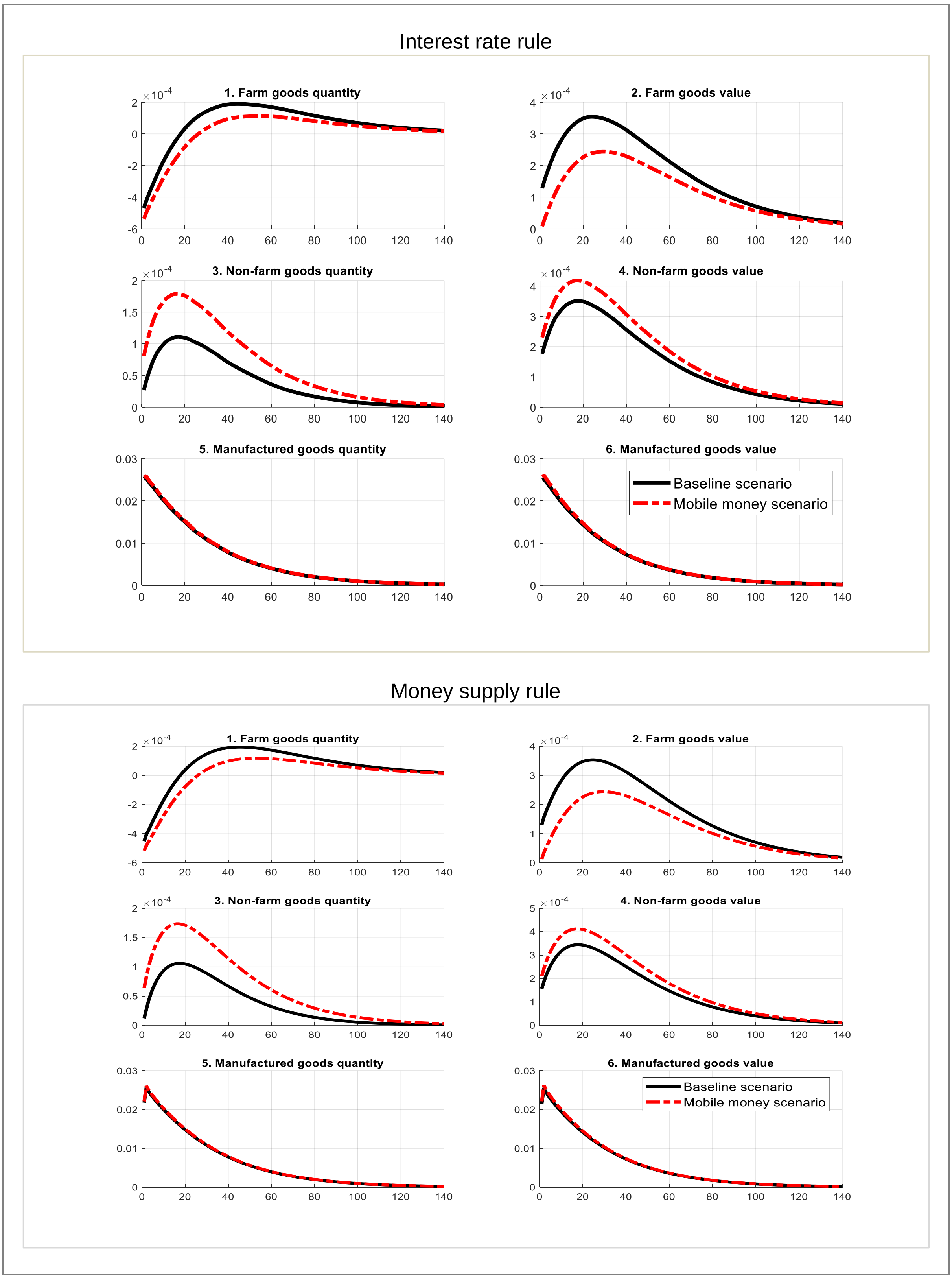


Figure E7C: Model 3 response of GDP aggregates to manufacturing shock

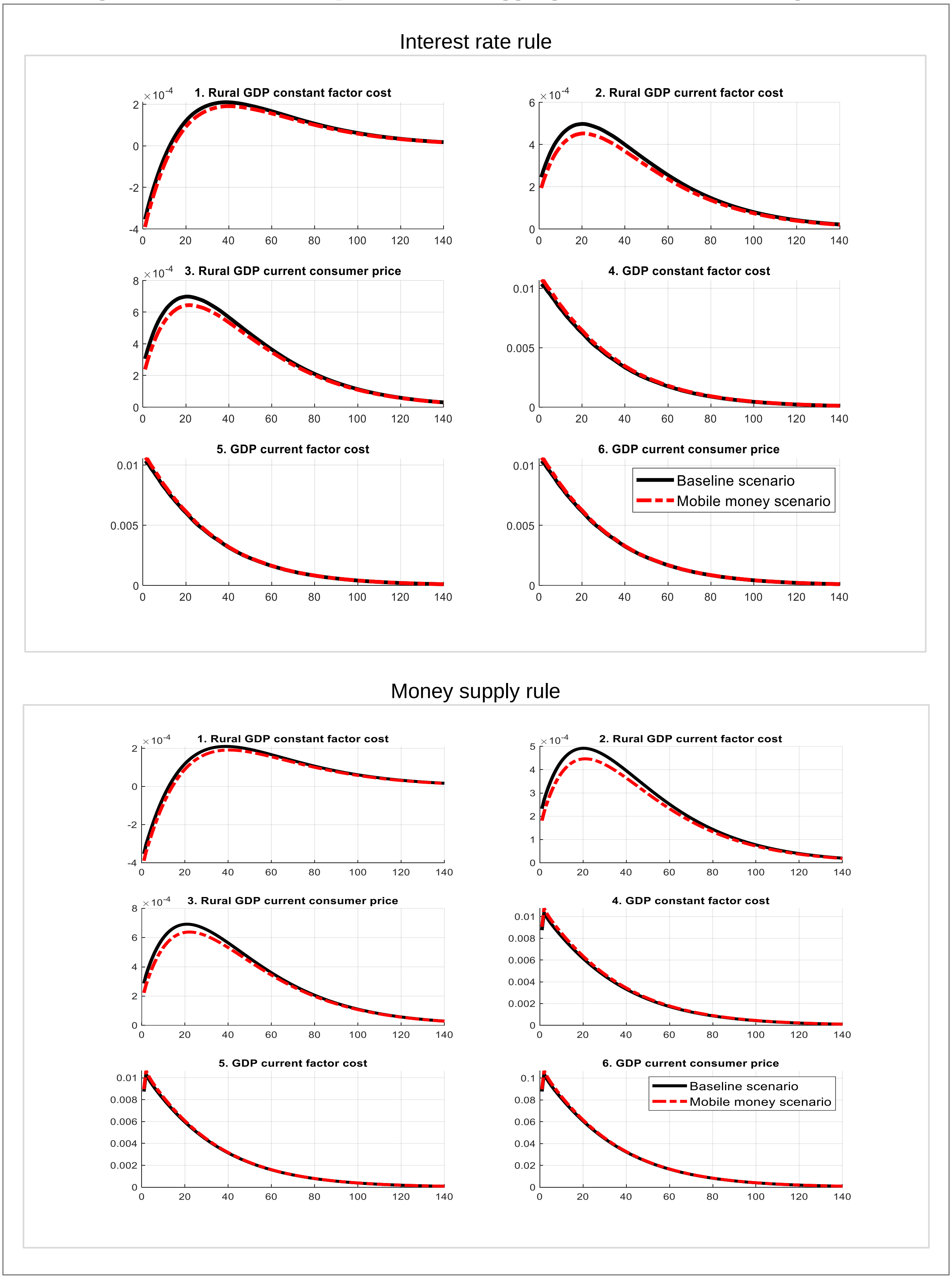
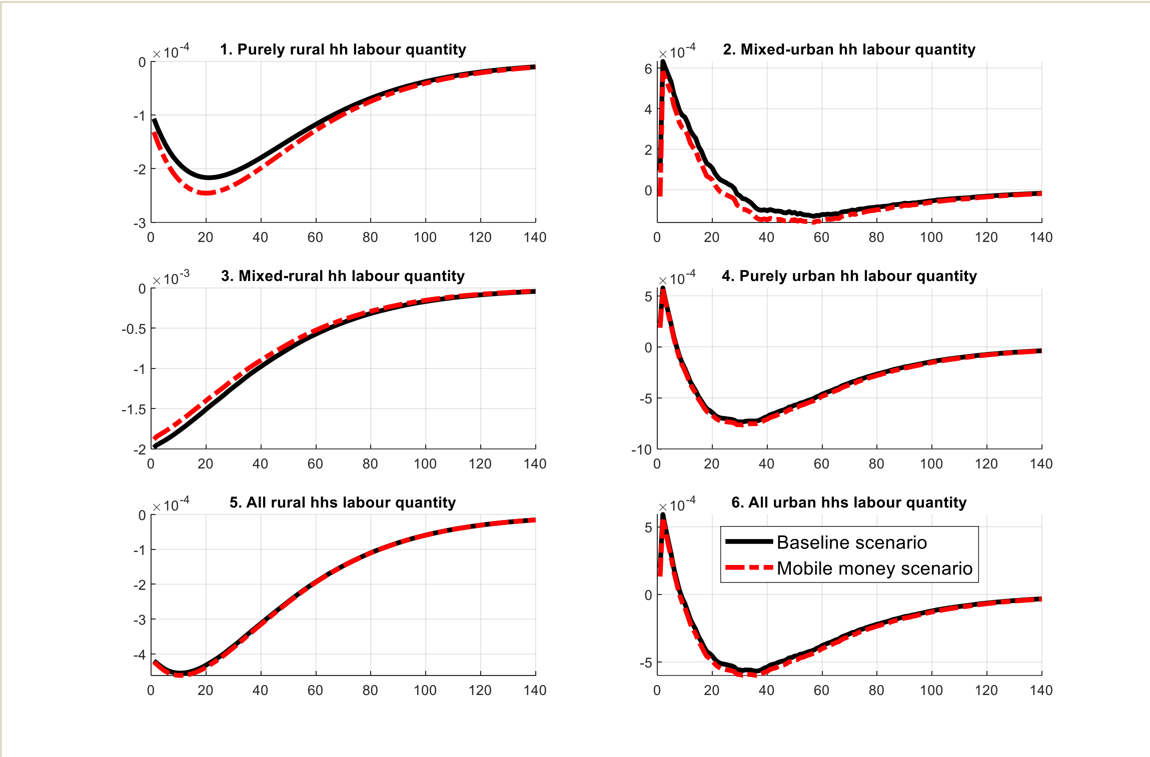


Figure E7D: Model 3 response of household labour quantity to manufacturing shock

Interest rate rule



Money supply rule

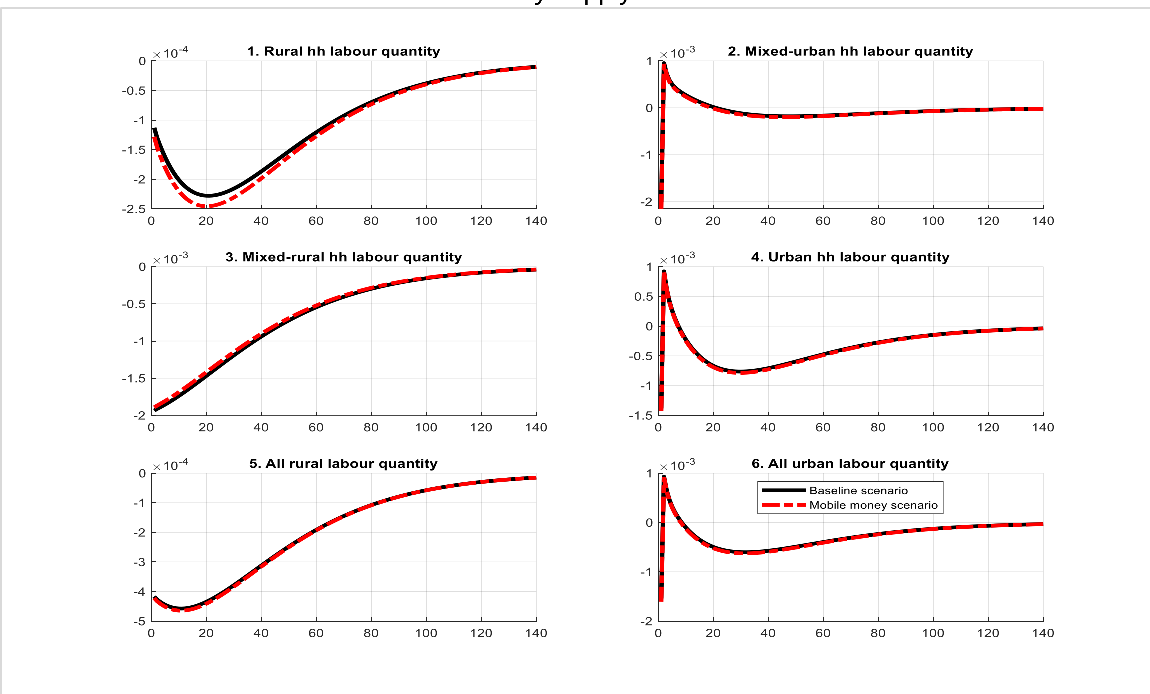


Figure E7E: Model 3 response of household labour value to manufacturing shock

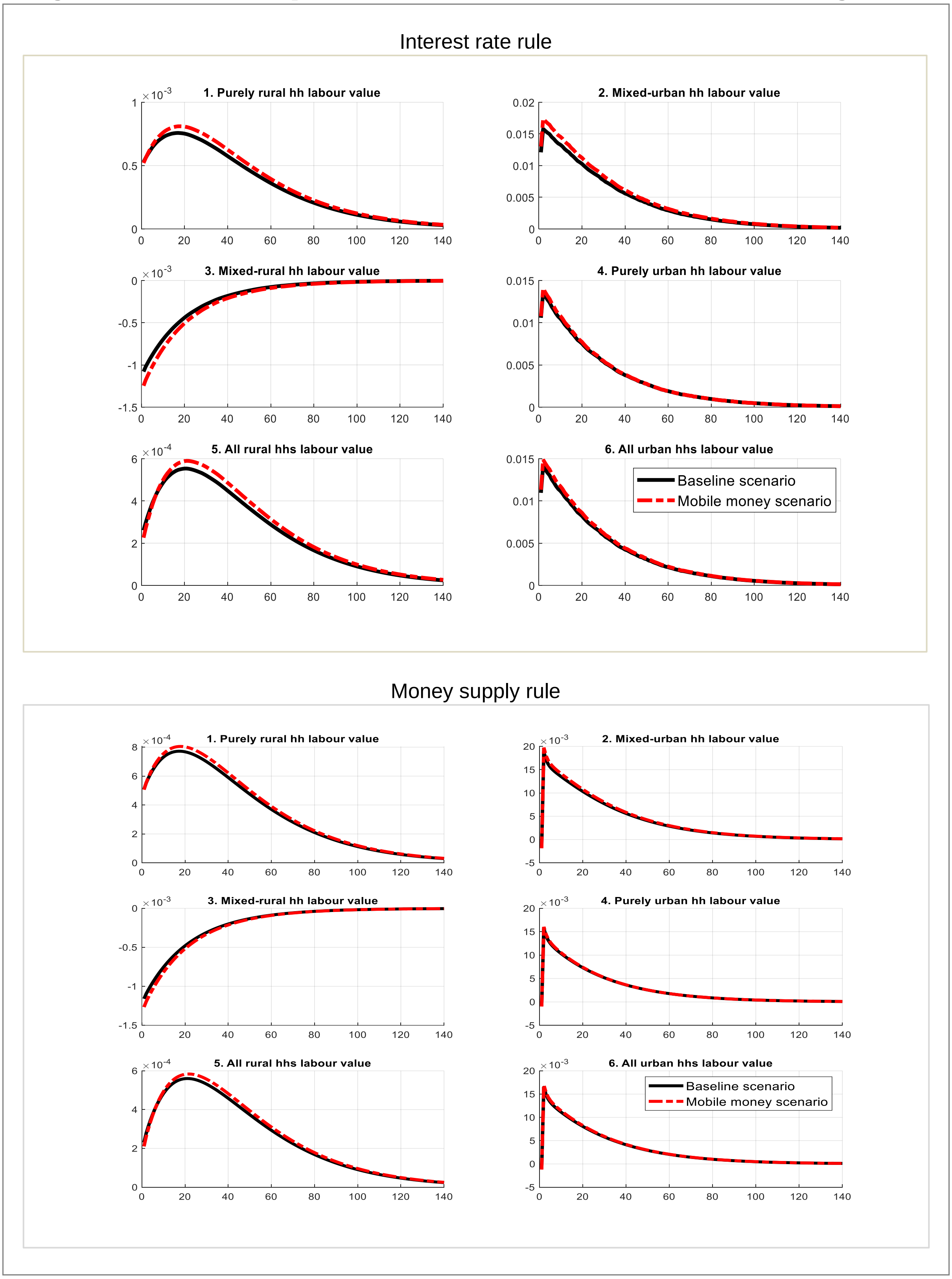


Figure E7F: Model 3 response of labour quantity and value in firms to manufacturing shock

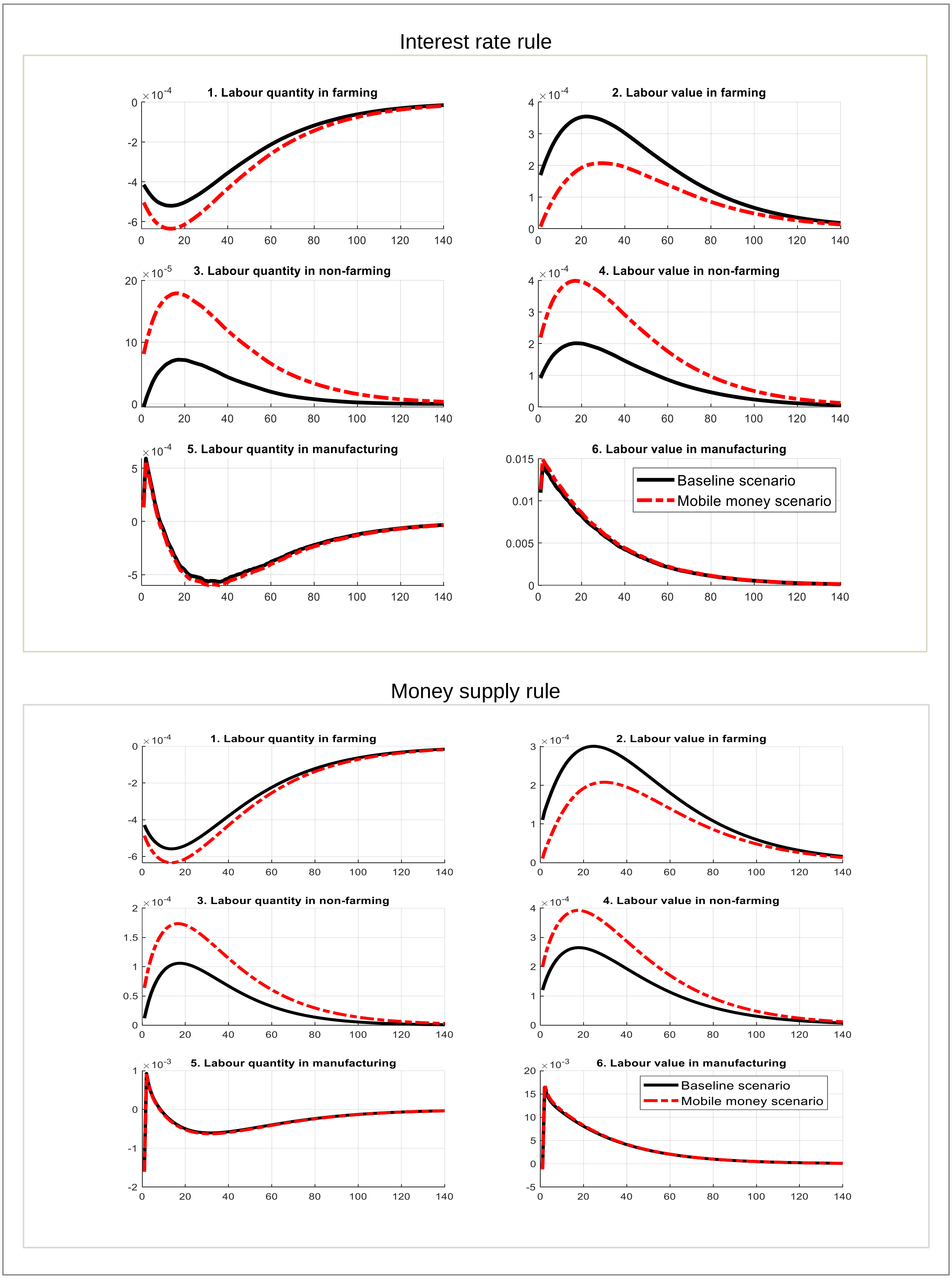


Figure E7G: Model 3 response of consumption to manufacturing shock

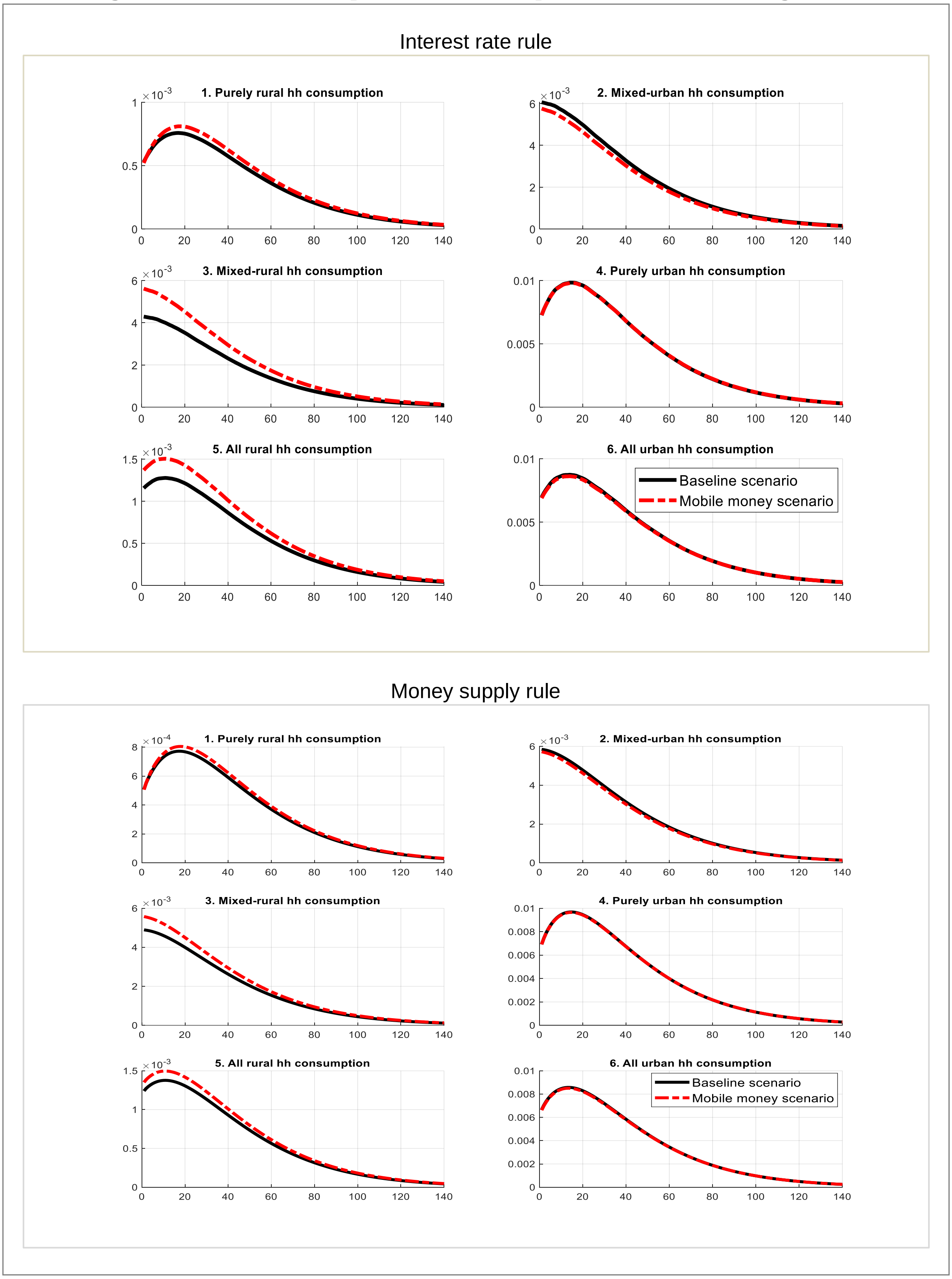


Figure E7H: Model 3 response of welfare to manufacturing shock

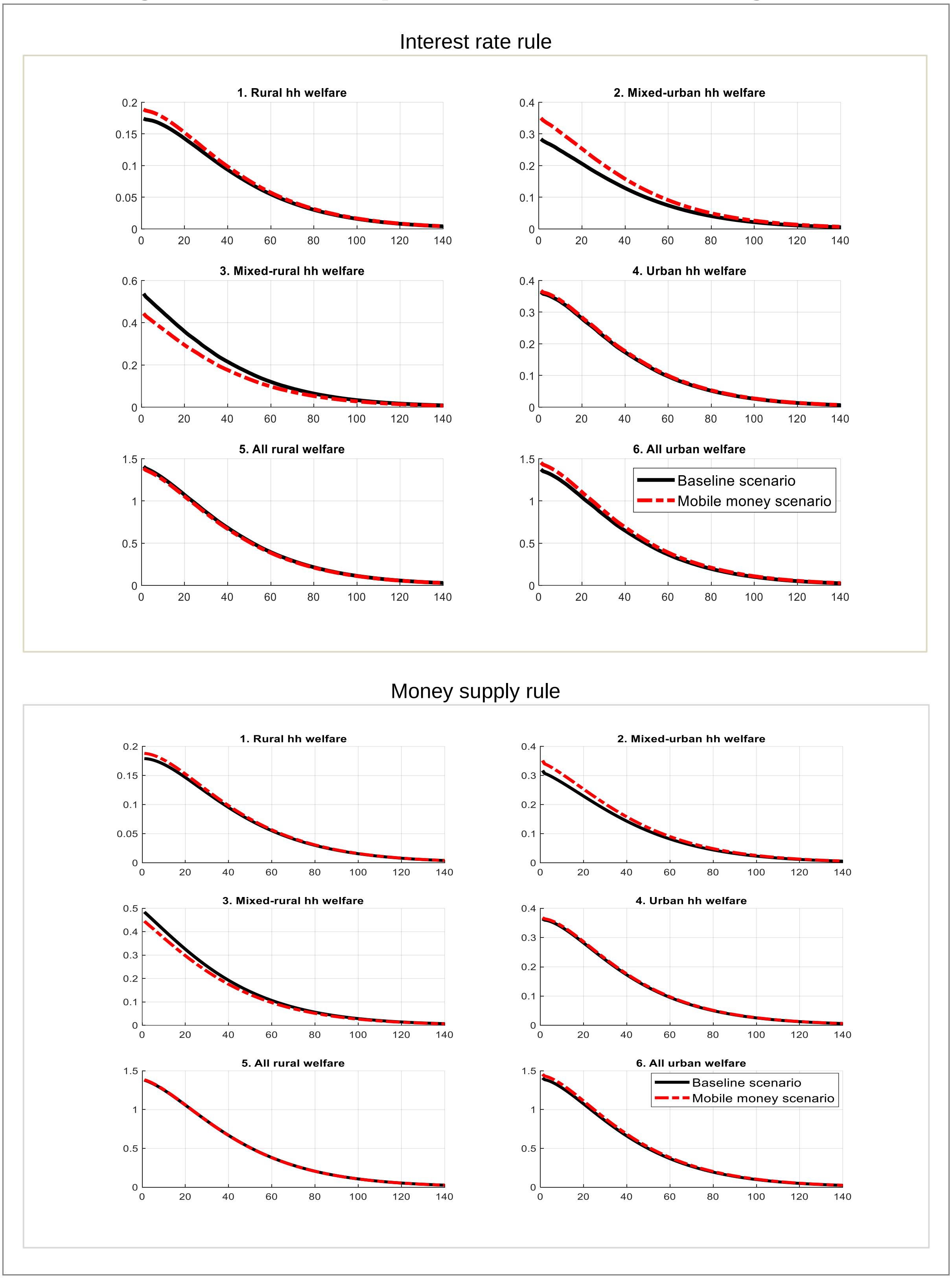


Figure E7I: Model 3 response of relative prices and wages to manufacturing shock

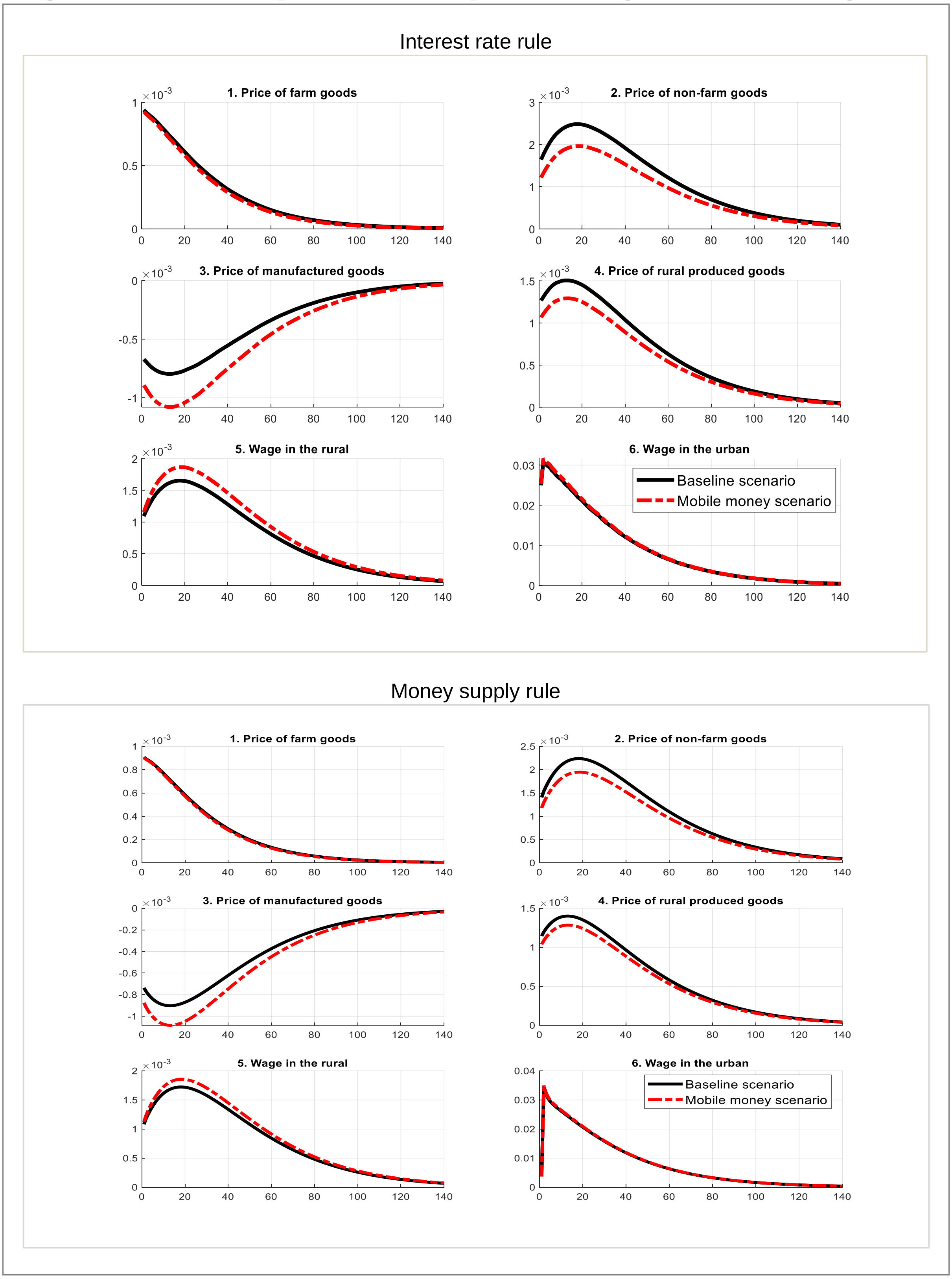


Figure E7J: Model 3 response of inflation and interest rate to manufacturing shock

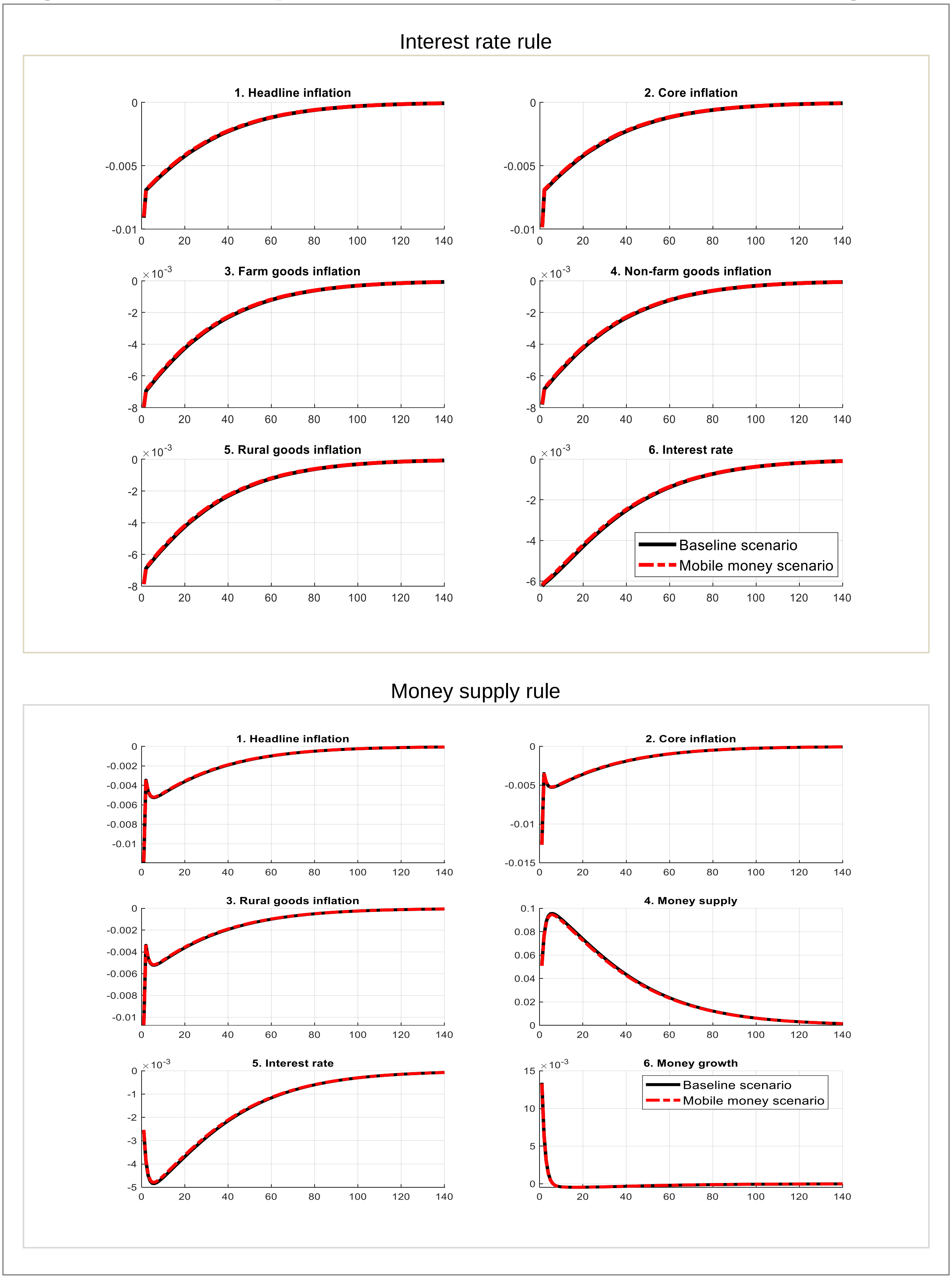


Figure E7K: Optimal policy response of inflation and interest rate to manufacturing shock

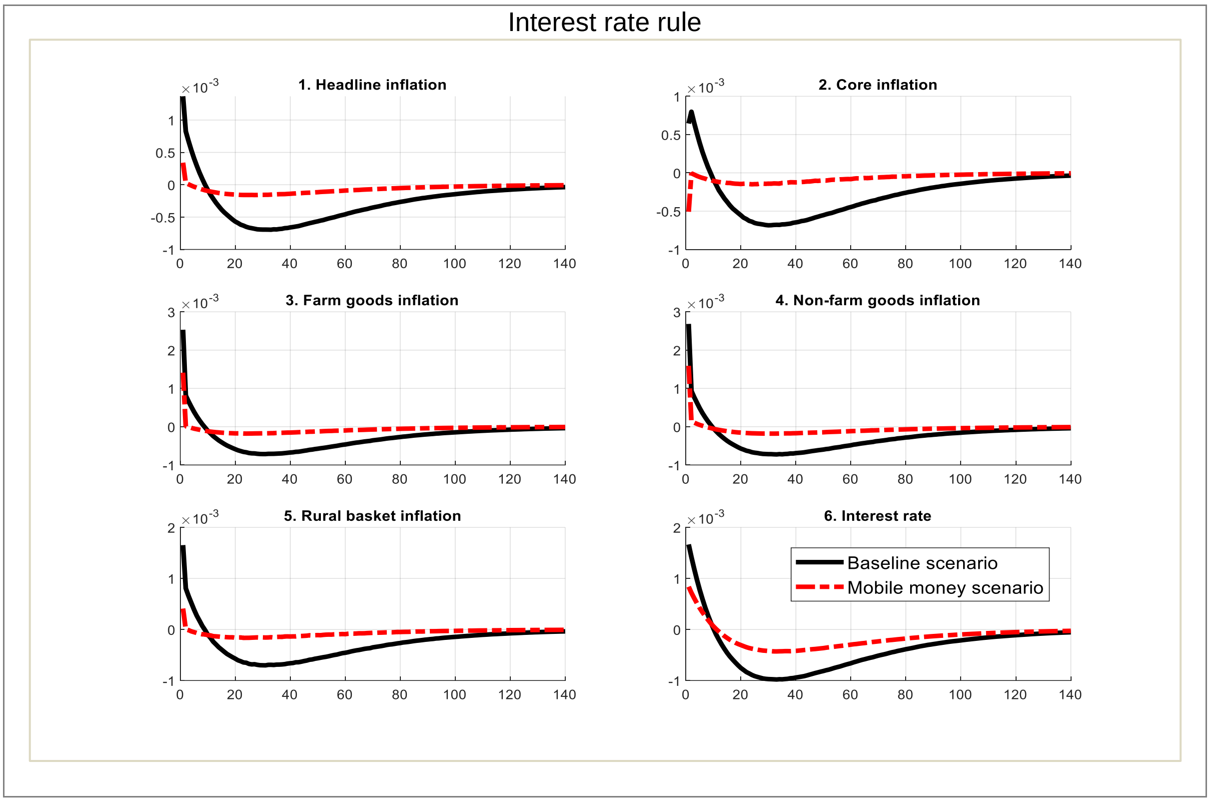
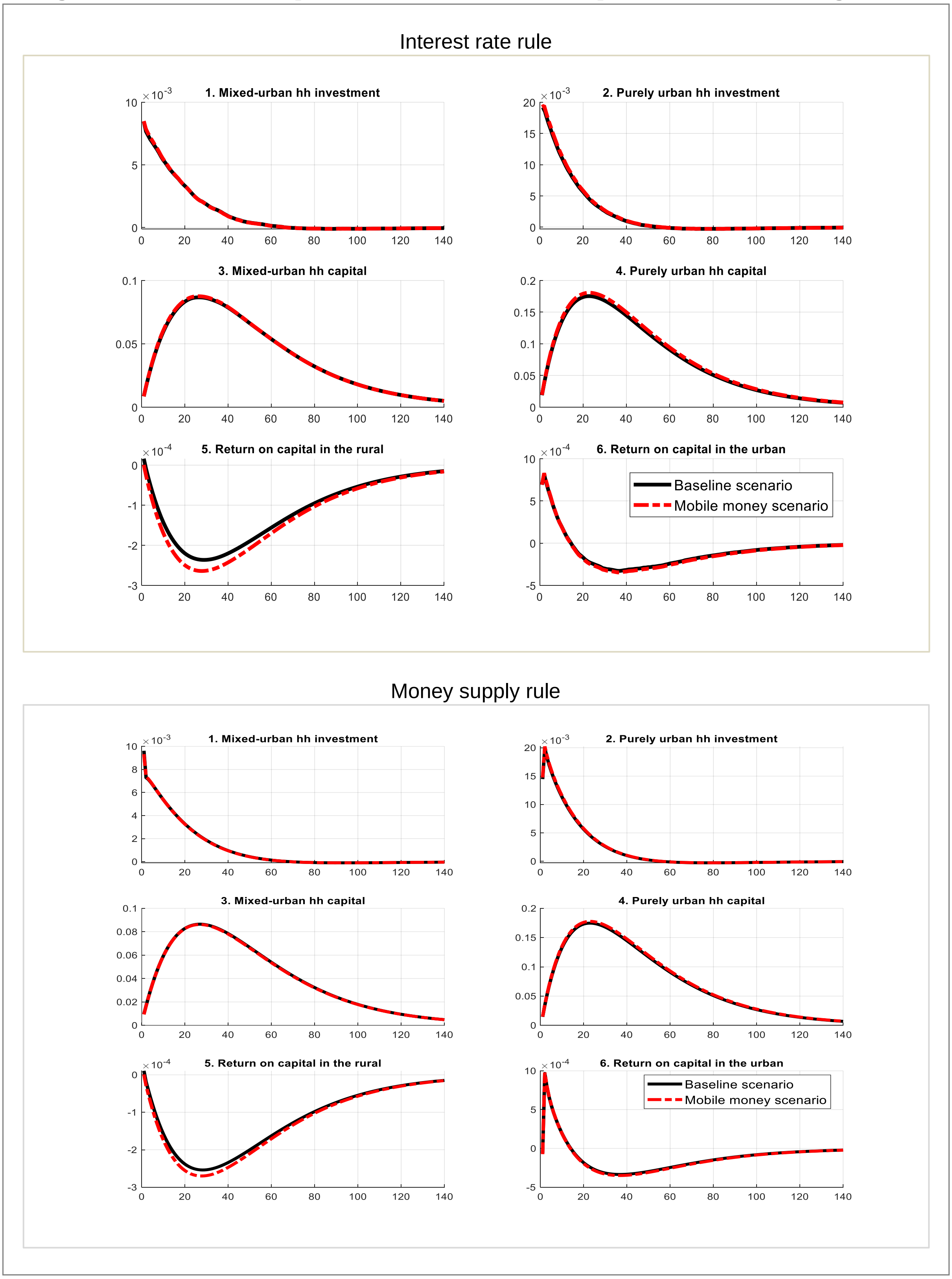


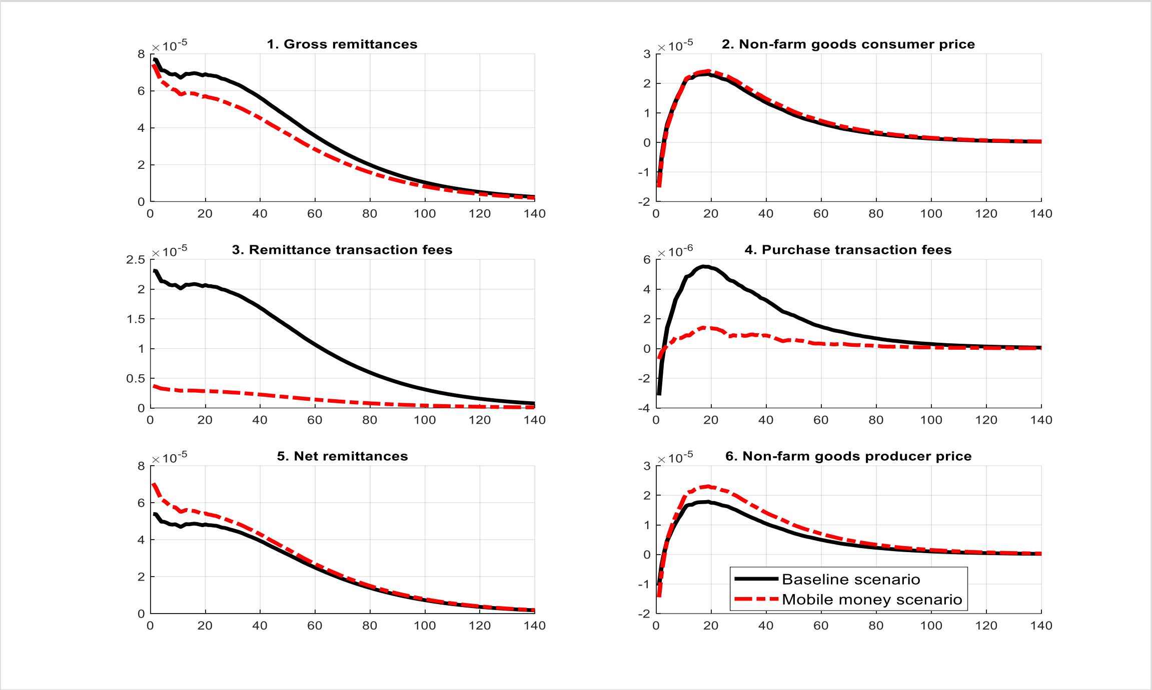
Figure E7L: Model 3 response of investment and capital to manufacturing shock



Model 3 impulse responses to policy shock

Figure E8A: Model 3 response of remittances and non-farm goods to policy shock

Interest rate rule



Money supply rule

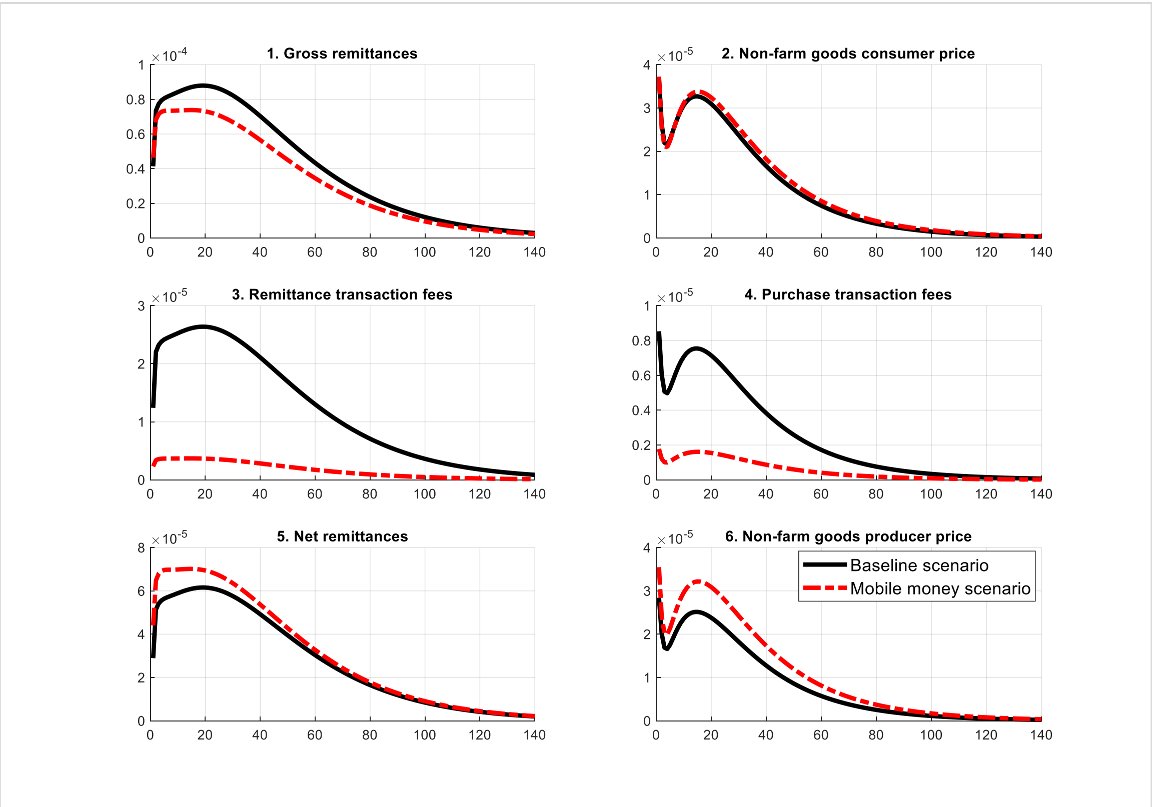


Figure E8B: Model 3 response of quantity and value output to policy shock

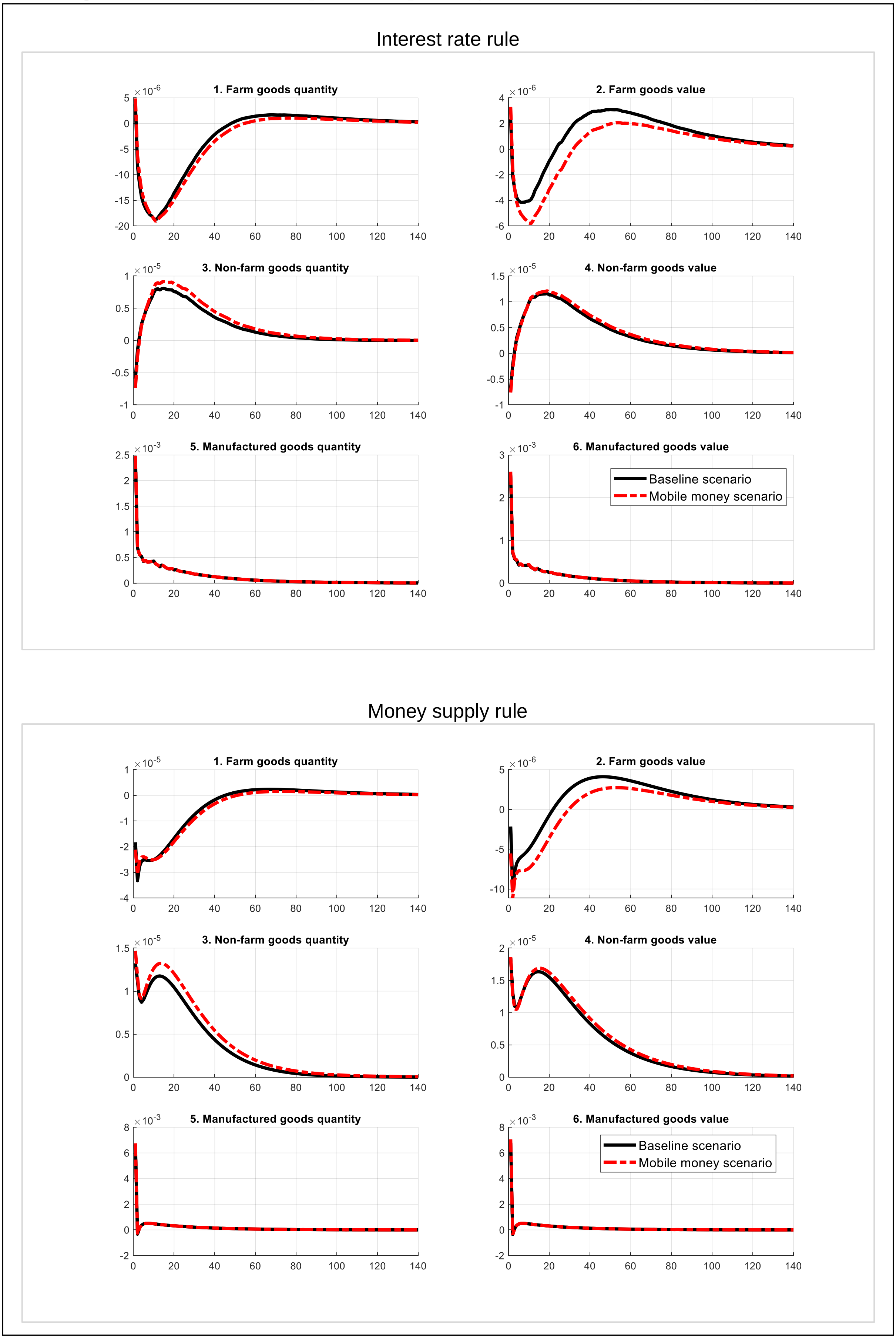


Figure E8C: Model 3 response of GDP aggregates to policy shock

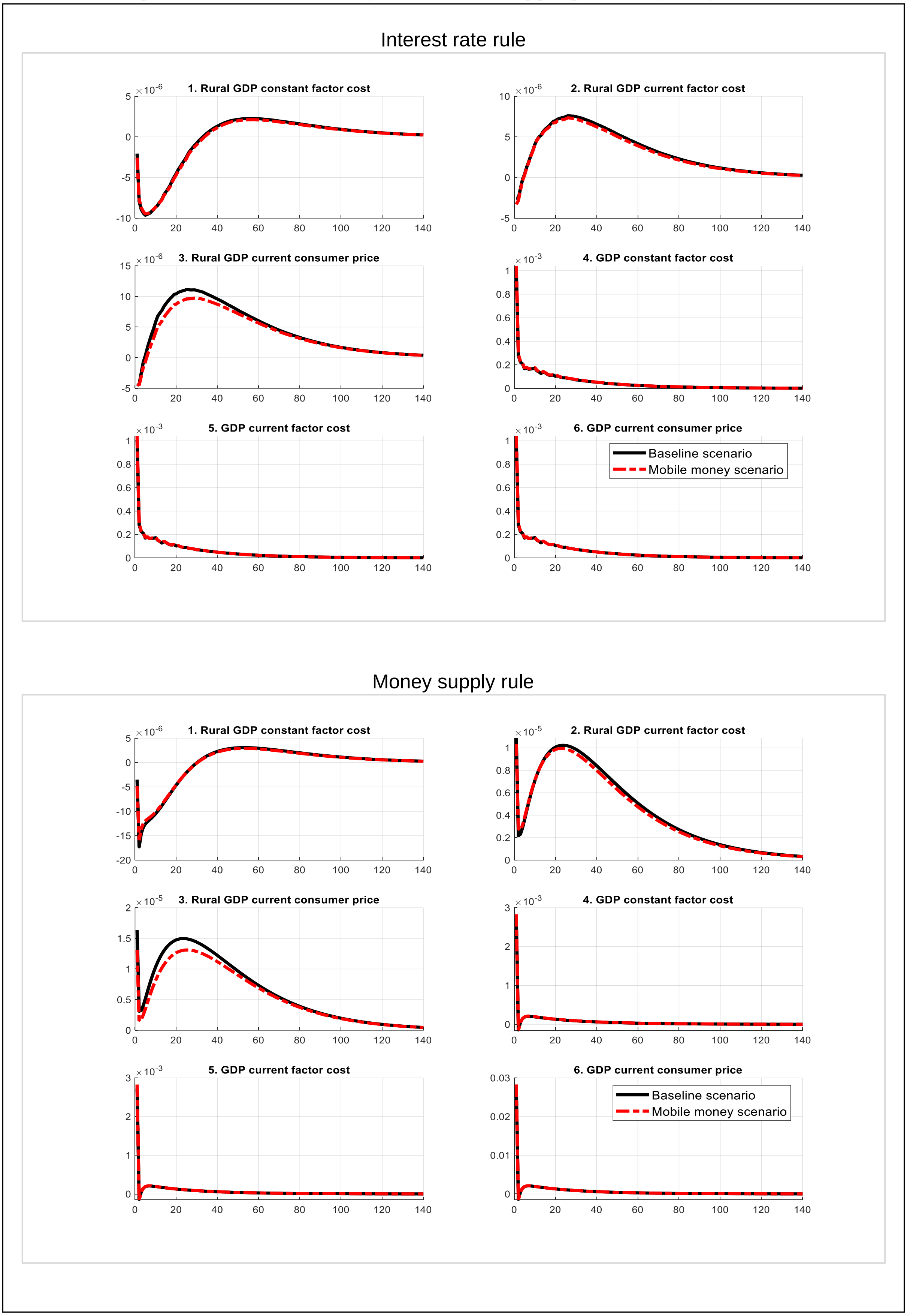


Figure E8D: Model 3 response of household labour quantity to policy shock

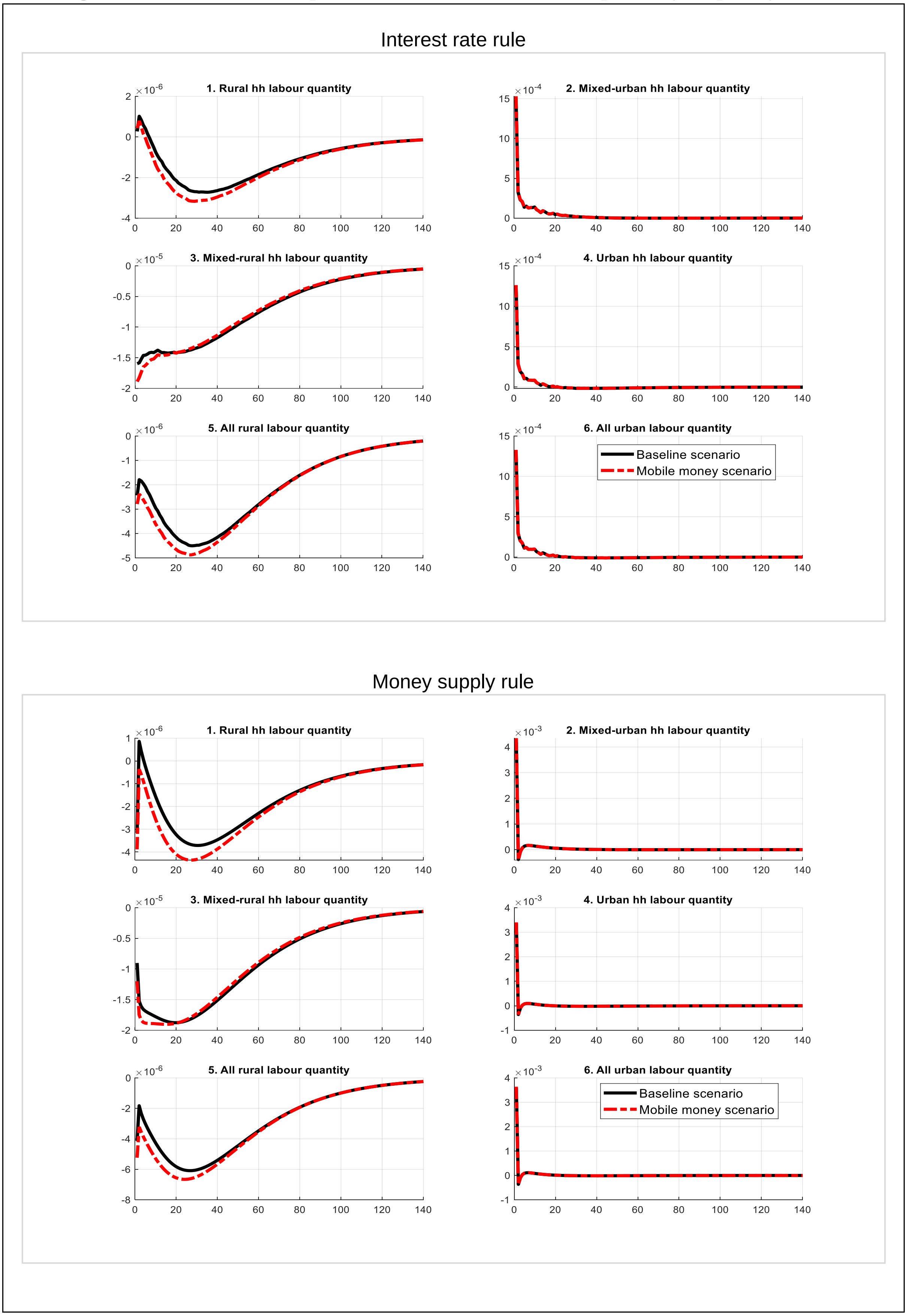


Figure E8E: Model 3 response of household labour value to policy shock

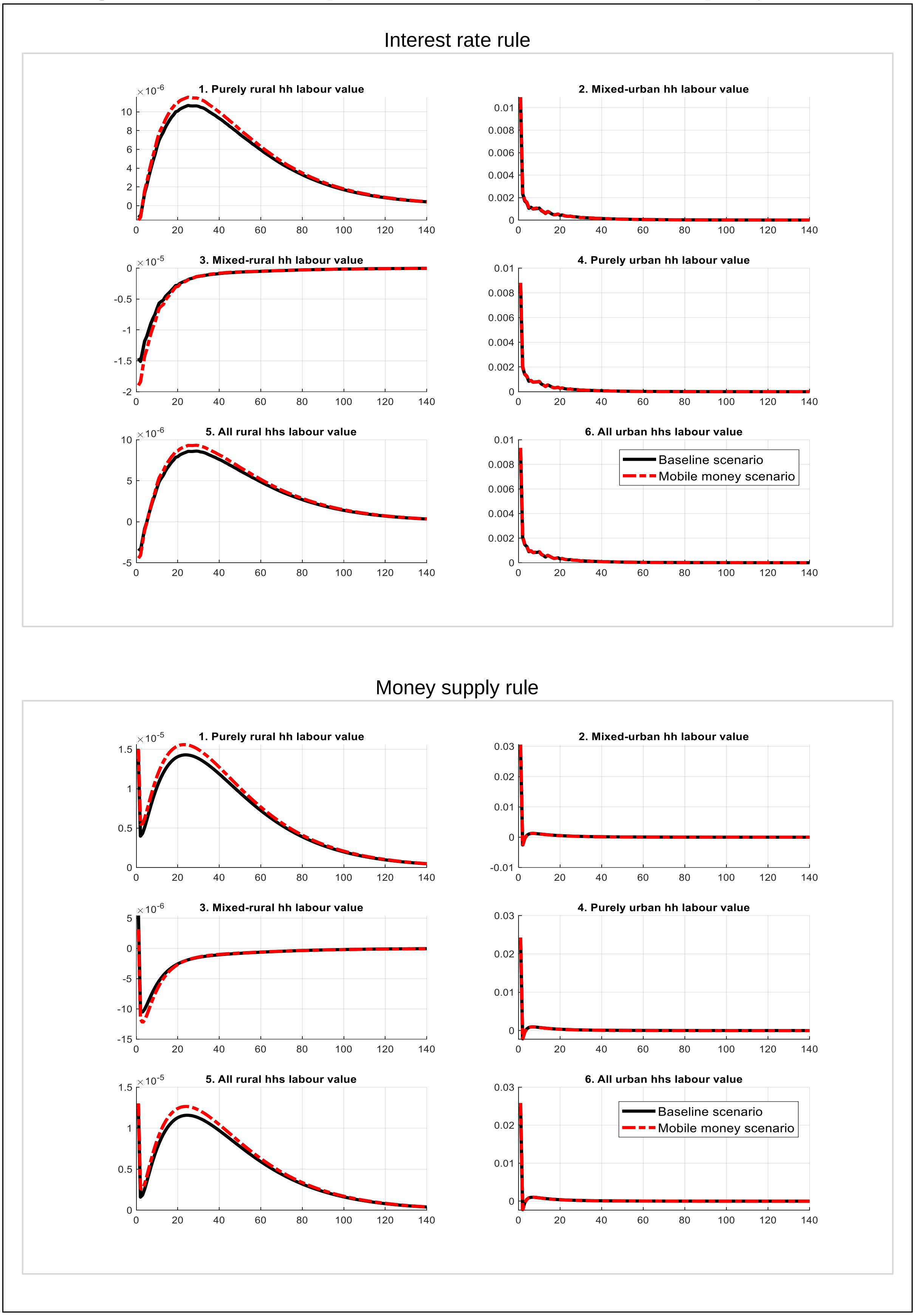


Figure E8F: Model 3 response of labour quantity and value in firms to policy shock

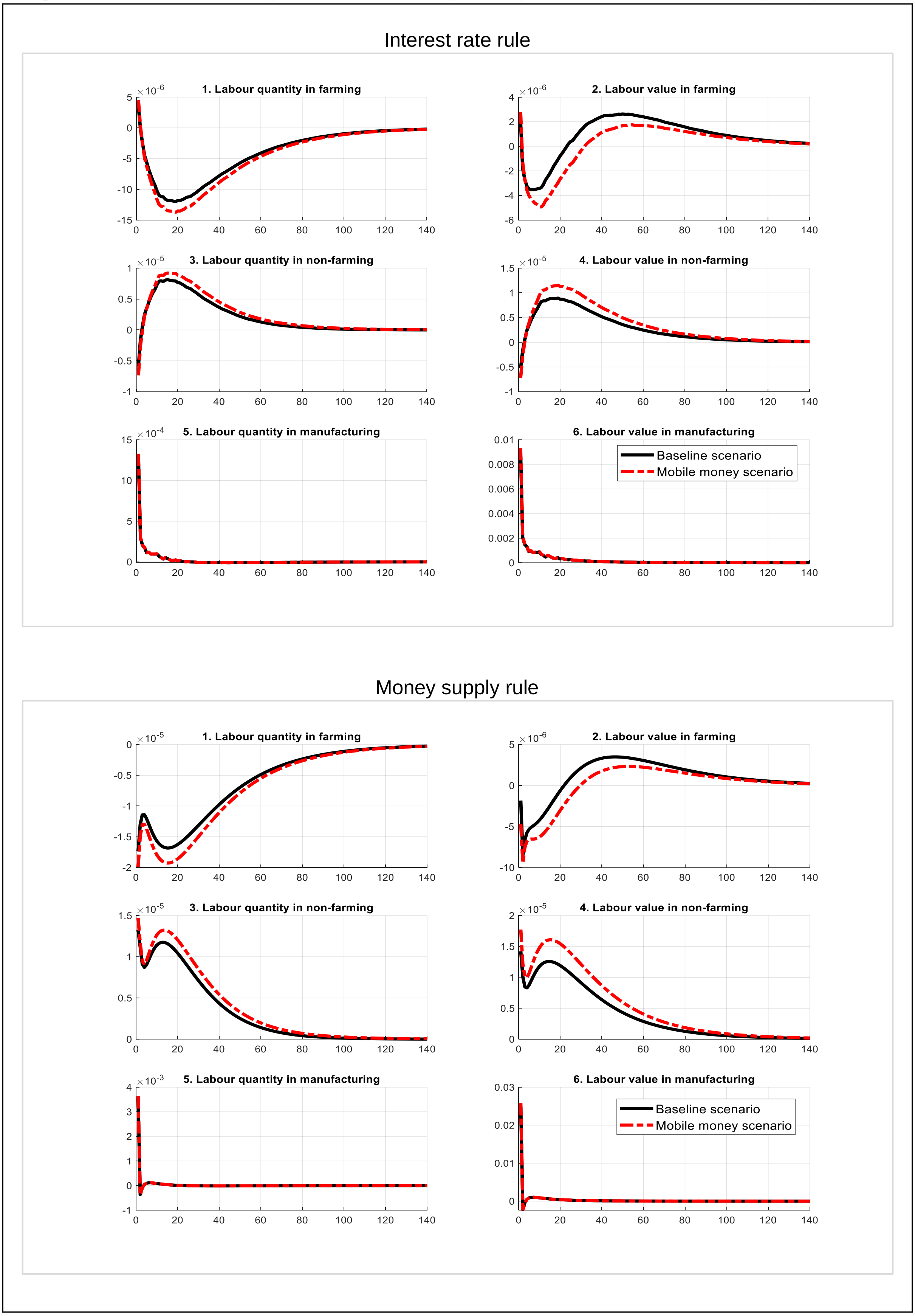


Figure E8G: Model 3 response of consumption to policy shock

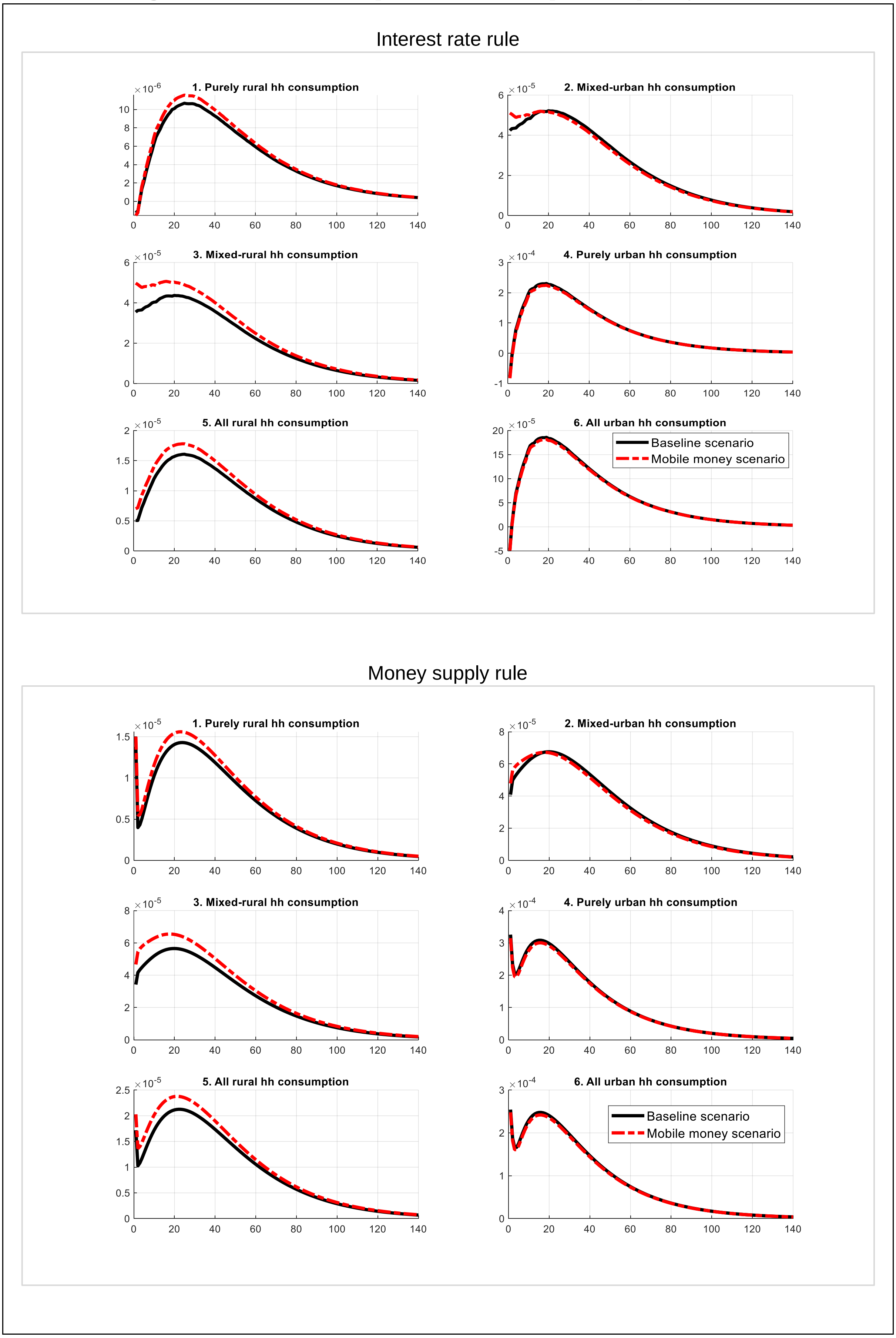


Figure E8H: Model 3 response of welfare to policy shock

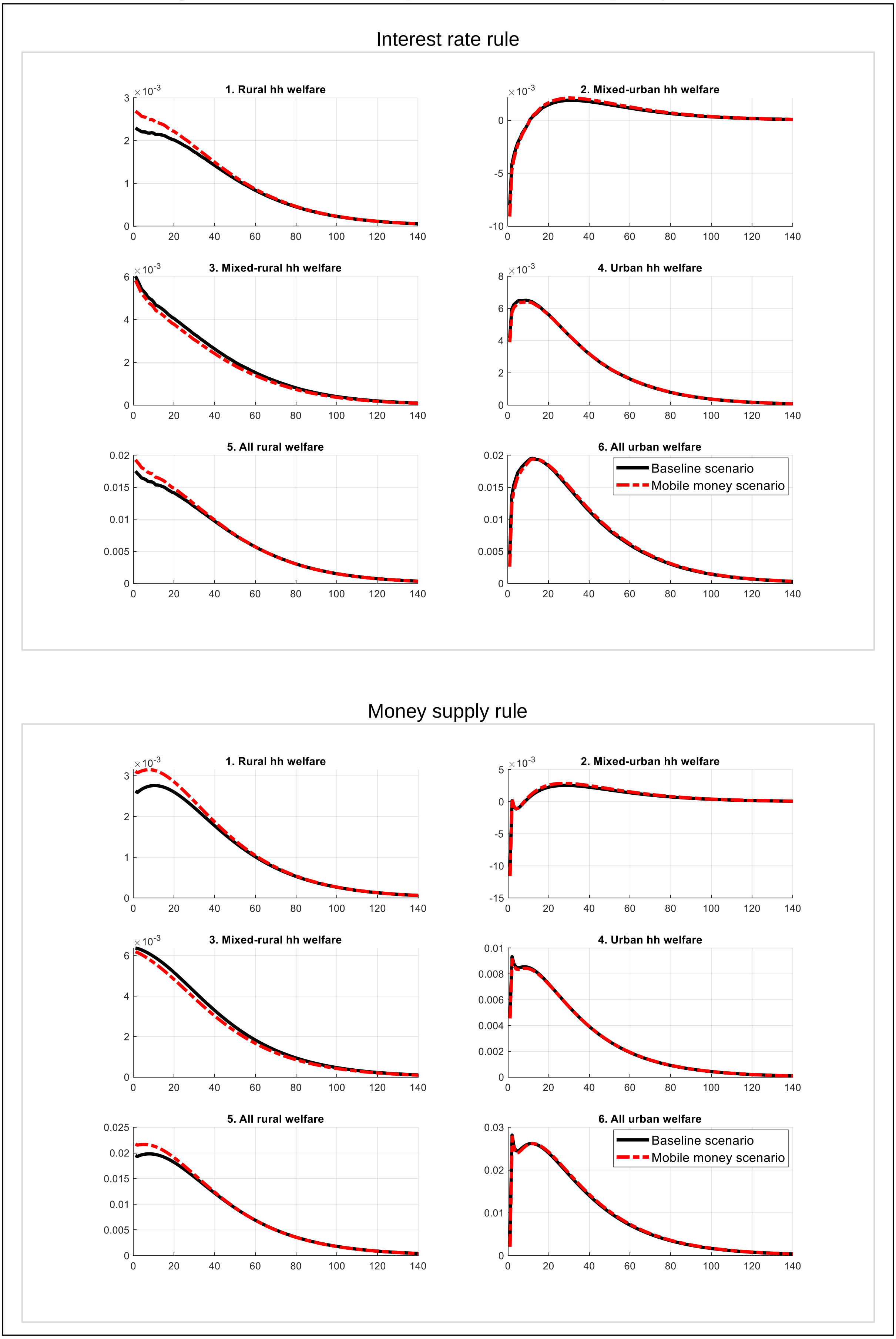


Figure E8I: Model 3 response of relative prices and wages to policy shock

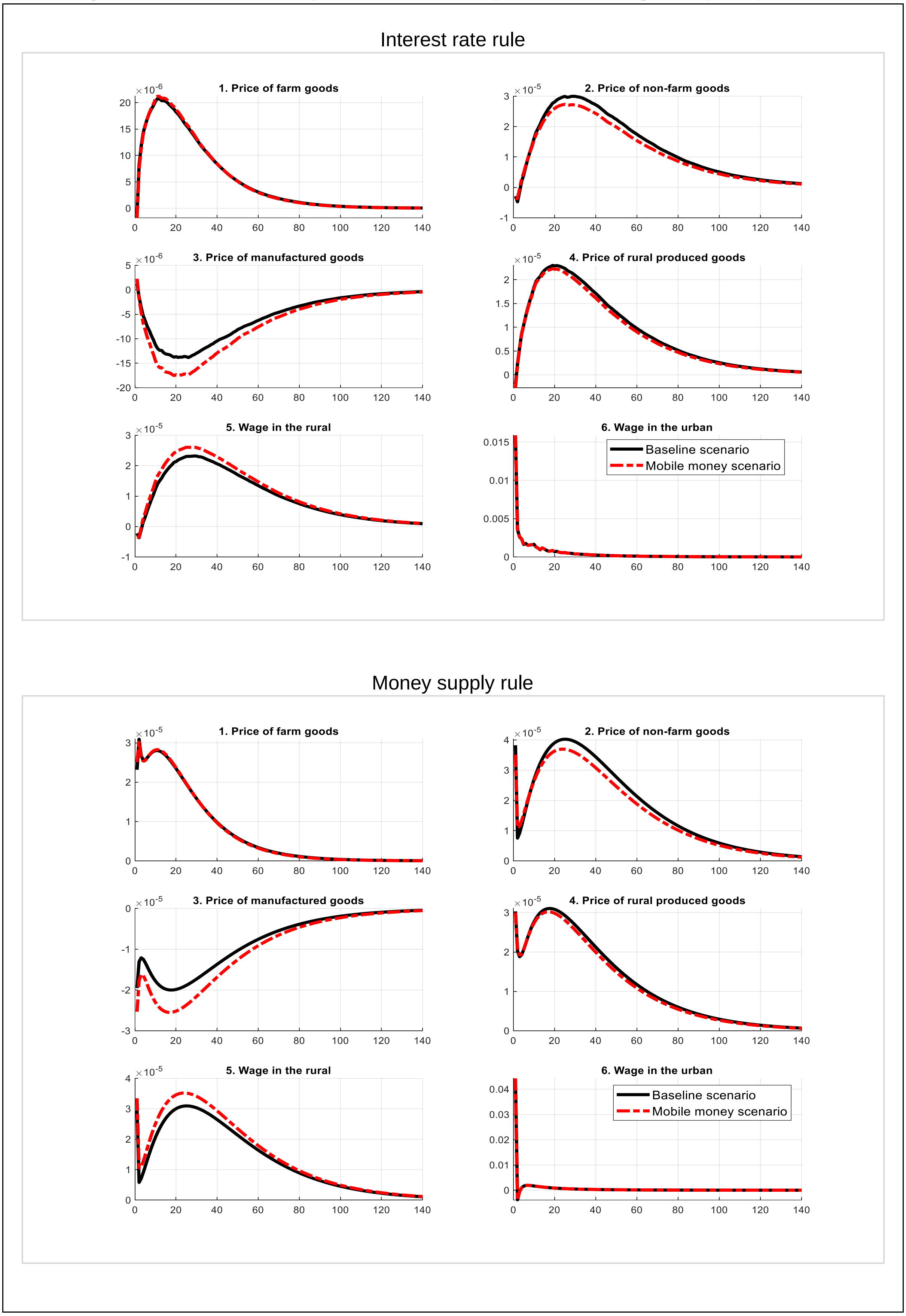
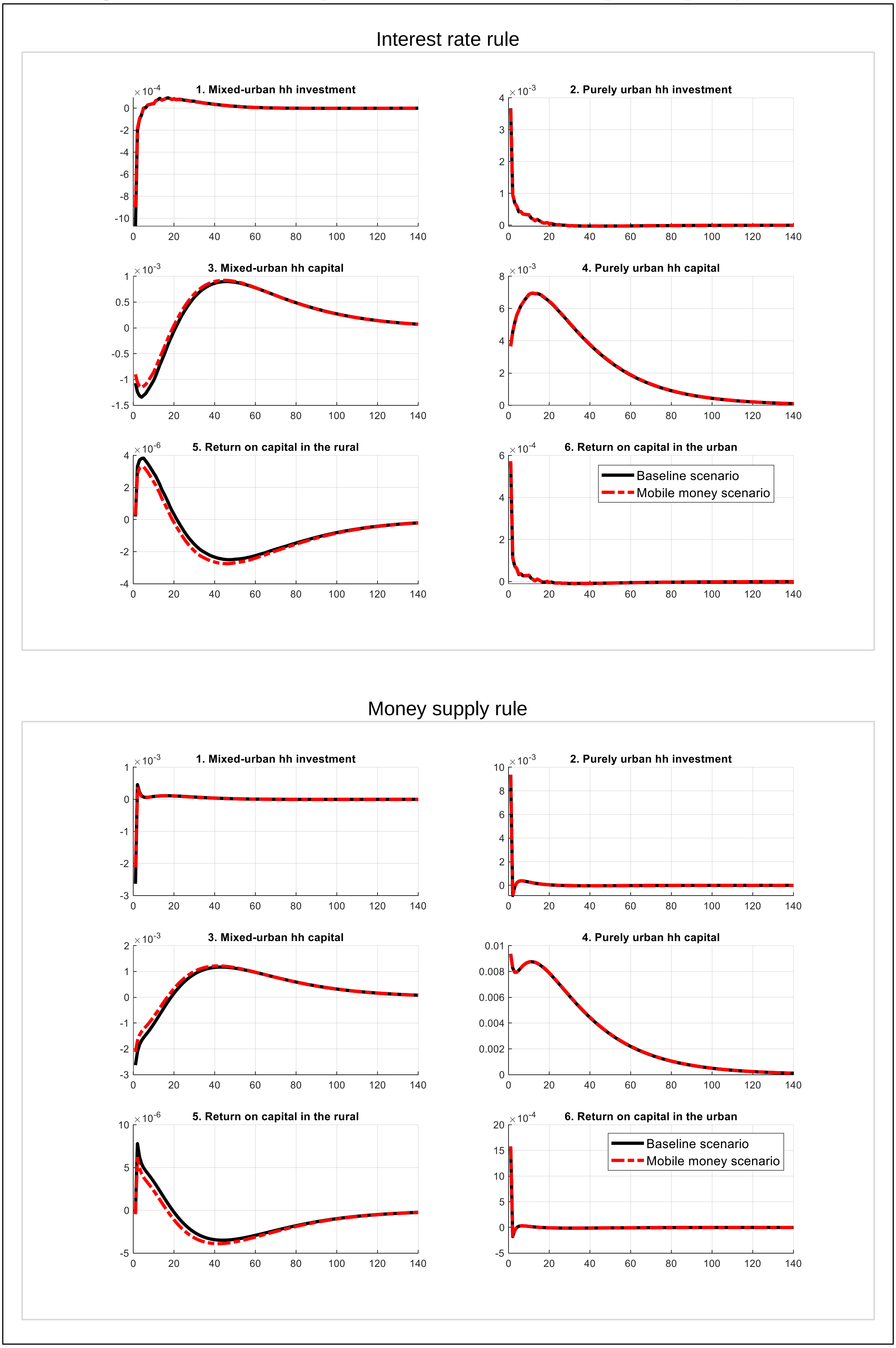


Figure E8J: Model 3 response of investment and capital to policy shock



Model 2 and Model 3 selected comparison of policy options

Figure E9A: Model 2 response of selected variables to non-farming shock, MRS versus IRR, mobile money scenario

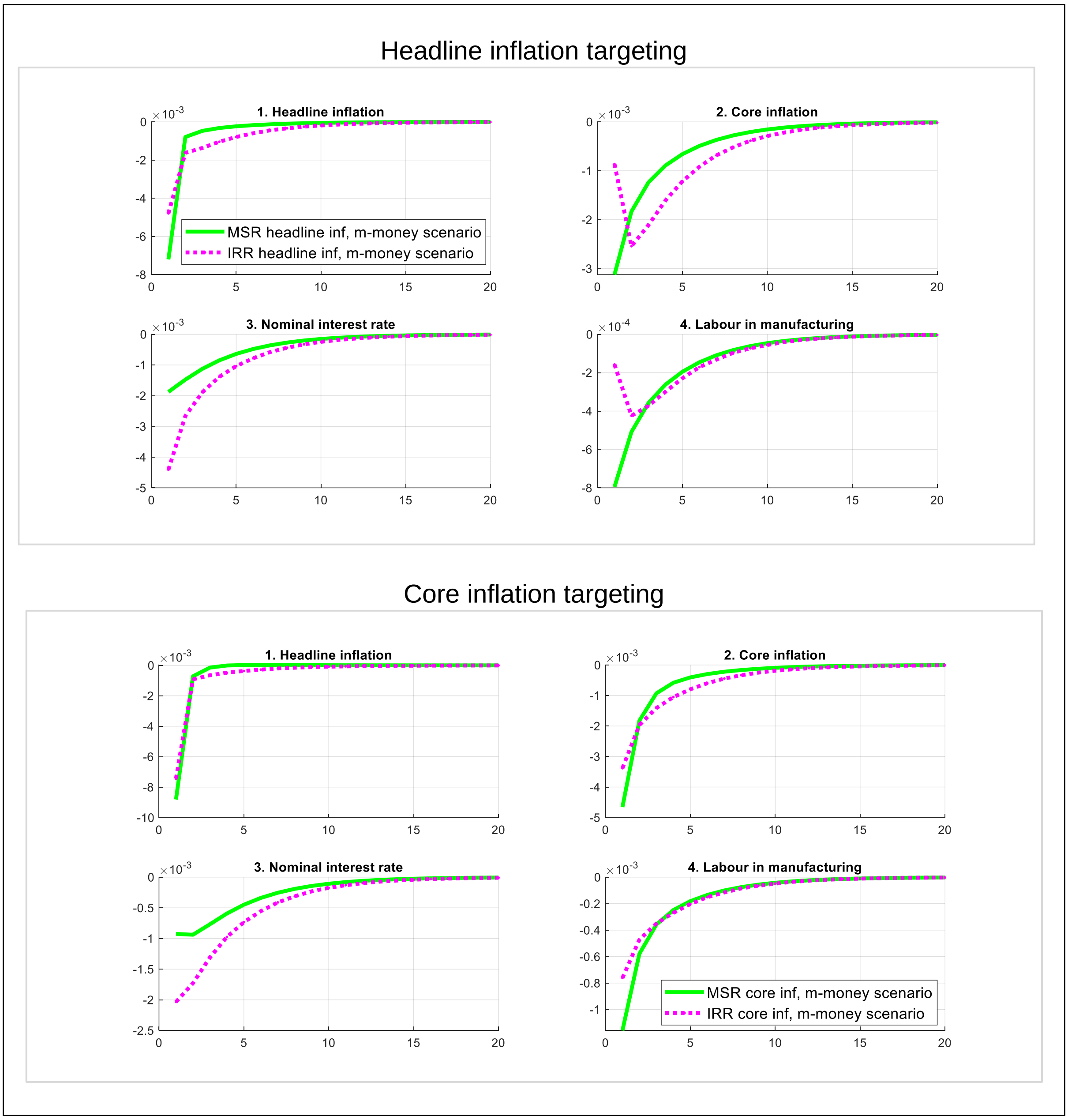


Figure E9B: Model 2 response of selected variables to manufacturing shock, MRS versus IRR, mobile money scenario

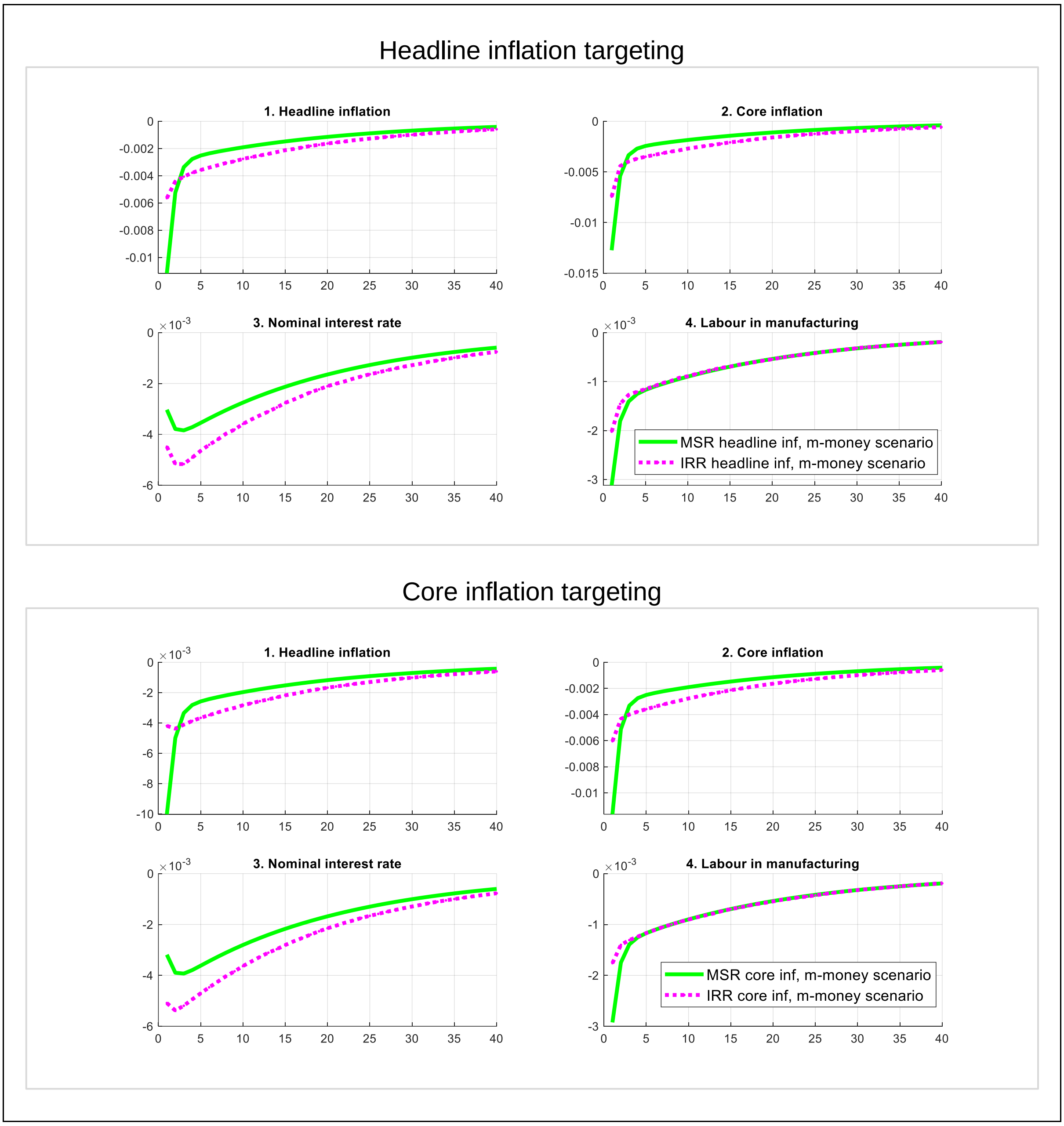


Figure E9C: Model 3 MRS versus IRR response of selected variables to non-farming shock, mobile money scenario

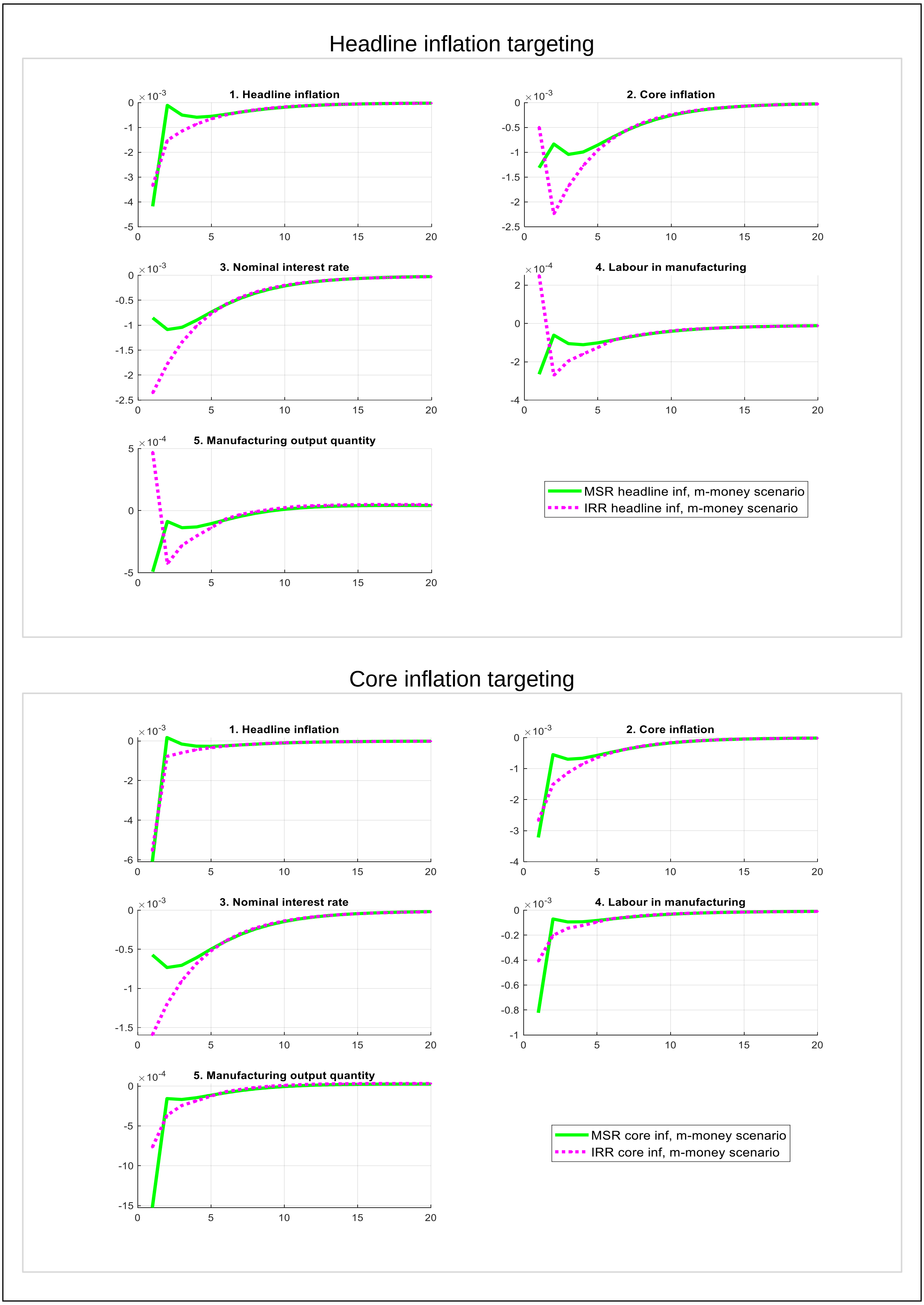


Figure E9D: Model 3 MRS versus IRR response of selected variables to manufacturing shock, mobile money scenario

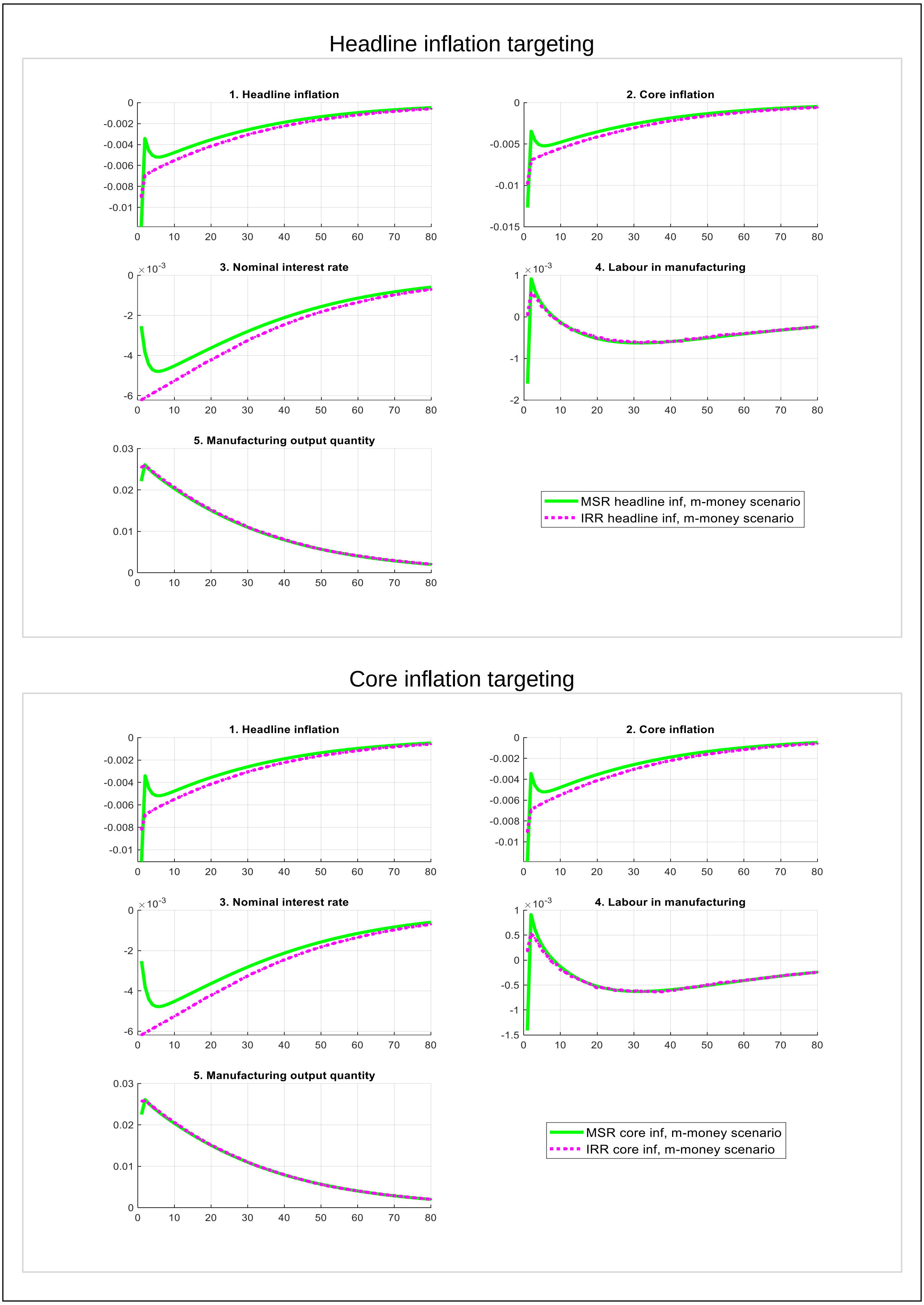


Figure E10A: Model 2 headline inflation targeting versus core inflation targeting, response to farming shock, mobile money scenario

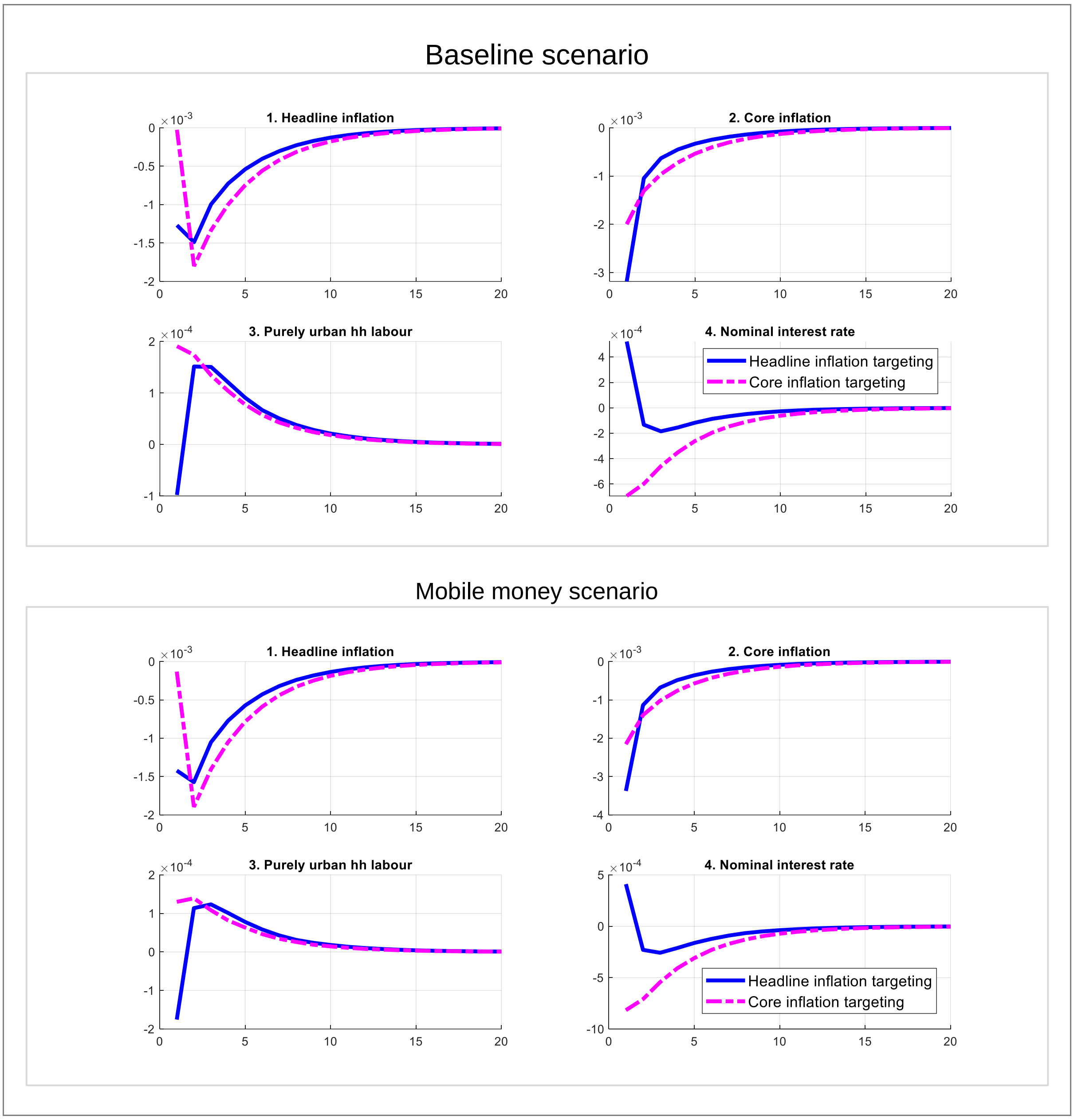


Figure E10B: Model 3 headline inflation targeting versus core inflation targeting, response to farming shock, mobile money scenario

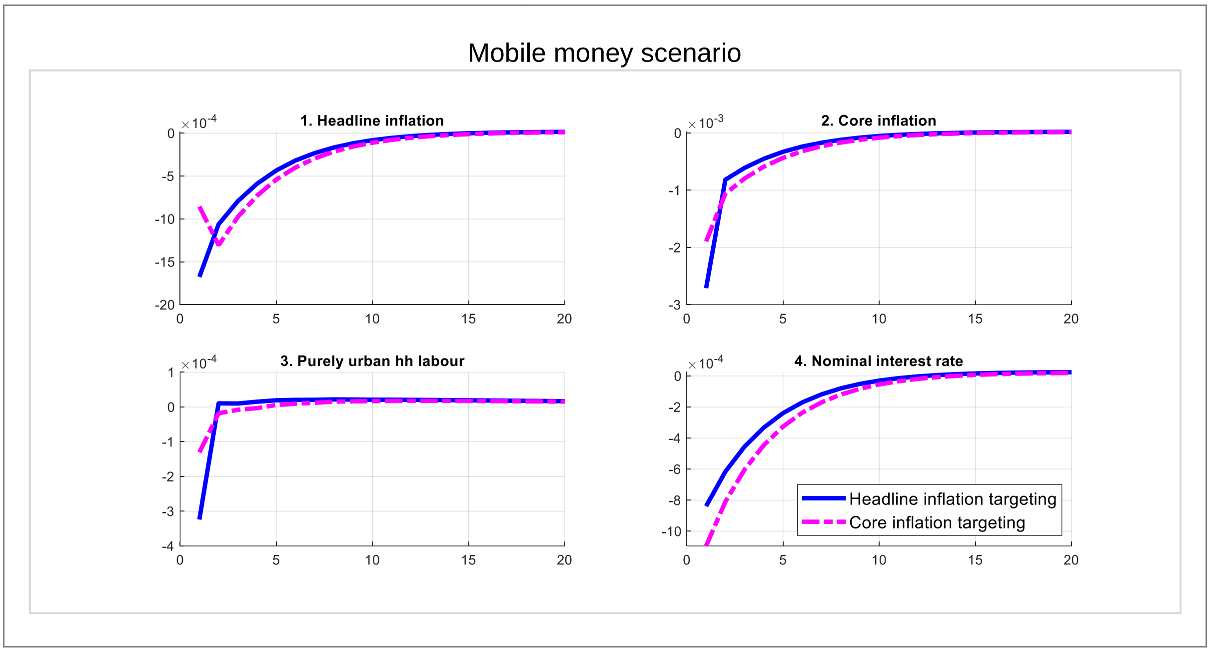


Figure E10C: Response of welfare to policy shock IRR, Model 2 versus Model 3, mobile money scenario

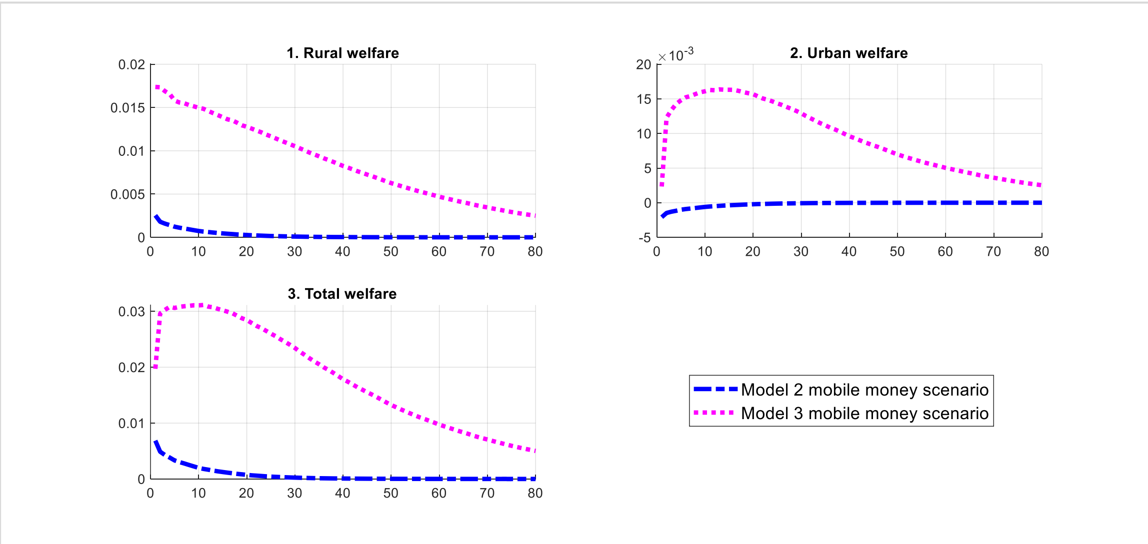


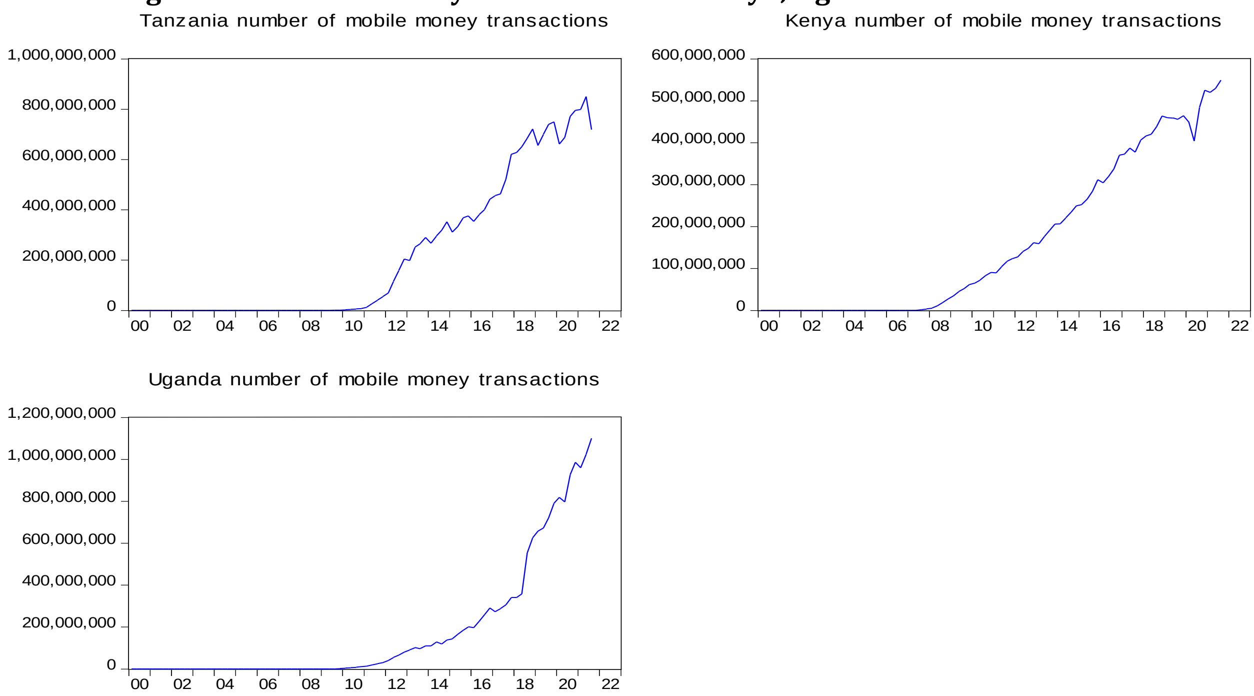
Table E1: Comparison of mean values of welfare, headline versus core inflation targeting

	Scenario	
Item	**Baseline**	**Mobile money**
Model 1		
Core minus headline	-7.00E-04	-4.00E-04
Model 2		
Core minus headline	-2.00E-03	-3.00E-04
Model 3		
Core minus headline	4.10E-03	6.50E-03

Chapter 4 Appendices

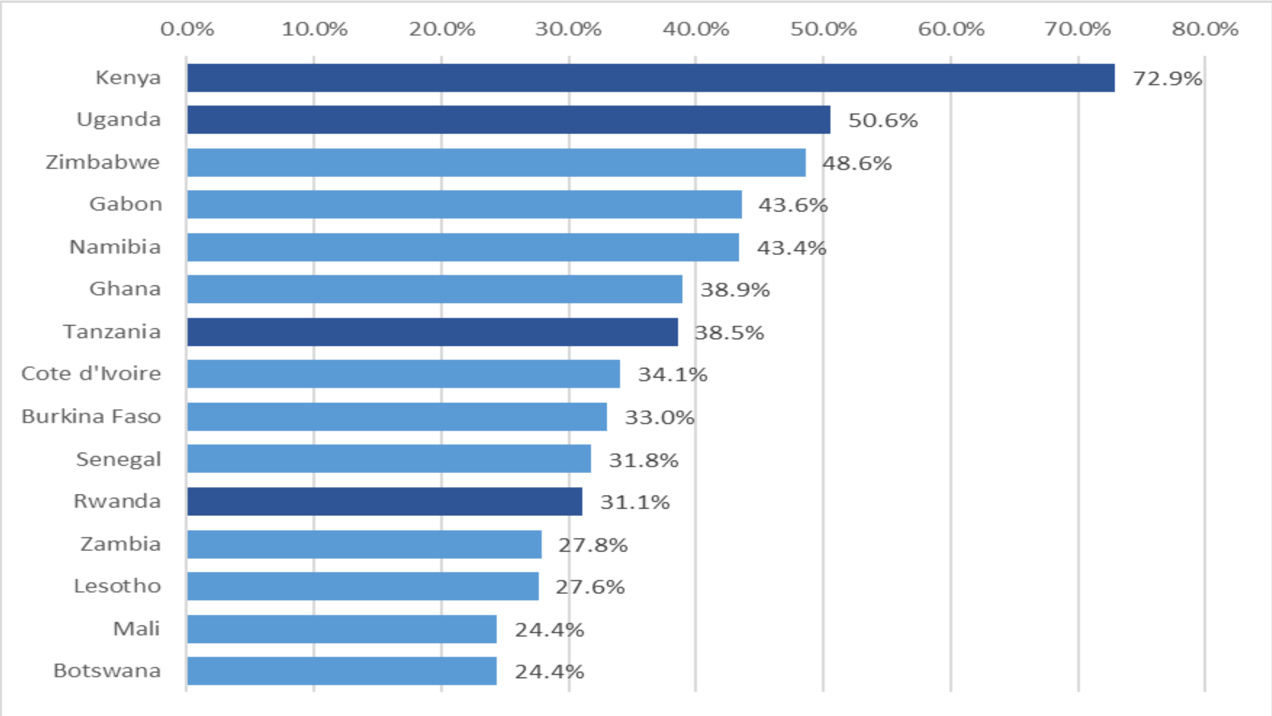
Appendix F: East Africa figures and tables

Figure F1: Mobile money transactions in Kenya, Uganda and Tanzania



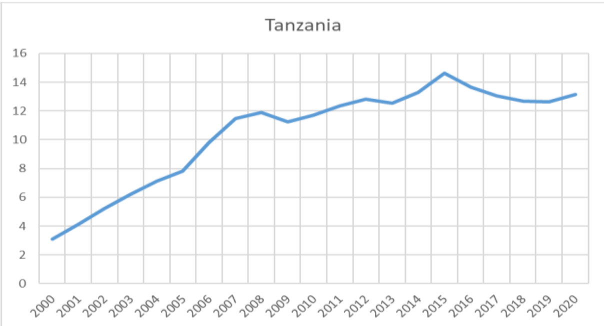
Source: Central banks of Tanzania, Kenya and Uganda.
Tanzania and Uganda data represent all mobile money transactions; Kenya data represent cash-in-cash-out mobile money transactions only.

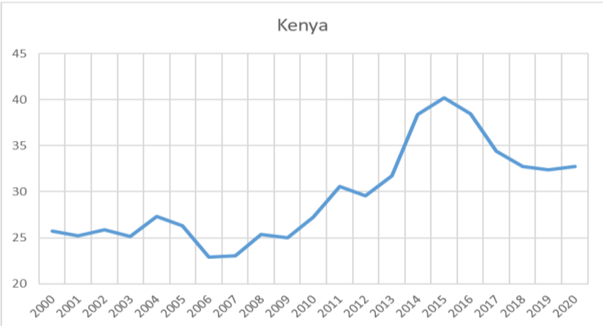
Figure F2: Mobile money account (% age 15+) 2017, selected SSA countries

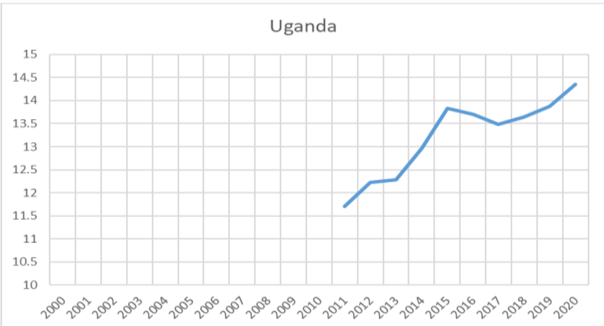


Source: World Bank Findex Data

Figure F3: Credit to GDP ratio, selected East African countries

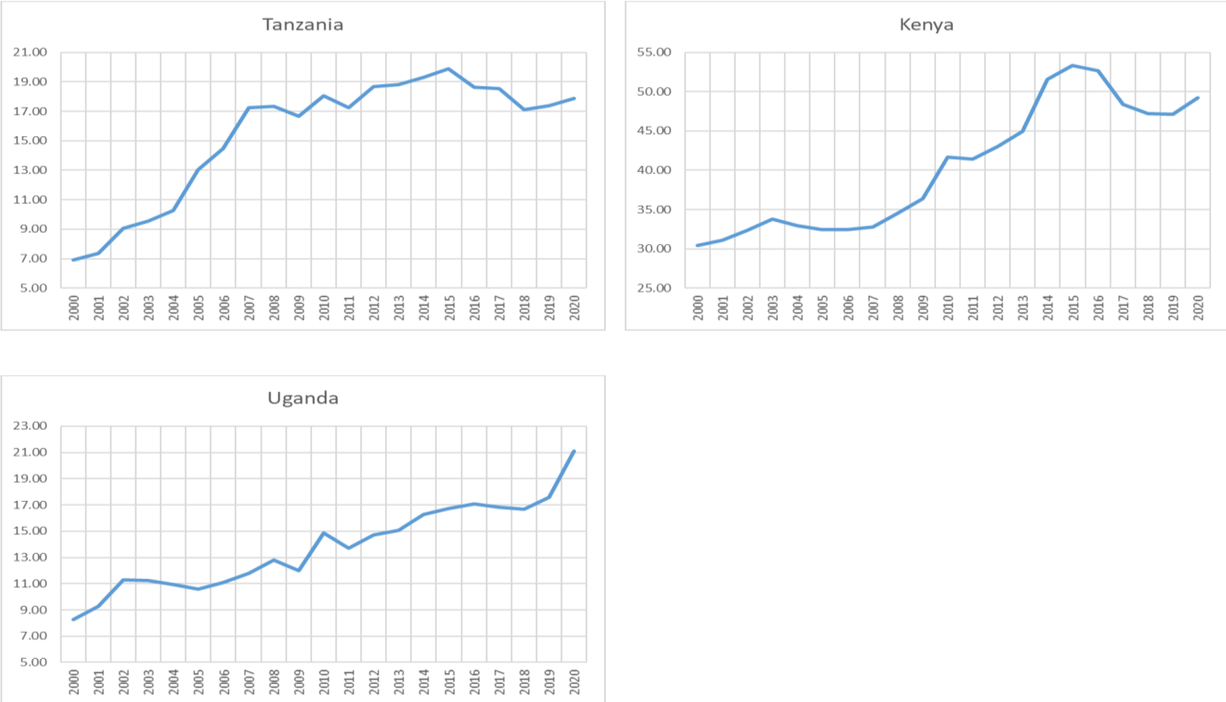






Source: World Bank, World Development Indicators

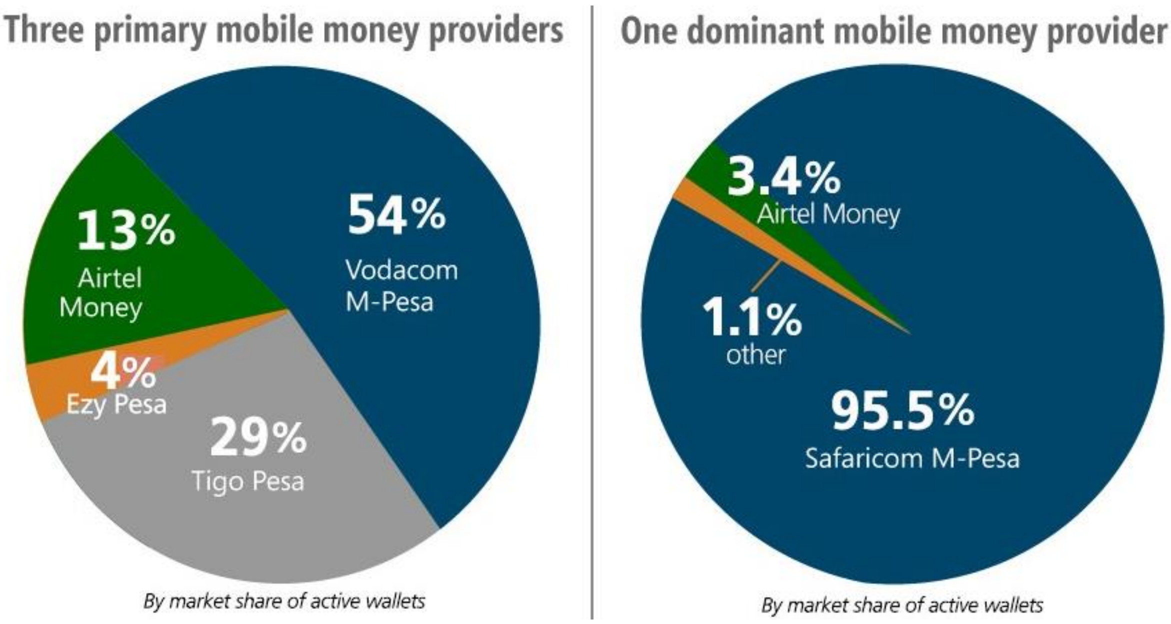
Figure F4: Bank assets to GDP ratio, selected East African countries



Source: The Global Economy

Figure F5: Mobile money market shares, Tanzania and Kenya 2015

Tanzania **Kenya**



Source: CGAP (2015)

Table F1: Snapshot of financial sector 2020, selected East African countries

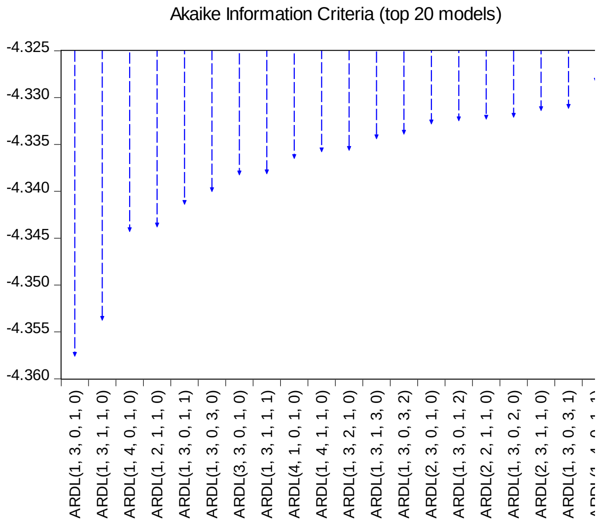
	Tanzania	Kenya	Uganda
Bank branches	969	1,502	566
ATMs	2,058	2,412	837
Bank agents	40,410	72,617	15,716
Mobile money agents	702,284	299,053	263,698
Mobile money active accounts	30,325,019	67,150,000	19,759,974
Number of bank deposit account holders	17,529,908	69,881,847	17,762,123
Population	59,730,000	53,770,000	45,740,000
GDP per capita (USD)	1,077	1,879	822
People per branch	61,641	35,799	80,813
People per bank agent	1,478	740	2,910
People per m-money agent	85	180	173
Branches by 100K people	2	3	1
M-money agents/bank branches	725	199	466
M-money agents/bank agents	17	4	17

Source: Bank of Tanzania Banking Supervision Report (2020); Bank of Uganda Banking Supervision Annual Report (2020); Central Bank of Kenya Banking Supervision Annual Report (2020); Uganda Bankers Association Annual Report (2020); Author's computations

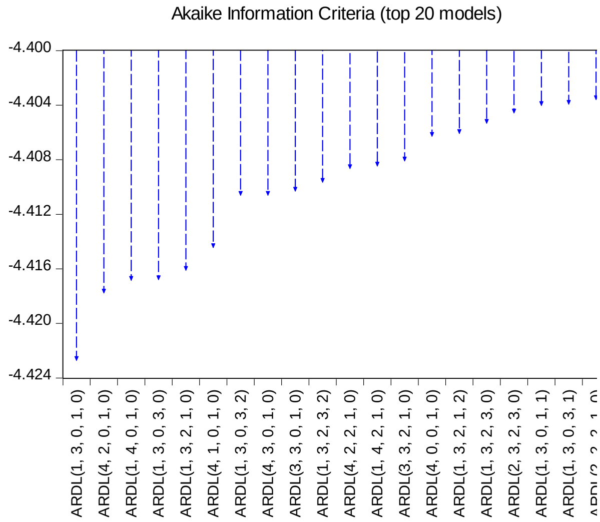
Appendix G: Figures and tables related to estimations

Figure G1A: Model selection summary for Tanzania

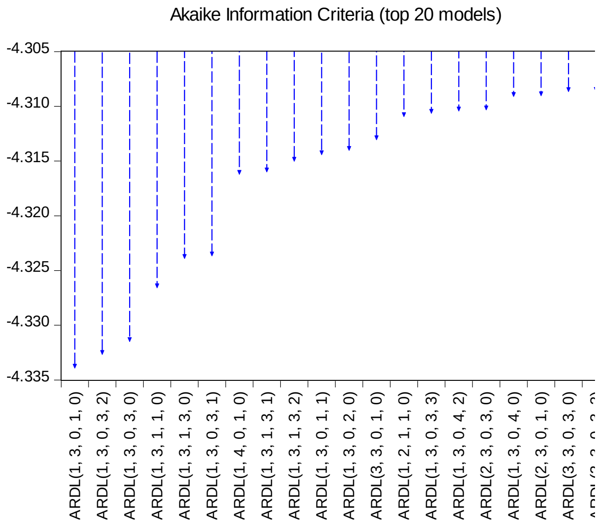
First equation full sample



Second equation full sample



Third equation full sample



Equation m-money sub-sample

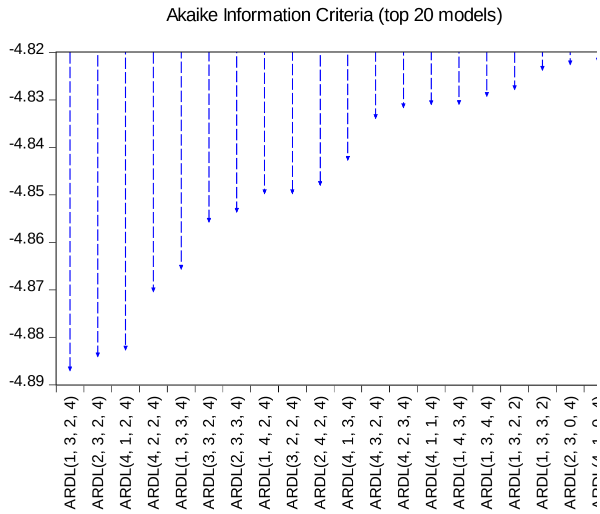
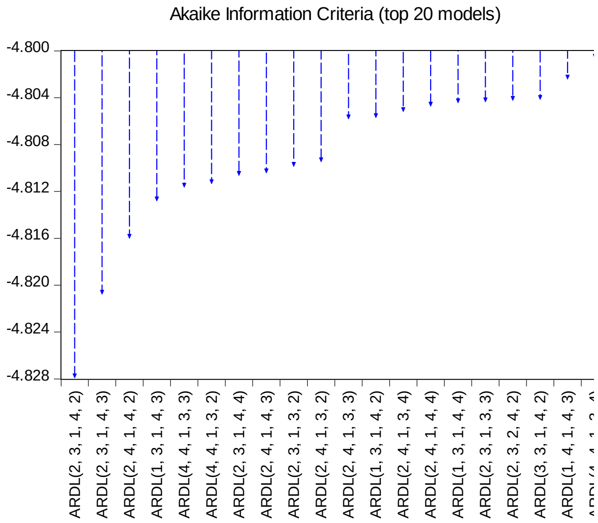
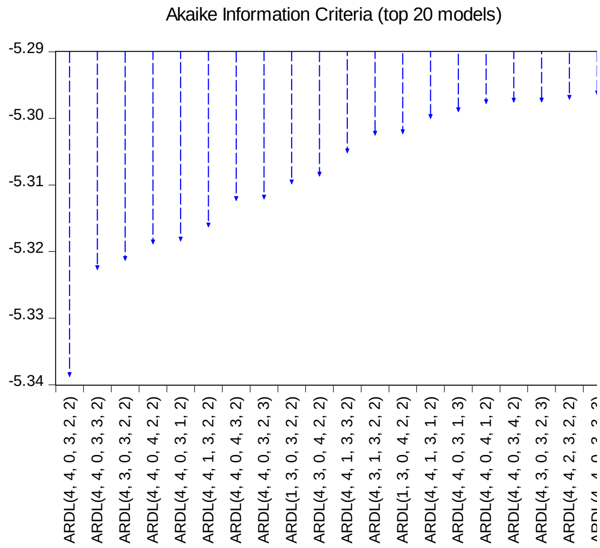


Figure G1B: Model selection summary for Kenya

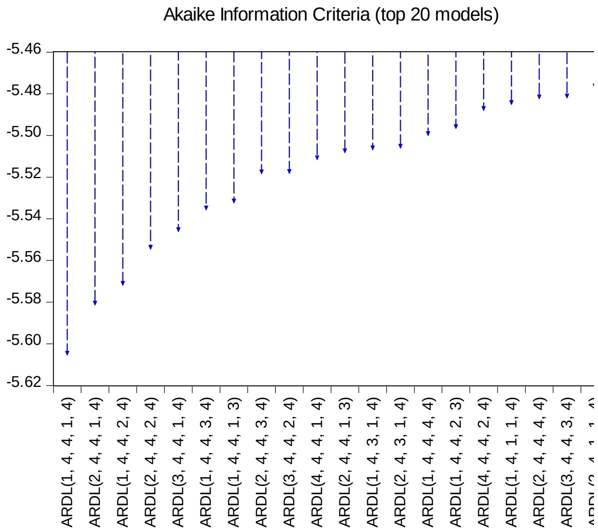
First equation full sample



Second equation full sample



First equation m-money sub-sample



Second equation m-money sub-sample

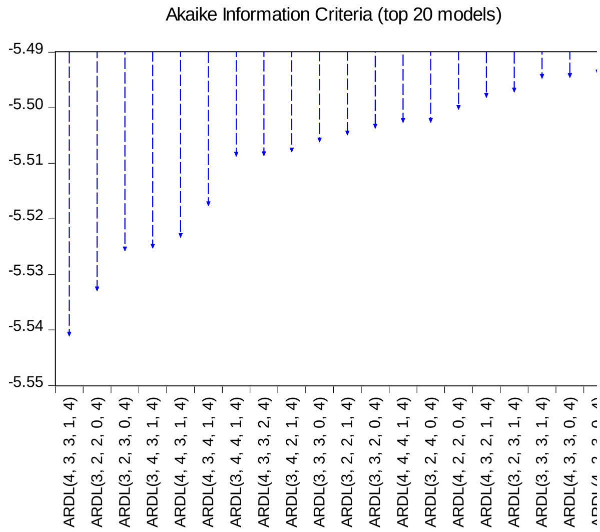
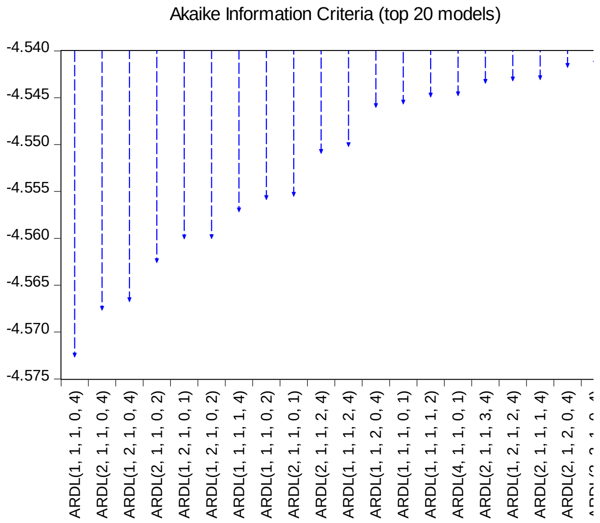
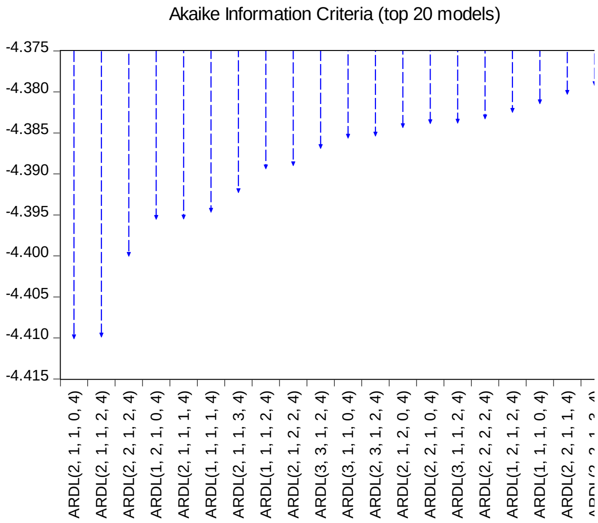


Figure G1C: Model selection summary for Uganda

First equation full sample



Second equation full sample



Equation m-money sub-sample

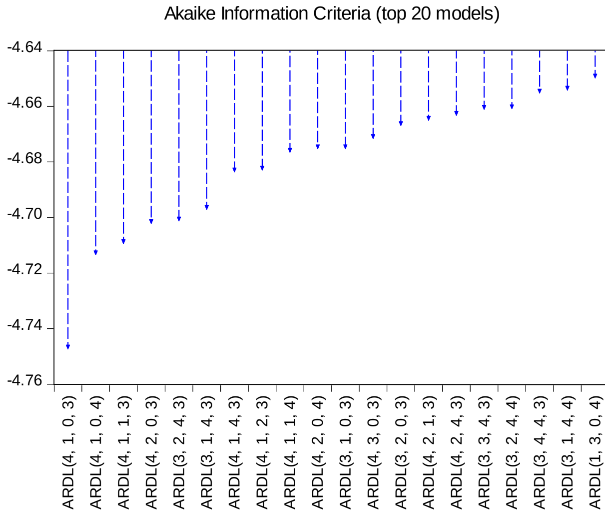
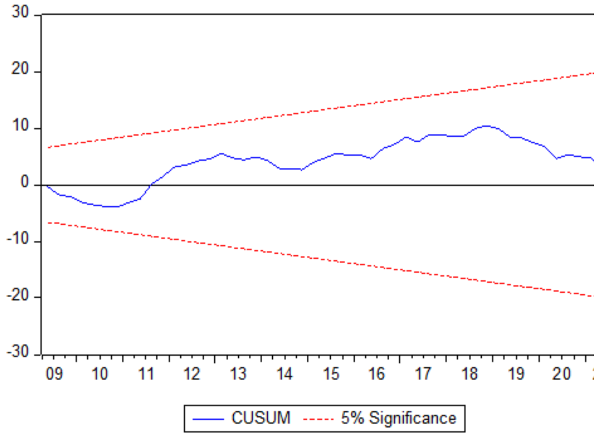
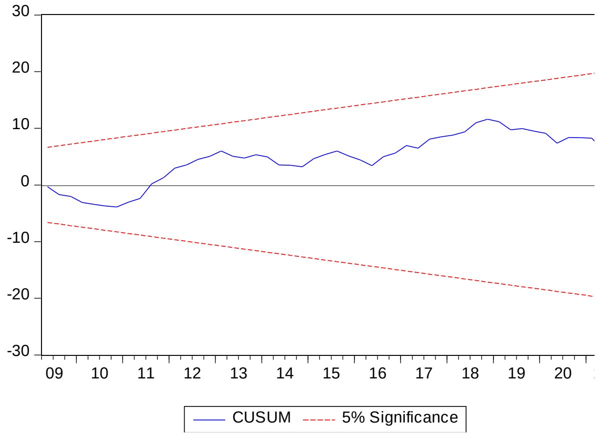


Figure G2A: Stability diagnostics QUSUM tests for Tanzania

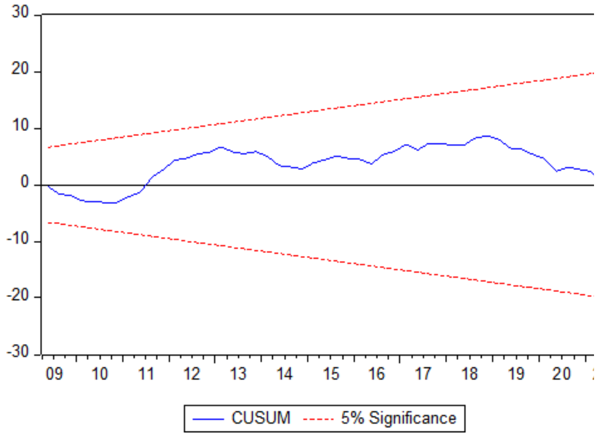
First equation full sample



Second equation full sample



Third equation full sample



Fourth equation m-money sub-sample

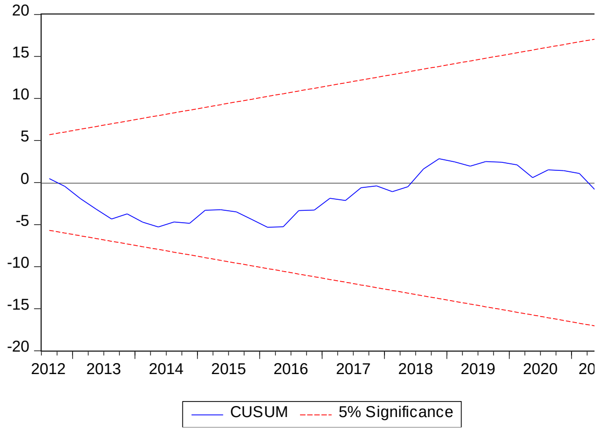
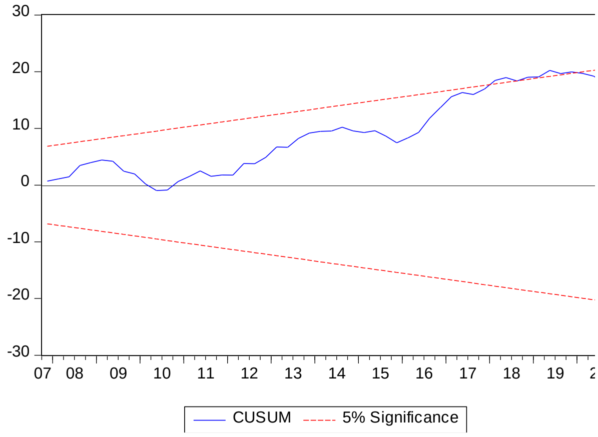
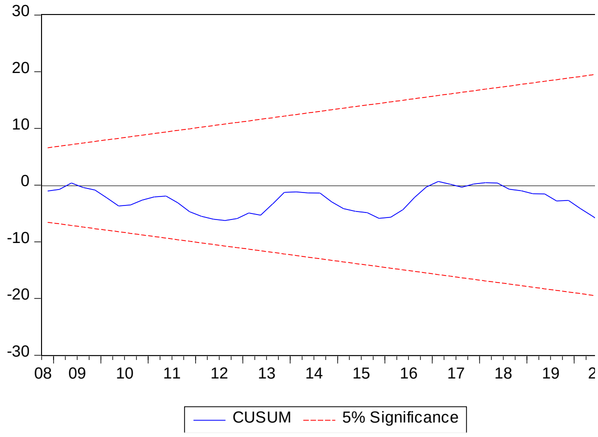


Figure G2B: Stability diagnostics QUSUM tests for Kenya

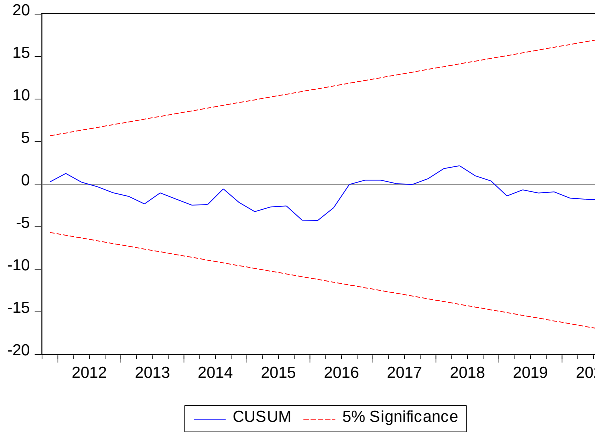
First equation full sample



Second equation full sample



First equation m-money sub-sample



Second equation m-money sub-sample

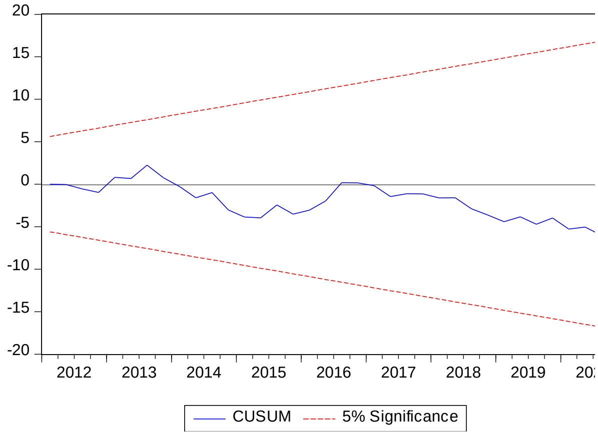
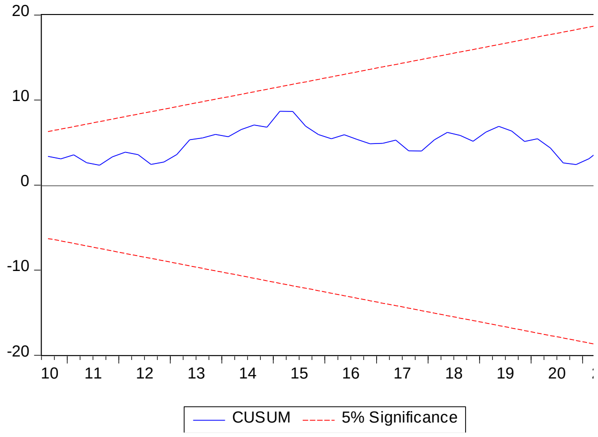
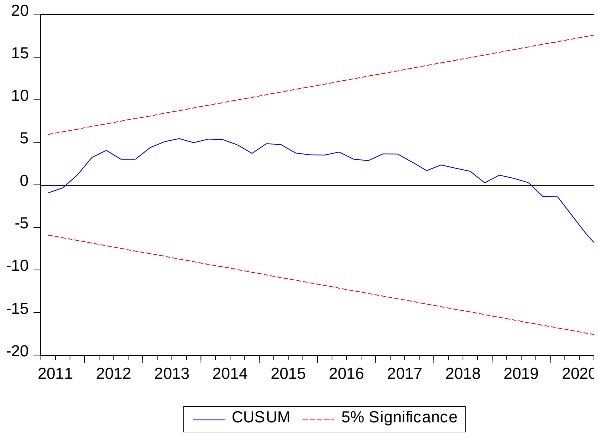


Figure G2C: Stability diagnostics QUSUM tests for Uganda

First equation full sample



Second equation full sample



M-money sub-sample equation

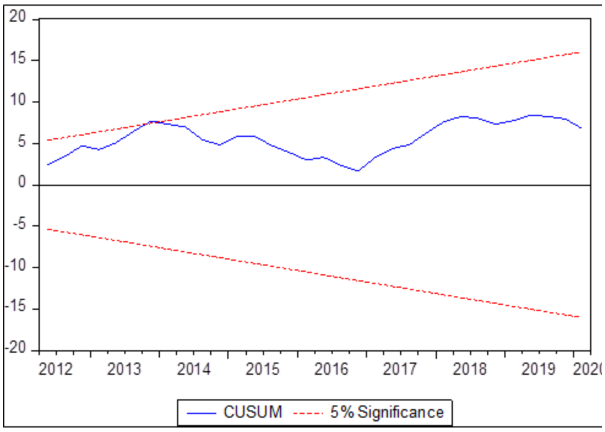
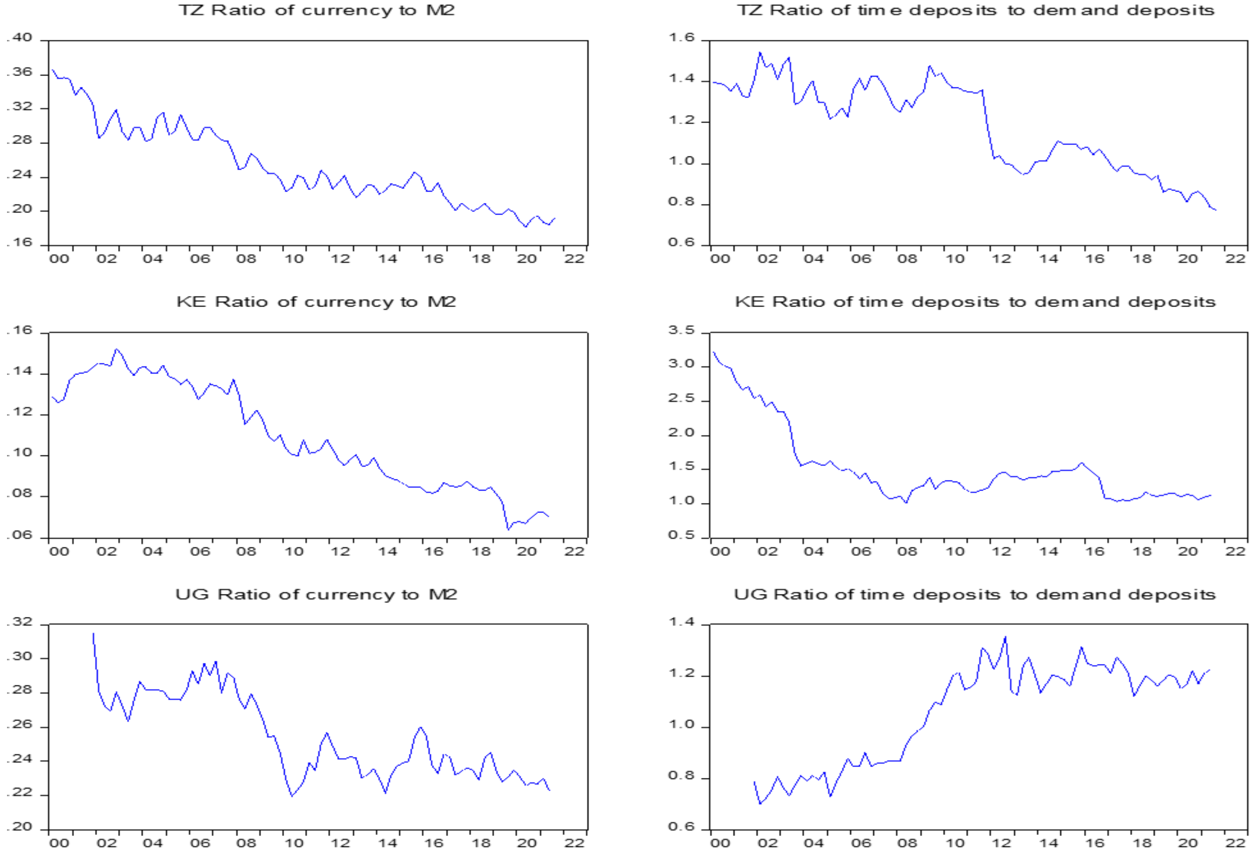


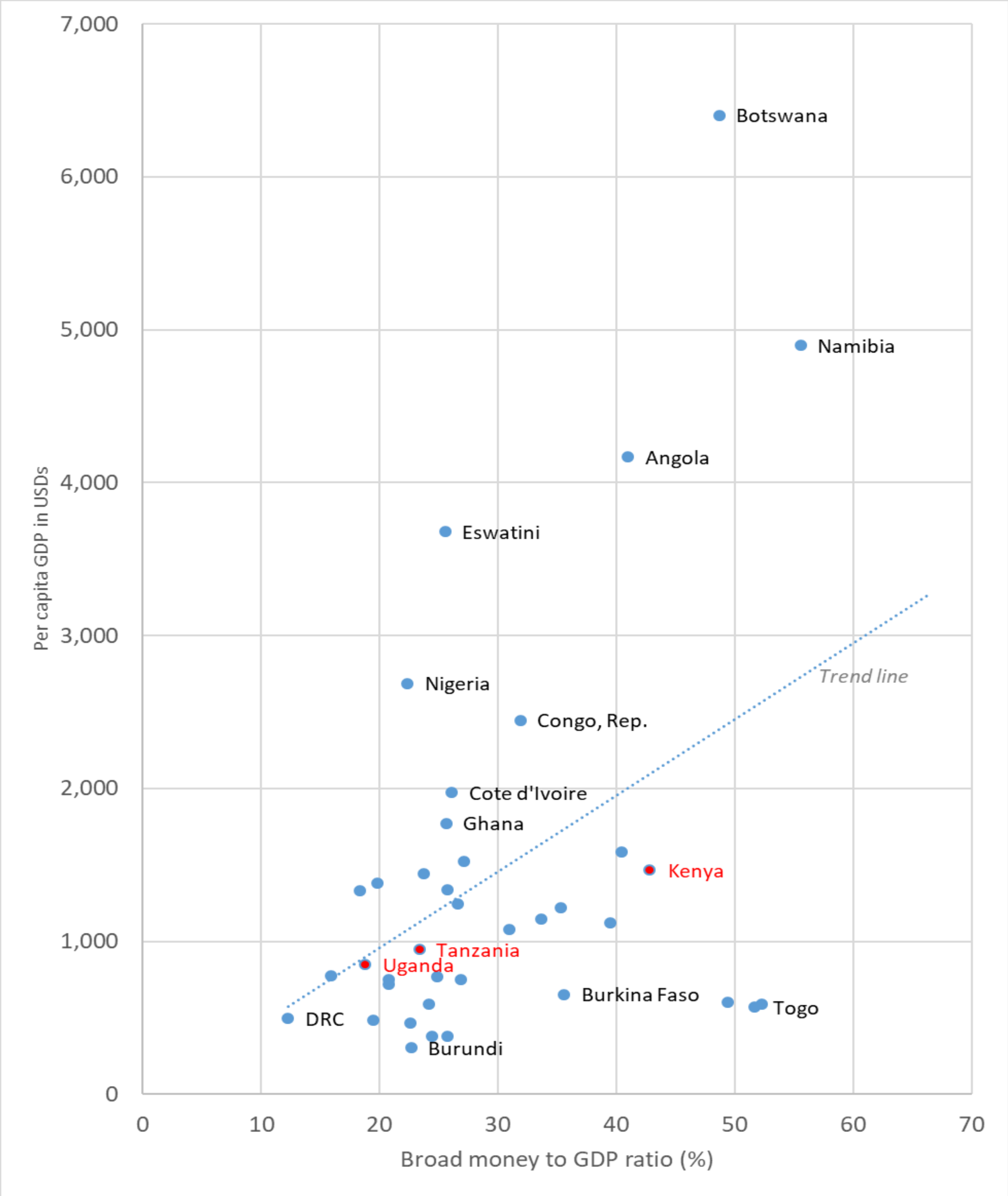
Figure G3: Other indicators used as proxies for financial innovation



TZ stands for Tanzania, KE for Kenya and UG for Uganda

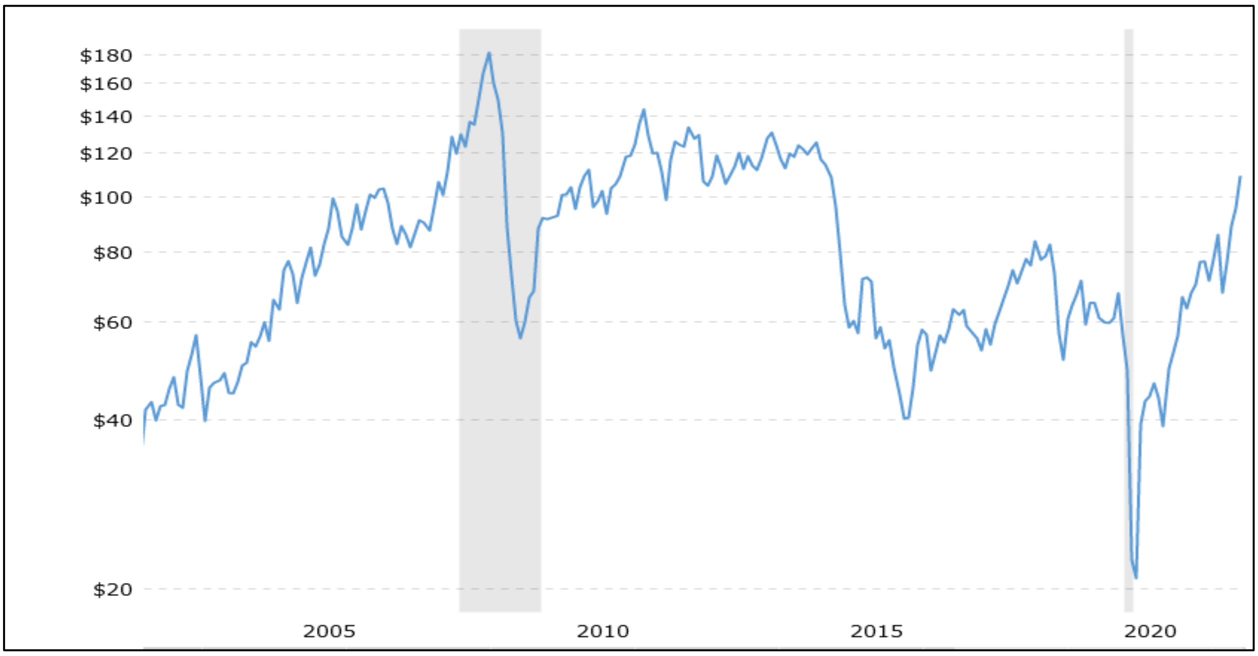
Appendix H: Global figures and tables

Figure H1: The ratio of money to GDP and per capita GDP in SSA (2015)



Source: World Bank, World Development Indicators

Figure H2: World market price of crude oil



Source: https://www.macrotrends.net/1369/crude-oil-price-history-chart

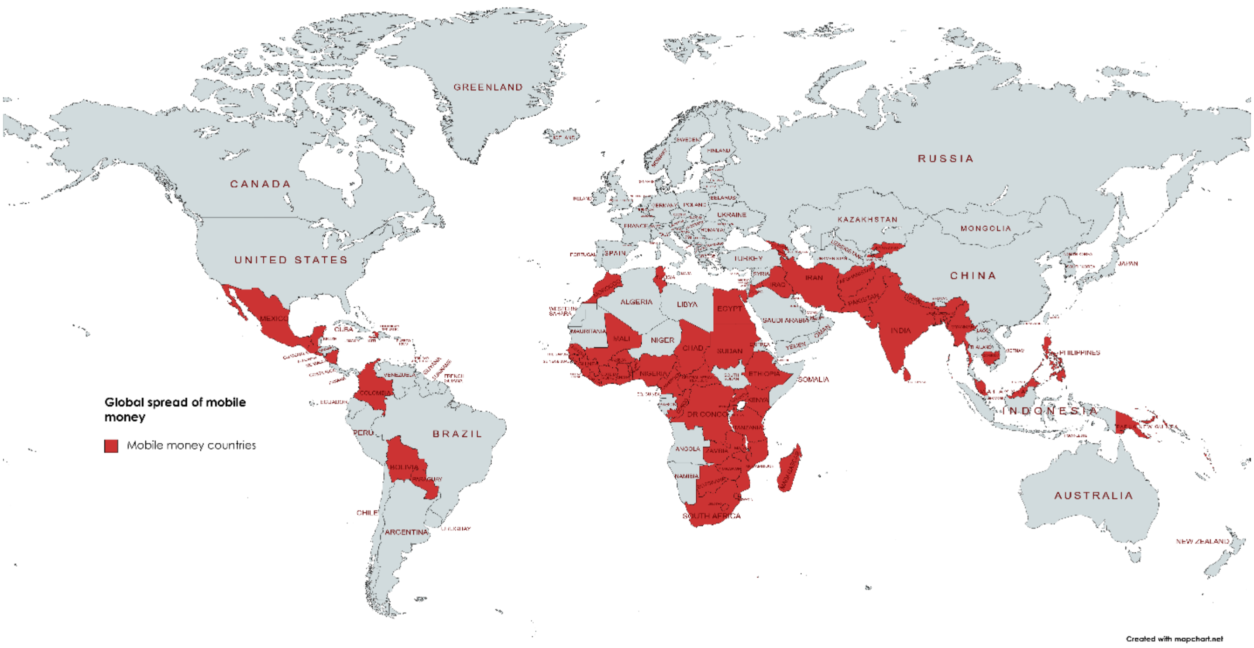
Figure H3: World market price of wheat

Source: https://www.macrotrends.net/2534/wheat-prices-historical-chart-data

Figure H4: World market price of corn

Source: https://www.macrotrends.net/2532/corn-prices-historical-chart-data

Figure H5: Global spread of mobile money

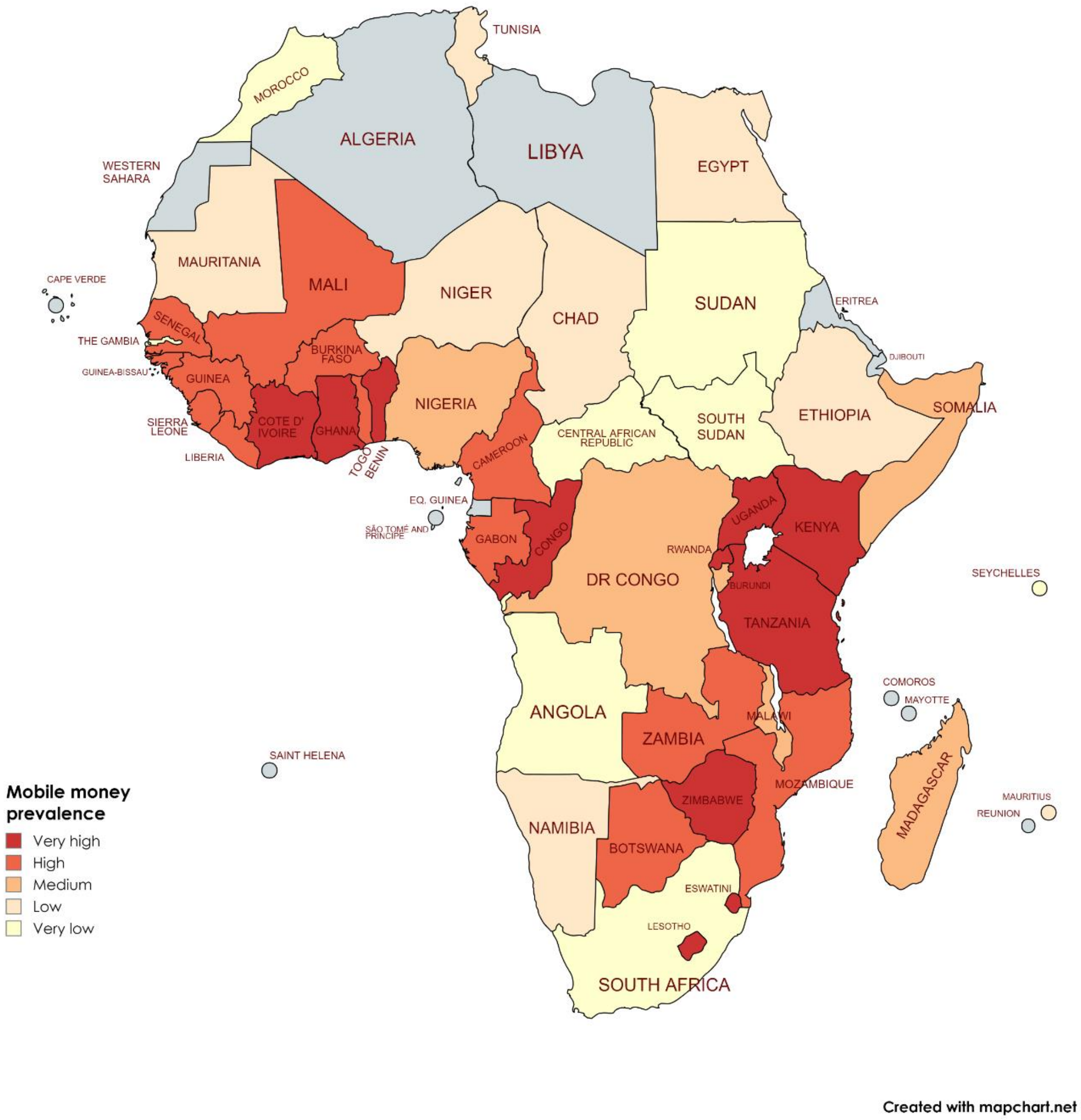


Source: GSMA 2021 countries participating in GSMA 2020 mobile survey. Map created with mapchart.net

Figure H6: East African Community countries

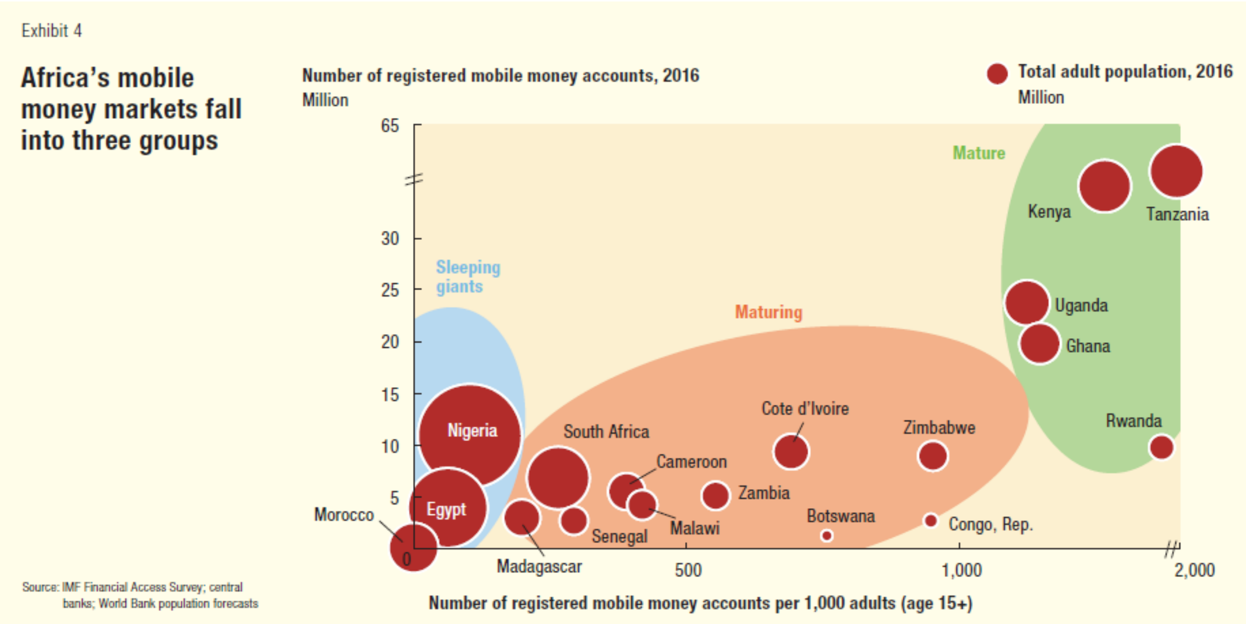
Source: Based on East African Community (2022). Created with mapchart.net

Figure H7: Mobile money prevalence index in Africa



Source: Andersson-Manjang (2021), Created with mapchart.net

Figure H8: Africa's mobile money markets, 2016



Source: Chironga *et al*. (2017)

Table H1: Financial development indicators and expected impact on income velocity of circulation

INDICATORS	EXPECTED RELATIONSHIP WITH VELOCITY
1. Developments that incentivize uptake of formal financial service	
Ratio of private sector bank credit to GDP	Positive
Ratio of private sector bank credit to deposits	Positive
Ratio of private sector bank deposits to GDP	Positive
Ratio of the financial assets to the total wealth of the economy	Positive
Proportion of formally banked population	Positive
Proportion of population receiving remittances	Positive
Number of formally banked micro enterprises	Positive
Number of cashless transactions	Positive
Number of mobile accounts	Positive
Number of mobile transactions	Positive
Number of active bank accounts	Positive
Average cost of opening and maintaining bank account	Positive
2. Developments that increase outreach of the existing formal financial services	
Density of points of financial service relative to population, such as	
Bank branches	Positive
Bank agents	Positive
ATMs	Positive
POS terminals	Positive
The average distance to the nearest point of financial service	Negative
The percentage of population with active mobile money accounts	Positive
The average distance to the nearest mobile money agent	Negative
The number of mobile money transactions	Positive
3. Developments that reduce transactions costs	
The volume or the value of transactions going through the improved channels of transactions such as	
Internet banking	Positive
Electronic funds transfers	Positive
Mobile banking	Positive
Mobile money	Positive
4. Developments that enlarge the aggregate size of monetized activities in the economy	
Trend—deterministic or stochastic	Negative
The ratio of monetary to non-monetary GDP	Negative
Ratio of currency in circulation to broad money	Positive