Capital-Skill Complementarity and the Immigration Surplus

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Abstract

We build a neo-classical growth model with overlapping dynasties and capital-skill complementarities to evaluate changes in immigration policy. Calibrating the model using U.S. data, we quantify the differential effects of skilled and unskilled immigration on factor returns and on the welfare of different sectors of the population. An influx of high-skilled immigrants lowers the wages of skilled workers, raises the wages of unskilled workers, and because of the relative complementarity between capital and skilled labor, substantially raises the rate of return to native-owned capital. By contrast, an influx of unskilled immigrants produces an opposite effect on wages, and has only a negligible effect on the return to capital. Because of capital skill-complementarity, an increase in the number of skilled immigrants generates an immigration surplus—the overall welfare benefit accruing to the native population—that is approximately ten times larger than the immigration surplus generated by an identical increase in the number of unskilled immigrants. This differential welfare effect is far higher than can be accounted for by the disparity between the productivities of each type of worker.

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1 Introduction

In most countries of the developed world, immigration, rather than natural increase, is now the dominant source of population growth (see Figure 1). Nonetheless, the combination of low birth rates and increasing life spans will in the future compel governments to either admit even more working-age immigrants, or cope with the economic consequences of a declining share of working-age people within the population. Those countries that choose to permit more immigration will also need to decide whom to admit from among a vast available pool of potential immigrants who differ in age, culture, nationality, and skill level.

In this paper we focus on the last of these distinctions. We build an overlapping dynasties model of the U.S. economy with two types of labor inputs to demonstrate that skilled and unskilled immigrants have profoundly different welfare implications for the resident population. We find that if capital and skilled labor are complementary, there is a very large contrast between the size of the welfare surplus generated by an influx of high-skilled immigrants and that generated by a similar sized influx of low-skilled immigrants. Furthermore, differences in productivity between the two types of workers alone do not account for the much larger surplus generated by skilled immigrants. Rather, because of the complementarity between the labor of skilled immigrants and native owned capital, the pattern of changes in factor returns is most propitious for the native population when the influx of immigrants is composed of skilled workers.

Until 1965, the United States allocated a set number of immigration visas to citizens of each country. The 1965 amendments to the Immigration and Nationality Act replaced these country quotas, as well as preferences for certain skilled occupations, with a system that made family unification the primary criterion for admission to the United States. Immediate relatives of United States citizens enter without limit— in the year 2005, 436,000 acquired permanent residence status. Other relatives of U.S. citizens are admitted as family-sponsored preference immigrants—since 1990 the limit for all family-sponsored immigrants has been either 226,000, or 480,000 minus the number of people admitted under the category of immediate relatives during the previous year, whichever is larger. The limit for employment-based preference is 140,000, however unused family preference visas from the previous year are also made available for immigrants with special skills or training (as well as investors). In 2005 nearly a quarter million people—a historic high—obtained permanent residence status under this category.

The net rate of immigration to the United States has more than doubled since 1965, from 1.5 per thousand to an average of 3.2 per thousand during the 1990's. The rules no longer favor immigration from countries in Europe with levels of educational attainment similar to those that prevail in the

United States. Instead, people from less developed countries arrive legally as immediate relatives of U.S. citizens, or family sponsored immigrants, or as illegal aliens (and then legalize their status). Upon attaining citizenship, these immigrants bring their immediate relatives, and sponsor members of their extended families, who in turn repeat the process once they are naturalized. If in 1960, 75.0% of the foreign born population in the United States was from Europe and 9.8% from Latin America, by 2000 the relative shares had reversed, reaching 15.3% and 51.0% respectively.

Figure 1 About Here

At one time, the U.S. public was mainly concerned with whether immigrants were too successful when competing with natives for jobs. Today the focus has shifted to doubts about whether, because of their lack of education, today's immigrants have the skills necessary to support themselves in a modern economy. Among immigrants arriving in the United States from Latin America, 34.6% have less than nine years of schooling, and the percentage with less than five years' schooling equals the percentage with at least a Bachelor's degree—11.2%. More than half the Latin American immigrants are from Mexico, and of these, 48.4% have less than nine years of schooling, 16.5% less than five, and only 4.2% at least a Bachelor's degree. Among native-born Americans, 25.6% have at least a Bachelor's degree and only 4% less than nine years of schooling.

Not all newcomers are uneducated. Beginning in 1992, the United States began granting 65,000 visas per annum to temporary workers with special skills—nearly all recipients of these H1-B visas have college or advanced degrees. In 1998 Congress passed the American Competitiveness in the Workforce Act, temporarily increasing the number of H1-B visas to 115,000 per year in 1999 and 2000, and to 107,500 in 2001. The American Competitiveness in the Twenty-First Century Act of 2000 (AC21) added an extra 347,500 visas by raising the cap to 195,000 for each of the years 2001, 2002, and 2003—for a total of 585,000 over three years. In 2004 the number of visas returned to its original ceiling of 65,000 (including a few thousand visas set aside for citizens of Singapore and Chile under the terms of their free trade agreements with the U.S.). Since 2005, there are also an additional 20,000 H1-B visas available annually for foreign citizens who have completed graduate degrees at American universities. Officially, H1-B visas are temporary, but after a few years in the United States, most of those admitted under the H1-B visa program easily attain permanent residence status.

In terms of educational attainment, immigrants are far more heterogeneous than the rest of the U.S. population. The contrast between the average years of schooling attained by Latin American immigrants arriving under the auspices of family unification, on the one hand, and the recipients of H1-B visas (two thirds of the total are from Asia) on the other, highlights the diversity of today's immigration flows.[1] The distinction between these two sources of immigration also demonstrates how Western countries can design policies that determine, to a large degree, what kind of immigrants they admit.

Many European countries, as well as Australia, are tightening rules for those claiming political asylum to stem the flow of unskilled immigrants, while also experimenting with new schemes to attract workers with specific skills. Australia, Canada, and the U.K. use point systems with weights for educational attainment, language proficiency, and employment history to determine who may obtain work permits and immigration visas.

In a static economy with undifferentiated labor (Borjas (1995)), immigrants generate higher rates of return to capital, which more than compensates for concomitant drops in wages—representative native households enjoy a small 'immigration surplus'. Using Weil's (1989) optimal growth model with overlapping dynasties, Ben-Gad (2004) demonstrates that the immigration surplus is much smaller if capital accumulation and the labor supply are endogenous. In Section 2, we extend the overlapping dynasties model to include skilled and unskilled workers, each supplying a distinct type of labor. The populations of each type of worker grow continuously from natural increase, and from a constant inflow of both skilled and unskilled immigrants.

In Section 3, we introduce the nested constant elasticity of substitution production function (Sato (1967) and Krusell *et. al.* (2000)), which combines the two types of labor with capital to produce the single consumption good. We also briefly describe the U.S. data and empirical studies we use to parameterize the baseline model.

In Section 4, we use the model to calculate impulse responses for skilled and unskilled wages, the rate of return to capital, and per-capita output, following a decision by the U.S. government to raise the number of either skilled or unskilled immigrants arriving in the country by an additional sixty thousand each year, over the course of ten years. This means that the ordinary net flow of immigration to the United States, on average 3.2 per thousand during the 1990's, rises to 3.4 per thousand for one decade only. In each case we compare the results generated by the model to the behavior of wages and per-capita output if the economy were completely open with capital flowing freely from abroad—its rate of return determined exogenously on world markets.

Weil's framework permits us to isolate the welfare effects of changes in immigration policy by vintage of dynasty, as well as skill-type. To measure the welfare impact of a change in the size

[1]Overall, the most educated immigrants are from Africa (49.3% have at least a Bachelor's degree and 17.4% graduate degrees) and Asia (44.9% have at least a Bachelor's degree and 16.9% graduate degrees). European immigrants occupy the middle ground—32.9% have at least Bachelor's degrees but 12.7% have less than nine grades of schooling. *Source: 2000 Current Population Survey*, U.S. Census Bureau.

and/or composition of future immigration flows on the population already resident, we use the impulse responses for factor returns to calculate compensating differentials—the equivalent permanent percentage changes in consumption that yield identical changes in utility—for members of these 'native' dynasties. In Section 5 we first consider how the influx of additional skilled immigrants affects the welfare of skilled and unskilled members of native dynasties separately, and then calculate the immigration surplus—the overall affect of the policy on the native population's welfare, when that population is considered as a whole. The substitution elasticities Krusell *et. al.* (2000) estimate for the United States economy imply a high degree of complementarity between the labor supplied by skilled immigrants and native-owned capital. This capital-skill complementarity results in the immigration of skilled workers generating a much larger surplus for the native population than the surplus generated by an overall increase in immigration that does not change the skill-composition of the population.

In the second half of Section 5, we analyze the welfare effects of a same-sized influx of unskilled workers. The labor supplied by these immigrants is a relative substitute for native–owned capital—the return to capital rises, but only by a small amount. For the baseline model, an unskilled immigrant generates a surplus that is just over a tenth the surplus generated by a skilled immigrant. We also consider the effect of different-sized increases and decreases in the rates of immigration on welfare.

In Section 6, we investigate the sensitivity of our results to compressing or extending the time period over which a given number of immigrants arrive. We also consider the behavior of the model if the additional immigrants are no longer assumed to arrive without any capital. Finally, in this section we investigate the behavior of the model for alternative parameterizations of the production function, including one that corresponds to the Cobb-Douglas specification.

For most developed countries, the marginal supply of both skilled and unskilled immigrants from impoverished foreign countries is both very large and not very elastic—we do not model the decision to move made by the immigrants themselves. Instead, the number and type of immigrants are policy variables, regulated by the rationing of visas, or by the resources invested in the prevention of illegal immigration.[2]

Storesletten (2000) demonstrates that immigration by high-skilled workers is beneficial to natives, while unskilled immigration is harmful—all on purely fiscal grounds. Likewise, given the growing empirical evidence in favor of capital-skill complementarities, we find strong reasons to believe that skilled immigration is far more beneficial to the economy than unskilled immigration, even when

[2]See Galor (1986), Djajic (1989), and Borjas (1994) for models with endogenously determined patterns of immigration.

abstracting from fiscal considerations.

2 The Basic Model

Consider a model in which new immigrants—both skilled and unskilled—join the economy as founding members of new infinite lived dynasties. Initially we assume that all present and future members of a given dynasty supply inelastically only skilled labor l_S, or unskilled labor l_U. Throughout we employ the subscript $i \in \{U, S\}$ to distinguish between the two different types of dynasties. An immigrant of type i who arrived in the country at time s, and his (or her) descendants maximize utility beginning at time s:

$$\max_{c_i} \int_s^\infty e^{(\rho-n)(s-t)} \ln c_i(s,t)\, dt, \quad i \in \{U, S\}, \tag{1}$$

subject to a time t budget constraint:

$$\dot{k}_i(s,t) = (1-\tau)\left(w_i(t)l_i + r(t)k_i(s,t)\right) - nk_i(s,t) - c_i(s,t), \quad \forall s,t, \quad i \in \{U, S\}, \tag{2}$$

where $c_i(s,t)$,and $k_i(s,t)$ represent the time t consumption and holdings of capital of the members of a type i dynasty of vintage s, $w_i(t)$ and $r(t)$ represent their time t wages and the rate of return of capital, τ the constant flat rate of tax they pay on both wages and capital income (net of depreciation), ρ is their subjective discount rate, and n is the rate of natural population increase.

The consumption rule for dynasty s at time t is:

$$c_i(s,t) = (\rho - n)\left[\psi_i(t) + k_i(s,t)\right], \quad \forall s,t, \quad i \in \{U, S\}, \tag{3}$$

where $\psi_i(t) = \int_t^\infty e^{-\int_t^u((1-\tau)r(v)-n)dv}(1-\tau)\, w_i(u)l_i du$ is the present discounted value of all future net income from labor of type i, from time t forward. Immigrant households of type i enter the economy at time t at a rate of $m_i(t)$, and on average, arrive with an amount of capital, $k_i(t,t) \geq 0$, brought from the old country.

We assume that the government's budget is always balanced, and that the flat rate income tax finances government consumption, which equals a constant fraction τ of net domestic product. Aggregate consumption and capital evolve according to:

$$\dot{C}_i(t) = (\rho - n)\left[(1-\tau)\, r(t)\left(\Psi_i(t) + K_i(t)\right) - C_i(t) + e^{nt}M_i(t)m_i(t)\left(\psi_i(t) + k_i(t,t)\right)\right], \ i \in \{U, S\}, \tag{4}$$

$$\dot{K}_i(t) = (1-\tau)\left(w_i(t)L_i(t) + r(t)K_i(t)\right) - C_i(t) + e^{nt}M_i(t)m_i(t)\, k_i(t,t), \tag{5}$$

where $C_i(t)$, $K_i(t)$, and $\Psi_i(t)$ are respectively the time t consumption, physical capital holdings, and the present value of future earnings aggregated over all the households with skill-level i, and

$M_i(s)$ is the number of households with skill-level i that have accumulated by time s.[3] A labor enhancing technology growing at the rate x ensures the existence of steady state per-capita output growth—total effective labor input of type i, at time t, is $L_i(t) = e^{(n+x)(t-b)} M_i(t) l_i$.

The behavior of the economy is determined by four laws of motion for stationary per-capita consumption $\tilde{c}_i(t) = \frac{C_i(t)}{e^{(x+n)(t-b)} M_i(t)}$ and capital $\tilde{k}_i(t) = \frac{K_i(t)}{e^{(x+n)(t-b)} M_i(t)}$:

$$\dot{\tilde{c}}_i(t) = ((1-\tau) r(t) - x - \rho) \tilde{c}_i(t) - (\rho - n) \tilde{k}_i(t) m_i(t) \kappa_i(t) \quad i \in \{U, S\}, \tag{6}$$

$$\dot{\tilde{k}}_i(t) = (1-\tau) \tilde{w}_i(t) l_i + ((1-\tau) r(t) - x - n - m_i(t) \kappa_i(t)) \tilde{k}_i(t) - \tilde{c}_i(t) \quad i \in \{U, S\}, \tag{7}$$

where $\kappa(t) = \frac{k(t) - k(t,t)}{k(t)}$ is the fractional difference between per-capita capital and the capital imported by immigrants, and $\tilde{w}_i(t)$ is the stationary wage for type i. The production function $F : \mathbb{R}^3 \to \mathbb{R}$ is constant returns to scale in both types of labor and aggregate capital. Factors receive their marginal products:

$$r(t) = F_K \left(\widetilde{k}_U(t) + \eta(t) \widetilde{k}_S(t), l_U, \eta(t) l_S \right) - \delta, \tag{8}$$

$$\tilde{w}_i(t) = F_{H_i} \left(\widetilde{k}_U(t) + \eta(t) \widetilde{k}_S(t), l_U, \eta(t) l_S \right), \tag{9}$$

where δ is the rate of depreciation for physical capital, and $\eta(t)$ is the ratio of skilled to unskilled workers in the economy at time t: $\eta(t) = \frac{M_S(t)}{M_U(t)} = \frac{M_S(0)}{M_U(0)} e^{\int_b^t (m_S(z) - m_U(z)) dz}$.

3 Parameterizing the Baseline Model

3.1 The Nested CES Production Function

Empirical studies—starting with Griliches (1969)—typically find that the elasticity of substitution between skilled labor and capital is substantially lower than that between unskilled labor and capital. Subsequent work by Berndt and Christensen (1974) and Denny and Fuss (1977) confirmed Griliches' findings.

To permit the elasticity of substitution between capital and the two different types of labor to differ, we employ the nested constant elasticity of substitution aggregate production function

[3] Define $t = b$ as a date in the arbitrarily distant past $b < 0$, when the economy was founded by an initial cohort of size $M_U(b) + M_S(b) = 1$. Then $C_i(t)$, $K_i(t)$, and $\Psi_i(t)$ are the consumption, capital and the future earnings for the initial type i population at time b, and all the additional cohorts accumulated at rate $m_i(s)$ since b, all growing at the rate of n. Hence $C_i(t) = e^{n(t-b)} \int_b^t M_i(s) m_i(s) c_i(s,t) ds + e^{n(t-b)} M_i(b) c_i(b,t)$, $K_i(t) = e^{n(t-b)} \int_b^t M_i(s) m_i(s) k_i(s,t) ds + e^{n(t-b)} M_i(b) k_i(b,t)$, $\Psi_i(t) = e^{n(t-b)} \left(\int_b^t M_i(s) m_i(s) ds + M_i(b) \right) \psi_i(t)$, and $M_i(s) = M_i(b) e^{\int_b^s m_i(v) dv}$.

developed by Sato (1967):

$$F(K(t), L_U(t), L_S(t)) = \left[\alpha L_U(t)^{\vartheta} + (1-\alpha)\left(\beta K(t)^{\gamma} + (1-\beta) L_S(t)^{\gamma}\right)^{\frac{\vartheta}{\gamma}}\right]^{\frac{1}{\vartheta}}, \tag{10}$$

where $K(t) = K_U(t) + K_S(t)$ is the total stock of capital.[4] For the nested CES production function, the Allen-Hicks elasticities of substitution between unskilled labor L_U and the other two factors, skilled labor L_S and capital K, are identical: $\sigma_{US} = \sigma_{UK} = \frac{1}{1-\vartheta}$. The Allen-Hicks elasticity of substitution between capital and skilled labor is a function of factor shares, however following Krusell *et. al.* (2000) we employ a simplified definition of elasticity: $\sigma_{SK} = \frac{1}{1-\gamma}$.[5]

Defining a skilled worker as someone with more than eight years of education, Fallon and Layard (1975) estimated the parameters of the nested CES function (10). For their full sample of 23 countries, they found ϑ to be 0.33 and γ to be -2.45, implying partial elasticities of substitution of $\sigma_{UK} = 1.49$ and $\sigma_{SK} = 0.29$. For a restricted sample of rich countries the estimates were ϑ=0 .46 and $\gamma =$ -0.81, or $\sigma_{UK} = 1.85$ and $\sigma_{SK} = 0.55$. Following Krusell *et. al.* (2000), we define a skilled worker as someone with at least a four-year Bachelor's Degree, and for our baseline model, adopt their parameter estimates for the U.S. economy, ϑ= 0.401 and $\gamma =-0.495$ ($\sigma_{UK} = 1.67$ and $\sigma_{SK} = 0.67$).[6]

3.2 U.S. Immigration Between 1991 and 2000

Most legal immigrants arrive in the United States through some form of family sponsorship. Immediate relatives of United States citizens may enter without limit; during the 1990's about a quarter

[4]Also known as the two stage CES production function. The first stage combines skilled labor and raw capital to develop and maintain production capital: $K^* = (\lambda K^{\gamma} + (1-\lambda)(H_S)^{\gamma})^{\frac{1}{\gamma}}$. K^* is used by unskilled labor in the second stage to manufacture final goods: $Y = \left[\mu (H_U)^{\vartheta} + (1-\mu)(K^*)^{\vartheta}\right]^{\frac{1}{\vartheta}}$ (see Goldin and Katz (1998).

[5]For the nested CES function the Allen-Hicks partial elasticity of substitution between capital and skilled labor is $\frac{1}{1-\vartheta} + \frac{1}{\phi_{SK}}\left(\frac{1}{1-\gamma} - \frac{1}{1-\vartheta}\right)$ where ϕ_{SK} is the combined share of aggregate capital and skilled labor in production.

[6]In Lindquist (2005), the results for the Swedish economy are very similar, though both elasticities are a bit lower. For the full sample of countries the implied Allen-Hicks elasticity in Fallon and Layard's (1975) study is -0.49 or -0.29 when the sample is restricted to rich countries, and for Krusell *et. al.* (2000) the Allen-Hicks partial elasticity of substitution between capital and skilled labor is 0.36. By comparison, Berndt and Christensen (1974) estimate a translog production function—their estimates are: $\sigma_{UK} = 3.72$, $\sigma_{SK} = -3.77$, and $\sigma_{US} = 7.88$. Rather than counting years of schooling, the authors distinguish between production and non-production workers, and assume that the latter group is more skilled. A similar study by Denny and Fuss (1977) finds $\sigma_{UK} = 2.86$, $\sigma_{SK} = -1.88$, and $\sigma_{US} = 4.76$ when the production function is estimated, and $\sigma_{UK} = 1.5$, $\sigma_{SK} = -0.91$, and $\sigma_{US} = 2.06$ when a cost function is used. Finally, Polgreen and Silos (2005), reestimating the Krussel *et. al.* (2000) model using Baysian estimation techniques and two alternative measures of the capital equipment stock, find that the value of σ_{UK} ranges from 2.087 to 9.052, and the value of σ_{SK} ranges from 0.607 to 0.857.

of a million arrived each year. Other relatives of U.S. citizens are admitted as family-sponsored preference immigrants—the Immigration Act of 1990 set the limit for all family sponsored immigrants as either 226,000, or 480,000 minus the number of people admitted under the category of immediate relatives during the previous year, whichever is larger. The United States also allocates 140,000 employment-based preference visas for workers with special skills or training (as well as investors), and an additional 55,000 visas are allocated by lottery under the diversity program. The United States also admits refugees and asylum seekers (refugees are admitted from abroad on the basis of a yearly quota set annually by the president). After a year, refugees and asylees are eligible for permanent residence—between 1991 and 2000 just over one million were admitted. The inflow of illegal immigrants between 1990 and 2000 is estimated to be about 350,000 per year.[7]

In 1992 the United States began granting 65,000 H-1B visas per year. In 1999 and 2000 the number of these visas rose to 115,000 per year. H1-B visas are non-immigrant visas that permit holders to work in the United States for three years. However, the visas can be renewed at least once, and applicants are permitted *dual intent*—they may plan to apply for, and obtain, permanent residence while still holding the visa.[8]

In total, after subtracting emigration (eighty percent of those leaving the United States are foreign born), the net rate of migration to the United States between 1991 and 2000 was 3.2 per thousand. Although a much larger fraction of immigrants have less than nine years of schooling, the percentage of the foreign-born with Baccalaureate degrees closely matches that of the general population—25.8% of foreign-born people in the United States over the age of 25 have college degrees, as compared to 25.6% of the total U.S. population. For the initial stock of skilled and unskilled workers we set $M_S(0) = 0.256$ and $M_U(0) = 0.744$ and set the steady state rates of immigration for both skill types to $m_S = m_U = 0.0032$.[9] We initially assume that all immigrants arrive in the United States after having exhausted any savings on travel expenses or establishing a household—we set $\kappa_S = \kappa_U = 1$. If the rates of legal and illegal immigration to the United States during the decade of the 1990's

[7] U.S. Immigration and Naturalization Service, Office of Policy and Planning, 2003, *Estimates of the Unauthorized Immigrant Population Residing in the United States: 1990 to 2000*.

[8] In the past at least half of those admitted under the program changed status and ultimately became permanent residents (see Lowell (2001)).

[9] At the high end, graduate education declines slightly with the degree of nativity: 9.7% of the foreign born have graduate degrees, as do 8.9% of natives with foreign-born parents, but only 8.2% of natives with native-born parents. Grade school education rises more steeply with nativity—22.2% of the foreign-born and 10.1% of the natives with foreign-born parents have less than nine grades of schooling (7.2% of the foreign-born have less than five), against only 4.5% with less than nine grades among the native-born population with native parents (see U.S. Department of Commerce, Bureau of Census, *Profile of the Foreign-Born Population in the United States: 2000*, December 2001).

carry forward, and the rate of out migration continues to hold steady at one per thousand, foreign migration will augment the U.S. population by close to ten million additional people over the course of this decade.

3.3 The Baseline College Premium and Distribution of Capital

We choose the other parameters of the model to match U.S. data during the 1990's. The ratios of mean earnings and income for households as well as individuals with bachelor's degrees to those without range from 2.13 to 2.71 as measured by the U.S. Census. The 1998 Survey of Consumer Finances reports on net wealth as well as income and earnings. The ratio of mean earnings is 2.35, income is 2.3 while net wealth is 3.3. The gap between median earnings and wealth is smaller—2.4 versus 3.06. In the initial steady state, the ratio of capital held by skilled and unskilled agents must be equal to the ratio of their wages—we choose an intermediate number 2.7 for our simulations.

3.4 Calibration of the Economy

In addition to raising the ratio of workers to equipment on factory floors, immigrants increase the demand for all manner of capital items, including residences and even consumer durables. Therefore we adopt the widest possible definition of privately held capital, one that includes all privately held fixed assets, consumer durables and private inventory stocks.[10] Output is defined to include both gross domestic product and services from consumer durables.

To calibrate the model, we follow the practice outlined in Cooley and Prescott (1995). We sum all types of unambiguous capital income, i.e., rental income, profits and net interest, together with consumption of fixed capital, and divide the sum by the portion of gross domestic product that does not include unambiguous capital income, i.e., consumption of fixed capital and proprietors' income. We multiply this fraction—the share of capital in measured GDP—by GDP, subtract consumption of fixed capital, and divide the result by the sum of private fixed assets and private inventories. This yields the baseline pre-tax interest rate—an average of 7.82% per annum between 1991 and 2000.

Table 1 About Here

Combining the interest rate with the depreciation rate for consumer durables (the consumption of consumer durables divided by its stock) and multiplying by the stock of consumer durables yields the service flow from consumer durables. Dividing the capital stock (as defined above) by the sum

[10] We abstact from capital in the government sector. Immigrants may use more government services, yet if some public goods are not perfect rivals in use, the immigrant's impact on the government sector will be ambiguous.

of GDP and these service flows, yields a ratio of capital to output that averaged during this period 2.38. Combining consumer durable service flows with capital income, and dividing by the sum of GDP and service flows yields our measure of the share of capital in GDP—between 1991 and 2000 this averaged 0.36.

The values of γ and ϑ from Krusell *et. al.* (2000), when combined with the capital-output ratio and the share of capital in output, are sufficient to calculate the weights in the nested CES function (10)—α=0.366 and β=0.775. Given these values we calculate the steady state marginal product of capital and subtract the annual rate of interest to obtain the economy-wide annual rate of depreciation, δ =0.0731.

The tax rate on household income, averaged over the period between 1991 and 2000, was 15%, the tax rate on labor income was 24%, the tax rate on gross capital returns averaged 19%, and on net capital returns 26%.[11] The share of government consumption, as a fraction of the sum of net national product and the implied services derived from consumer durables, averaged over the same period 19%. In order to abstract from questions of tax incidence and the effects of distortionary fiscal policy, we set both the share of government consumption and the tax rate on income equal to 0.19.[12] Given the tax rate, we calculate the value of the subjective discount rate—ρ=0.0429.

4 Temporary Surges in the Rate of Immigration

4.1 Raising Skilled Immigration for Ten Years

In 1992, under the provisions of the 1990 Immigration Act, the United States government began granting 65,000 H-1B visas to foreigners in 'specialty occupations'. The program expanded with passage of the American Competitiveness in the Workforce Act of 1998, which temporarily increased the number of these visas to 115,000 per year in 1999 and 2000, and 107,500 in 2001. The American Competitiveness in the Twenty-First Century Act of 2000 (AC21) raised the cap further to 195,000 for each of the years 2001, 2002, and 2003. The effective cap for 2004 and beyond is 58,200 for workers in the for-profit private sector.[13]

[11] These calculations are based on Gomme and Rupert (2005), but include services from consumer durables. Given the inelasticity of labor supply we can treat the tax rate on labor income as net of transfer payments.

[12] In an economy where government consumption is a fixed fraction of output, setting the tax rate on capital income to this fraction is the Ramsey optimal policy (see Turnovsky (1996) and Ben-Gad (2003)).

[13] Non-profit institutions, including universities, are now exempt from caps and since 2005, an additional 20,000 H1-B visas are available to foreign citizens who have completed Master's or higher degrees at U.S. universities. Finally, an additional 1,400 and 5,400 additional professional visas are allocated to nationals of Chile and Singapore respectively, under the terms of their free trade agreements with the United States—these

Since its inception, the H1-B visa program has become an important conduit for immigration of skilled workers to the United States—nearly all recipients have college or advanced degrees. Suppose that in the context of the baseline model, the government announces that it will permit the rate of immigration to immediately rise from 3.2 to 3.4 per thousand during one decade. This corresponds to the United States issuing sixty-thousand additional visas per year, equivalent in magnitude to approximately doubling the size of the H1-B visa program. Rather than absorbing about nine million six hundred thousand new immigrants over the course of a decade, instead ten million two hundred thousand immigrants arrive. To understand the impact of policies designed to facilitate immigration of skilled workers—such as the H1-B visa program—we begin by assuming that all the additional immigrants are college-educated.

The change in the rate of immigration for workers of type i, from the steady state rate of immigration m, is $m_i(t) - m = \frac{1}{T} \ln \left[1 - \left(1 - e^{\epsilon T}\right) \frac{\mu_i}{M_i(0)}\right] \mathcal{U}(T-t)$, where ϵ is the overall increase in the rate of immigration, μ_i is the fraction of workers of type i in the immigration surge, T the duration of the surge, and $\mathcal{U}$ is the unit step indicator function.[14] Setting $\epsilon = 0.0002$, $\mu_S = 1$, $\mu_U = 0$, and $T = 10$, the solid curves in Figure 2 represent the impulse responses for factor returns and per-capita output following a decade-long increase in the number of skilled immigrants of sixty thousand per annum. The impulses in Panels a), b), and d) are the fractional deviations of the de-trended wages and per-capita output from the initial balanced growth path. For the rates of return to capital in Panel c), the horizontal axis is the baseline pre-tax rate of 0.0782.

Whereas the overall rate of immigration rises to 3.4 per thousand, the rate of immigration for skilled workers rises from 3.2 per thousand to just under 4.0 per thousand, and the rate of immigration for the unskilled remains constant at 3.2 per thousand. The curves with long dashes represent impulse responses following an influx of the same magnitude; but the rates of immigration for both types rise to 3.4 per thousand, and the immigration surge does not alter the distribution of skilled and unskilled workers. In this case $\mu_S = 0.256$ and $\mu_U = 0.744$; just over one-hundred and fifty thousand additional skilled workers enter the United States, alongside nearly four-hundred and fifty thousand unskilled immigrants.

The area between the solid and dashed curves in Figure 2 is emphasized in gray, and represents the net change in factor returns and per-capita output that results from the increase in the relative share of skilled workers from 25.6% to 26.12%, abstracting from those changes in the economy induced by the rise in the overall size of the population. The curves with short dashes illustrate the behavior of factor returns and per-capita income if the economy is completely open to the importation of capital

are classified as H1-B1 visas.

[14]The Unit Step function $\mathcal{U}(x)$ takes the value zero if $x \leq 0$ and one if $x > 0$.

from abroad, and its rate of return is fixed at the initial calibrated rate.

Figure 2 About Here

The surge in skilled immigration causes the wages for skilled workers in Panel a) of Figure 2 to immediately begin declining. In the long-run, long after the last of the additional workers has arrived and the economy has converged to its new steady state, the supply of skilled workers has increased 0.78% above its previous trend, and skilled workers' wages—detrended for exogenous technological growth—have declined by just over 0.29%. Hence the long-run wage elasticity for skilled workers is 0.37—close to the 0.4 weekly wage elasticity (across all skill groups) measured by Borjas (2003). However, towards the end of the decade, as the last of the extra immigrants are arriving, the decline in skilled wages is far more substantial—just over 0.43%.

To understand why the skilled wage initially drops below its long-run value, note that in our model the economy ultimately accumulates the same amount of capital as it would if capital flowed freely and instantaneously from abroad, and the long-run drop in the wage is identical. However, in the open economy the decline in the skilled wage is more gradual, because as the number of skilled workers increases, the economy constantly imports the amount of capital necessary to leave the rate of return constant. By contrast, if capital does not flow freely from abroad, the accumulation of capital through heightened local savings is far more sluggish, and wages for skilled workers decline more rapidly, and further, before partially recovering.

Why does the drop in skilled wages initially overshoot its long-run value? First, the increase in population lowers the ratio between capital and labor. Sixty-five percent of the overshooting in the wage for skilled workers occurs because the economy fails to accumulate capital at a pace sufficient to compensate for this dilution of the capital stock. Second, a surge in skilled immigration skews the composition of the workforce in a way that makes it more complementary to capital. Thirty-five percent of the overshooting results from the delay in accumulating the capital necessary to accommodate this change in the composition of the workforce. Barring the free importation of capital, heightened savings only gradually provide the economy with the extra capital required to match the 0.2% rise in the size of the workforce, as well as the additional 0.4% necessary to accommodate its changed composition.

Discounting by the steady state after-tax interest rate, the influx of extra skilled immigrants is responsible for skilled workers experiencing a drop in the present value of their wages of 0.27%. By contrast, raising both rates of immigration to 3.4 per thousand, so that the influx does not upset the relative share of skilled workers in the labor force, induces a temporary drop in skilled wages that amounts to a mere 0.018% in present value terms. If we assume that capital flows freely from abroad, the influx of skilled immigrants induces a drop of 0.21% in the present value of wages for skilled workers, while a rise in immigration that merely replicates the existing workforce has no effect on wages.

The enhanced flow of skilled workers makes the labor unskilled workers provide relatively more scarce. The unskilled wage in Panel b) of Figure 2 rises until it is just over 0.27% higher. In the short-run, capital dilution slightly detracts from these gains—capital complements unskilled labor, even though the two factors are also relative substitutes. Only if capital flows freely into the country do unskilled workers immediately enjoy the full increase in their wage; generated by the arrival of each additional skilled immigrant.

The labor provided by unskilled workers is less complementary with capital than the labor provided by skilled workers. Therefore the dilution of the stock of capital generated by immigration has less of an effect on their wages. Raising the rates of immigration for both types of workers to 3.4 per thousand lowers the present value of unskilled wages by less than 0.006%. Overall increases in the rates of immigration cause wage inequality to decline, though only by a negligible amount.

On the other hand, a rise in the rate of immigration for skilled workers only significantly lowers the wage premium skilled workers enjoy. If initially workers in the model with college degrees earn 170% more than their unskilled counterparts, this premium drops to 168.20% by the time the last of the additional immigrants has arrived in year ten, before recovering slightly and stabilizing at 168.48% in the long-run.

In Borjas (1995) the stock of capital is fixed. An influx of capital-poor immigrants permanently lowers the capital-labor ratio, and by permanently raising its rate of return generates a small surplus for native owners of capital. Alternatively, if capital flows freely between countries, world markets determine capital's rate of return and a single country's immigration policy will not affect it. In this model, as in Ben-Gad (2004), the supply of capital is endogenous, so the impact of capital dilution alone is temporary and modest. Raising the rate of immigration for both types of workers to 3.4 per thousand raises the rate of return to capital in Panel c) of Figure 2 by just under nine-tenths of a basis point in year ten. However, if the entire surge in immigration is composed of skilled workers, the rise in the rate of return is almost three times greater—just over two and a half basis points at the peak in year ten. Capital-skill complementarity generates the entire gray-colored gap between the two curves in Panel c) of Figure 2. As we demonstrate in Section 5, these higher rates of return generate substantial welfare benefits for the resident population.

Finally, consider the behavior of per-capita output in Panel d) of Figure 2. The additional skilled workers are 170% more productive than unskilled workers, and 26.5% more productive than the average worker in the economy as a whole. Admission of these skilled workers raises per-capita production until it is 0.255% higher. In an economy with completely free capital movements, the entire increase would be achieved at the end of the decade. In our model the capital stock does not adjust immediately to changes in the size or make-up of the population, and the increase is more gradual.

How does per-capita income respond to a temporary, same-sized rise in both rates of immigration? The arrival of capital-poor immigrants temporarily lowers per-capita output until the capital stock has time to adjust to the larger labor force. Once the capital stock has adjusted, per-capita output returns to its initial path.

4.2 Raising Unskilled Immigration for Ten Years

Suppose we once again raise the number of immigrants by sixty thousand per annum for one decade only, but this time all the additional six hundred thousand immigrants are unskilled. Setting $\epsilon = 0.0002$, $\mu_S = 0$, $\mu_U = 1$, and $T = 10$, the solid curves in Figure 3 represent the response of factor returns and per-capital output when the overall rate of immigration rises to 3.4 per thousand for one decade only, but the rate of immigration for skilled workers remains constant at 3.2 per thousand, and the rate for unskilled workers rises to just under 3.47 per thousand.

By the end of the decade, the supply of unskilled labor rises by slightly over .27% above its previous trend. Unskilled wages in Panel b) of Figure 3 drop by just under .09% in the long run, and slightly more than .1% in the short run.[15] Once again the own-wage elasticity roughly matches the estimates in Borjas (2003).

Figure 3 About Here

Capital dilution no longer offsets the increase in unskilled wages as in Figure 2, but rather in Figure 3 exacerbates their decline. More generally, the increase in the size of the population and the change in its composition no longer reinforce, but rather offset each other in determining the amount of capital in the economy. The first effect dominates slightly, so the amount of capital in the economy rises to accommodate the expanded size of the labor force, but the adjustment is small. The increase in the share of unskilled workers dampens the effects of capital dilution on factor returns, so the difference between the short-term behavior of factor shares and output in our model and in a model with free capital movements is less pronounced.

[15] As we see in Table 6 below, the Allen Hicks own wage partial elasticities of complementarity for the baseline model, are much higher (in absolute value) for skilled than unskilled workers. However, the long-run equilibrium wage elasticities generated by the model, are approximately the same across the two groups and close to the elasticities measured by Borjas (2003).

The long-run wage for skilled workers rises by just over one tenth of one percent. Capital dilution dampens the short-term rise in skilled wages, causing it to increase monotonically, without achieving the temporary peak it would have otherwise. Despite the differences in magnitudes, qualitatively, immigration by skilled or unskilled workers produces a roughly symmetric pattern of changes in the different wages. The surge in unskilled immigration, though temporary, raises wage inequality—in the long-run, the college premium rises to 170.53%.

When the additional immigrants are skilled, capital skill complementarity and capital dilution raise in tandem the rate of return to capital. By contrast, if the immigrants are unskilled, the relative substitutability between capital and unskilled labor counteracts the positive effect of capital dilution, dragging down the rate of return to capital in Panel c) of Figure 3. At its peak, in year ten, the rate of return rises by a mere three tenths of a basis point—a small fraction of the rise induced by immigration of the same number of skilled workers. By the same token, a decision to lower the number of unskilled immigrants arriving in the United States by six hundred thousand over the course of a decade lowers the rate of return by approximately the same, very small amount.

Consider once again the across the board increase in immigration that permits just over an additional one hundred and fifty thousand skilled, and nearly four hundred and fifty thousand unskilled immigrants to enter the United States over the course of ten years; a policy whose effects are represented by the dashed curves in both Figures 2 and 3. The rate of return to capital rises by just under nine-tenths of a basis point, which is three times higher than if all the immigrants are unskilled, but less than half as high as when all the immigrants are skilled.

Why is the contribution of unskilled immigration to capital's rate of return so small? On one hand, by abstracting from the many different types of physical and organizational capital, we no doubt miss the serious harm that the imposition of severe restrictions on the immigration of unskilled workers will cause certain sectors of the U.S. economy. On the other hand, for owners of the types of capital that might replace some of these workers in the production process, a drop in the number of unskilled immigrants will prove beneficial. At the aggregate level, given the elasticities of substitution found by Krusell *et. al.* (2000), we conclude that overall, the common perception that unrestricted immigration by low-skilled workers strongly serves the overall interests of a country's *rentier* class deserves serious reexamining.

For the same reason that the arrival of skilled immigrants, 26.5% more productive than the average worker in the economy, ultimately raises per-capita output, the arrival of unskilled immigrants in Panel d) of Figure 3, 43.5% less productive, lowers it. Furthermore, because the adjustment in the stock of capital is relatively small, the drop is quicker. Of course none of this implies that the immigration of unskilled workers actually harms the incomes of the pre-existing population. Rather, it reflects the lower incomes of the additional immigrants themselves.

5 Welfare Analysis

Changes in immigration policy affect the welfare of the already resident, or native population through their impact on all the different factor returns. In this section, we quantify these welfare effects in terms of compensating differentials. For a native household, one already resident in the country at time $t = 0$ when the new policy is announced, and composed of workers of skill level i, consumption subsequent to the policy announcement evolves according to: $c_i(0,t) = e^{\int_0^t (r(v)-\rho)dv} c_i(0)$, where $c_i(0)$ is per-capita consumption at $t = 0$. We equate the utility derived from this time path of consumption to that obtained from consumption under a counterfactual assumption that the old policy was maintained $\bar{c}_i(0,t)$, multiplied by a constant value $(1 + p_i/100)$:

$$\int_0^\infty e^{-(\rho-n)t} \ln c_i(0,t)\, dt = \int_0^\infty e^{-(\rho-n)t} \ln \left[(1 + p_i/100)\, \bar{c}_i(0,t)\right] dt. \tag{11}$$

Solving for the compensating differential $p_i, i \in \{U, S\}$ yields:

$$p_i = 100 \times \left(e^{(\rho-n)\int_0^\infty \left(e^{(n-\rho)t} \int_0^t (1-\tau(v))(r(v)-r)dv + \ln c_i(0) - \ln \bar{c}_i(0) \right) dt} - 1 \right), \tag{12}$$

which is the percentage permanent increase in consumption that exactly compensates resident households of type i for the government's decision to deviate from its previous immigration policy. Calculating compensating differentials provides a convenient way to weigh the relative effects of the changes in the different factor returns—particularly when wages and the return on capital move in opposite directions.

Consider once again the across the board increase from 3.2 per thousand to 3.4 per thousand in the rates of both types of immigration—the policy that permits just over an additional one hundred fifty thousand skilled, and just under four hundred and fifty thousand unskilled immigrants to enter the United States over the course of ten years. In an economy with homogenous labor the complementarity between immigrant labor and native-owned capital, generates a welfare improvement for natives—what Borjas (1995) calls an immigration surplus—because the rise in the return to native-owned capital more than compensates for the drop in their wages. The benefit is small, and smaller still, if the supply of capital and labor is endogenous, as in Ben-Gad (2004). Similarly, in an economy with skilled and unskilled workers, as well as capital, if the elasticities of substitution are equal between all the different inputs, across the board increases in immigration generate small welfare improvements for both skilled and unskilled natives.

However, if there is a higher degree of complementarity between skilled labor and capital than between unskilled labor and capital, the temporary drop in per-capita capital that typically accompanies a surge of immigration reduces skilled wages more than it reduces unskilled wages. This is why (in the entries in the next-to-last two rows, first column of Table 2), though both skilled and unskilled natives enjoy the same proportional rise in capital income, the unskilled natives derive a small benefit, the equivalent of a permanent rise of 0.0042% in consumption, at the expense of skilled natives, who suffer a 0.0039% drop in permanent consumption.

Despite the heterogeneity of the native population, it is possible to calculate an overall immigration surplus. We define this as the compensating differential for a household whose labor income is derived from both skilled and unskilled wages, in proportions that match the skill distribution in the initial population, and whose capital holdings match the per-capita holdings for the entire native population:

$$\begin{aligned} & \int_0^\infty e^{-(\rho-n)t} \ln\left[\left(1-p/100\right)\left(M_S\left(0\right)c_S\left(0,t\right)+M_U\left(0\right)c_U\left(0,t\right)\right)\right]dt \\ = & \int_0^\infty e^{-(\rho-n)t} \ln\left[M_S\left(0\right)\bar{c}_S\left(0,t\right)+M_U\left(0\right)\bar{c}_U\left(0,t\right)\right]dt. \end{aligned} \tag{13}$$

Solving (13) yields p as a weighted combination of p_S and p_U:

$$p = \frac{M_S\left(0\right)\bar{c}_S\left(0\right)p_S + M_U\left(0\right)\bar{c}_U\left(0\right)p_U}{M_S\left(0\right)\bar{c}_S\left(0\right) + M_U\left(0\right)\bar{c}_U\left(0\right)}. \tag{14}$$

We can interpret p as the combined compensating differentials for the two types of workers, weighted by their respective shares in the native population at the time of the policy announcement—a number that reflects both the change in national income, and the ability of one group to compensate the other, and still enjoy part of the benefit from the new policy.

Table 2 About Here

The across-the-board decade-long rise in the rate of immigration of 0.2 per thousand per annum generates an immigration surplus of 2.9×10^{-4}%. How much is this worth? If annual private consumption in the United States was \$8.74 trillion in the year 2005, the decade-long rise in the rate of immigration for both skilled and unskilled workers from 3.2 to 3.4 per thousand generates a permanent benefit of \$24 million per year, or in present value terms a one-time payment of \$666 million.

Now consider the same-sized influx of additional immigrants, but all of them skilled workers. The gain to unskilled natives is worth a permanent increase in consumption of 0.206%—they enjoy not only a substantial increase in the income from the capital they own, but also a rise, rather than a decline, in their earnings. A policy that requires all the extra immigrants to be skilled generates a benefit to the unskilled majority that is forty-seven times higher than if the influx merely matches the economy's initial skill distribution. Skilled workers also experience a rise in their capital income, but the losses in wage income are deeper, and the harm to their welfare is equivalent to a decline of 0.2191% in permanent consumption—seventeen times greater than the losses they sustain when both rates of immigration increase equally. Although the change in policy raises the size of the population by only 0.2%, it generates a shift in welfare that is equivalent to an approximate $9.2 billion annual redistribution of consumption from skilled to unskilled households, or in present value terms, a single year's reallocation of $255 billion.

The influx of skilled workers lowers the present value of the weighted average of wages for members of the native population by 0.15%, while raising the rate of return to the stock of pre-existing capital by 0.32% in year ten. In addition, natives exploit the opportunity to augment their capital holdings by 0.06% through higher savings, adding an additional increment to their long-run capital income. As before, and as is the case for models with homogenous labor as well, for the average native household the rise in the rate of return to capital dominates the drop in wages. The difference is that if all the additional immigrants are skilled, the immigration surplus is equivalent to a permanent increase in consumption of 0.0013%—worth an additional $109 million per year. This is equivalent to raising native consumption for the first year only, by 0.0346% or $3.025 billion. Hence, an influx of immigrants comprised solely of skilled workers, yields a benefit more than seven and half times larger than that obtained from an increase in immigration which merely replicates the veteran population and the pre-existing flow of new arrivals.

Finally, consider the welfare effects of the same increase in the number of immigrants, when the increase is composed entirely of unskilled workers. The native unskilled suffer losses in welfare equivalent to a drop of 0.0653% in permanent consumption, as the very small rise in the rate of return to their capital cannot possibly compensate for the decline in their wages. The loss is relatively smaller than that sustained by skilled workers when all the additional immigrants are skilled, because the overall share of unskilled workers in the economy is nearly three times larger. The gains to skilled workers under this policy are smaller as well—equivalent to a permanent rise in consumption of 0.0706%.

How do natives fair on average? The value of p falls to $1.2\times10^{-4}\%$—equivalent to a permanent rise in total consumption of eleven million dollars, or a one year increase of $296 million. This means that the overall surplus generated by an unskilled immigrant is just under a tenth that generated by a skilled immigrant—a substantial difference considering that the marginal product of the latter is only 2.7 times larger than the marginal product of the former.

In the upper half of Figure 4, we plot the compensating differentials for skilled and unskilled natives, as the share of skilled workers, μ_S, in the immigration surge ranges from zero to one. The relationship between μ_S and p_S is decreasing and nearly linear, and between μ_S and p_U increasing and nearly linear. If the elasticities of substitution were equal between all the different inputs, the two curves would both cross the horizontal axis at $\mu_S = 0.256$, the point where the immigration surge exactly replicates the existing population. Instead, here, the two curves cross at $\mu_S = 0.241$, slightly above the horizontal axis. Hence there is a small region between $\mu_S = 0.24$ and $\mu_S = 0.242$ where the values of p_S and p_U are both positive, and increases in immigration within this narrow band of the skill-distribution are Pareto improvements. Obviously, as long as the immigration surge is still raising the share of unskilled workers in the population, skilled natives benefit because both wages and returns to capital rise. For unskilled natives, this small region is where the wage decreases are small enough that they are dominated by increases in the returns to capital.

Figure 4 About Here

The more skilled workers within a surge of immigration, the more the capital stock rises to accommodate it. Because agents in this economy wish to smooth consumption over time, savings do not adjust linearly. Therefore the return to capital is increasing and slightly convex in the value of μ_S, and so is the immigration surplus in the lower half of Figure 4.

For the same reason, the immigration surplus is increasing and convex in the magnitude of the immigration surge. In Table 3 we present values of p_S, p_U, and p as we vary the rate of immigration between 3.0 and 3.4 per thousand from its baseline rate of 3.2 (in Figure 5 we vary the rate of immigration between 3.0 and 3.4 per-thousand and the value of μ_S over the unit interval as well). Anticipating the rise in the rate of return that accompanies higher immigration, agents temporarily cut consumption and save more. Similarly, a drop in immigration generates a rise in consumption and a decline in capital accumulation. These responses are asymmetric—because of the concavity of the utility function, agents do not forgo consumption to accumulate capital as readily as they raise consumption to lower their capital-holdings. The result is that capital accumulates more slowly than it dissipates, and a rise in immigration raises the rate of return to capital more than a drop in immigration causes it to decline. Therefore, a reduction in immigration by a certain amount generates a smaller loss in welfare than the rise in welfare generated by an equal-sized increase.

Table 3 About Here

Figure 5 About Here

In 2005 a bill that would have raised the number of H1-B visas by an additional 30,000 per year passed in the U.S. Senate, but failed to pass in the House of Representatives. According to our model, implementation of the proposal over the course of ten years would have raised the wages for workers without college degree by nearly 0.14%. This rise in wages for the generally less affluent 74.4% of the population would have largely come at the expense of wages earned by workers with college degrees. All the same, the policy would have generated an immigration surplus for the native population as a whole, equivalent to a one-time payment of over $1.2 billion.

Compare these results to fiscal measures presently employed by governments throughout the developed world, designed to lower wage inequality. Raising the tax rates paid by high income workers or investors to finance lower taxes, wage subsidies, or transfers for low income workers generally entails a loss of efficiency—an increase in the dead-weight loss from distortionary taxation. Instead, by increasing the number of visas available to high skilled immigrants, policy makers could achieve many of their same goals, *vis-à-vis* reducing wage inequality, while generating welfare surpluses.

6 Sensitivity Analysis

6.1 Changing the Duration of the Impulses

Changing the number of immigrants that continuously arrive over the course of ten years simply scales up or down the impulse responses for factor returns and per-capita output. What happens if the duration of the policy is no longer ten years? What happens to factor returns and per-capita output if the country absorbs the same six hundred thousand skilled immigrants over the course of a single year? Or fifteen? Because capital supply is endogenous, immigration surges affect wages in the long-run only if they alter the long-run ratio of skilled to unskilled workers. Hence the long-run impact of a surge of immigration on wages is a function of its overall size and composition, and not the rate at which it occurs. To accommodate an additional six hundred thousand skilled immigrants—a rise of 0.2% in the size of the overall population—the aggregate stock of capital will ultimately rise by 0.58% and the per-capita stock of capital by 0.38%. However the shorter the duration of time over which the surge of skilled immigration is concentrated, the more the immigrants overwhelm the ability of the economy to adequately adjust its capital stock through additional savings. As a consequence, the short-run impact on factor returns is greater, and the behavior of the model differs most from what would obtain if capital moved freely from abroad.

Figure 6 About Here

Consider what happens if the entire surge in skilled immigration is concentrated within a year. In Figure 6, the nearly immediate arrival of an additional six hundred thousand skilled immigrants lowers skilled wages by 0.64% by the end of the year. If the identical number of skilled immigrants is evenly spread across a fifteen year interval, the maximum drop in the skilled wage is 0.39% in year fifteen. Similarly, if all the additional skilled immigrants join the economy over the course of a single year, by the end of that year the rate of return in Figure 6 rises by 6.2 basis points. If the same number arrive gradually over the course of fifteen years, the rate of return adjusts gradually as well, reaching a peak of 1.8 additional basis points in year fifteen before beginning its descent. The more compressed the time over which skilled immigrants arrive, the more intensely they compete in the labor market to work with the existing capital stock, and the more the capital's rate of return rises at the expense of skilled wages.

Figure 7 About Here

If the additional immigrants are unskilled, the economy only needs to increase the aggregate capital stock by 0.07% to accommodate the addition to the workforce—the per-capita capital stock declines by 0.13%. Again, the change in the composition of the labor force counteracts, rather than reinforces, the positive effect on the rate of return from capital dilution. This is why the short-run own-wage elasticity of unskilled workers in Panel b) of Figure 7 is not very sensitive to changes in the duration of unskilled immigration, when compared to the own-wage elasticity of skilled workers in Panel b) of Figure 6. The same is true for the return to capital.

Table 4 About Here

Compressing the period of time over which the immigrants arrive raises the gap between the effects of the policy on skilled and unskilled natives. If all the skilled immigrants arrive over the course of a single year, the losses to the skilled native population in Table 4 rise to 0.2664%, and the gains to unskilled increase to 0.2504%. Similarly, raising the time span causes both the gains and losses to slightly decline. The lower the value of T, the higher the rate of return to capital (though over a shorter period of time), and the greater the size of the immigration surplus.

6.2 Changing the Amount of Capital Immigrants Import

Till now we have assumed that all the immigrants arrive in the United States without any significant capital-holdings, and as a result, any increase in the rate of immigration initially lowers the capital-labor ratio. What if, instead, immigrants do arrive with capital?

Once again we assume that the underlying rate of immigration is 3.2 per thousand for both skilled and unskilled workers. These immigrants join the economy without owning any resources beyond the unit of labor they supply—the parameters of the model remain the same. Once more, suppose the United States decides to permit an additional 600,000 skilled workers to immigrate over the course of a decade. However, these are unlike the penniless immigrants granted entrance in the previous sections, or those that comprise the underlying surge—these additional immigrants arrive with some amount of capital. How much? Assume they arrive with 25%, 50%, 75%, or 100% of the capital owned by the average skilled person already working in the economy.

Figure 8 About Here

The behavior of the impulse responses in Figure 8 demonstrates that increasing the amount of capital these immigrants import neutralizes the effect of capital dilution on the model, until finally only the effect generated by the change in the composition of the labor force remains. Even so, because of the differences in the elasticities of substitution between the three factors of production, the behavior of the model differs from that of a model of an open economy with complete capital mobility, even if skilled immigrants arrive with 100% of the capital owned by their native counterparts. Until the economy generates the additional capital necessary to accommodate the surge of skilled immigrants, both types of wages and per-capita income remain below their long-run values, and the arrival of these immigrants still generates a temporary surge in the rate of return to capital of nine-tenths of a basis point by year ten.

Removing the effects of capital dilution from the surge of skilled immigrants changes the quantitative, but not qualitative behavior of the model, and dampens, but does not eliminate, the immigration surplus in Table 5. This is because capital dilution merely reinforces the effect generated by the change in the composition of the labor force. This is not so for a surge in unskilled immigration—here the two effects counteract each other.

Figure 9 About Here

In Figure 9, the arrival of an additional 600,000 unskilled immigrants over the course of a decade still raises the rate of return to capital (by just over a tenth of a basis point in year ten) even if they bring with them an amount of capital equal to 25% of the capital owned by unskilled workers. However, raise the amount of capital these immigrants import to 50%, and any change in the rate of return is indiscernible—the effects of capital dilution and the change in the composition of the workforce essentially cancel each other out. Indeed, factor returns and per-capita output behave as they would if capital were completely mobile. The small immigration surplus in Table 5 reflects the small rise in overall wages (0.0002%) the immigration surge generates.

Table 5 About Here

If the amount of capital the additional unskilled immigrants bring with them rises any further, the rate of return to capital temporarily declines. A surge of unskilled immigrants arriving with 75%

of the capital owned by native unskilled workers temporarily drives down the rate of return to capital by just under one fifth of a basis point in year ten. If these immigrants have the same amount of capital as their native counterparts, the rate of return drops by three-tenths of a basis point.

Two factors of production are arriving in the country simultaneously, unskilled labor and capital, and both are substitutes for native-owned capital. If the capital brought by immigrants is beyond the amount the economy requires in the long-run, the rate of return to capital declines. Therefore, although on average the wages for native workers increase slightly, native income declines, and the native population's welfare is harmed. Hence in Table 5, the immigration surpluses for a surge in immigration of unskilled workers arriving with 75% or 100% of native unskilled capital-holdings are negative.

6.3 Changing the Elasticities of Substitution

The results in the previous sections demonstrate that, given the elasticities of substitution between the input factors estimated by Krusell *et. al.* (2000), a rise in skilled immigration over and above the pre-existing flow generates an immigration surplus approximately ten times greater than that generated by the same number of unskilled immigrants. In this section, we consider how robust this conclusion is to alternative values for the elasticities of substitution.

The impulse responses in Figure 10 describe the reaction of factor returns and per capita output to, once again, the 60,000 per annum, ten-year increase in the inflow of skilled immigrants for different elasticities of substitution: when both elasticities of substitution are low ($\sigma_{SK} = 0.5$, $\sigma_{UK} = 1$) or high ($\sigma_{SK} = 1$, $\sigma_{UK} = 2$), and for each high and low combination, ($\sigma_{SK} = 0.5$, $\sigma_{UK} = 2$), and ($\sigma_{SK} = 1$, $\sigma_{UK} = 1$). The last set of elasticities corresponds to the Cobb-Douglas specification, where capital and skill are no longer relative complements. The general pattern of the impulse responses—a monotonic rise in (the detrended value of) unskilled wages, a sharp drop in (the detrended value of) skilled wages followed by partial recovery, a sharp rise in the rate of return to capital followed by gradual return to the long run rate of 7.82%, a gradual increase in per-capita output—are all qualitatively robust to our choices of σ_{SK} and σ_{UK}. The magnitudes of the impulse responses do vary, but these quantitative differences are best understood in the context of the Allen-Hicks partial elasticities of complementarity.[16]

[16] Partial elasticities of substitution measure the rate at which one factor is substituted for another following a shift in relative factor prices, assuming that total output and other factor prices remain constant. We are studying the effects of exogenous changes in the supply of inputs—immigrant labor. Therefore even though one input, capital, is not fixed in the long-run, the partial elasticities of complementarity—the relative changes in factor prices following a change in the ratio of inputs (with marginal costs and other inputs constant)—provide a more useful guide for understanding the behavior of the model than the more commonly reported

Figure 10 About Here

Both the short and long-run impacts of an influx of skilled immigrants on the wages of skilled workers are directly related to the absolute value of the own-price complementarity of skilled labor c_{SS} in Table 6. If both elasticities are low ($\sigma_{SK} = 0.5$, $\sigma_{UK} = 1$), the value of c_{SS} is -3.12, and by year ten, when all the six hundred thousand additional immigrants have joined the economy, skilled wages in Figure 10 are 0.61% lower than they otherwise would be. Once again, as capital accumulates to accommodate the additional workers, skilled wages recover some lost ground, but in the long-run remain 0.47% below their previous trend.

Table 6 About Here

Similarly, the wages for unskilled workers rise the most following an influx of skilled immigrants when the complementarity between skilled and unskilled labor is highest (and substitution is lowest). The manner in which the stock of capital responds over time to the influx of skilled immigrants also has an indirect effect on the reaction of unskilled wages. The higher the complementarity between the skilled immigrant's labor and capital, the greater the rise in the capital stock. Capital and unskilled labor are relative substitutes, but still complement each other. Hence the combination of low substitution between skilled and unskilled labor, and high complementarity between capital and unskilled labor (corresponding to $\sigma_{SK} = 0.5$, $\sigma_{UK} = 1$), implies the highest long-run rise in unskilled wages, 0.43%.

In a static model, the response of the return to capital to an increase in skilled immigration would be both permanent, and solely determined by the degree of complementarity between capital and skilled labor. Here, with capital adjusting through changes in savings, temporary influxes do not affect the long-run rate of return, and though the short-run rate of return is determined primarily by the elasticity of complementarity between capital and skilled labor, the own price complementarity of capital plays a role as well. This additional factor also influences the immigration surplus.

If the elasticities of substitution are $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 1$, the elasticity of complementarity between skilled labor and capital is highest, c_{SK} =1.75, and by year ten, the influx of skilled immigrants raises the rate of return to capital by 2.7 basis points. The more the elasticity of substitution between skilled labor and capital rises, the lower the elasticity of complementarity, and the lower the short-run response of the rate of return. For the Cobb-Douglas specification ($\sigma_{SK} = 1$ and $\sigma_{UK} = 1$), the elasticity of complementarity between capital and skill, c_{SK}, is equal to 1, and the rate of return to capital rises by no more than 1.4 basis points. However, holding constant the value of σ_{SK} while

and estimated elasticities of substitution.

raising the value of σ_{UK} lowers the value of c_{SK}, but the own price complementarity of capital drops (in absolute value) with increases in σ_{UK}, and this effect dominates. The lower (in absolute value) is c_{KK}, the less the rate of return is responsive to the additional capital that is gradually accumulating to accommodate the additional workers. If $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 2$, then c_{SK} is only 1.25, but in year ten the rate of return is 3.1 basis points above its long-run value.

The response of unskilled wages to an influx of unskilled immigrants in Figure 11 is primarily determined by the value of c_{UU}—the higher its value (in absolute value), the greater the drop in unskilled wages. The largest long-run decline in unskilled wages, 0.16%, occurs where both the elasticities of substitution are low ($\sigma_{SK} = 0.5$ and $\sigma_{UK} = 1$), and the smallest decline, 0.08%, occurs where both elasticities are high ($\sigma_{SK} = 1$ and $\sigma_{UK} = 2$). A secondary determining factor is the relative complementarity between skilled labor and capital, when compared to the complementarity between unskilled labor and capital: c_{UK}^{SK}=c_{SK}-c_{UK}. The higher the value of c_{UK}^{SK}, the greater the drop in unskilled wages.

Figure 11 About Here

The complementarity between unskilled and skilled workers, c_{US} (equal to c_{UK}), is what primarily determines the response of skilled wages to the influx of unskilled immigrants. If $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 1$, the complementarity between the two types of labor is high, and long-run skilled wages are 0.16% higher as a consequence of the influx of unskilled immigrants. If $\sigma_{UK} = 2$, the rise is only 0.09%. Again the value of c_{UK}^{SK} plays a secondary role: The higher its value, the greater the rise in skilled wages. The rate of return to capital changes only slightly, regardless what parameters we choose, ranging from 0.21 of a basis point if $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 2$, to 0.52 of a basis point for the Cobb-Douglas specification ($\sigma_{SK} = 1$ and $\sigma_{UK} = 1$).

What do these patterns of factor returns imply for welfare? As we would expect, there is an inverse relationship between the immigration surpluses generated by the different types of immigrants and the elasticity of substitution between the labor they supply and the capital owned by the native population. That said, the immigration surpluses generated by high skilled immigration in Table 7 are remarkably similar across a wide range of parameterizations of the model, ranging from an increase of 0.0010% in permanent consumption for the Cobb-Douglas specification ($\sigma_{SK} = 1$ and $\sigma_{UK} = 1$) to 0.0016% if $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 2$. By contrast, the impact of unskilled immigration is far more sensitive to the choice of elasticity, ranging from an increase in permanent consumption 8.0×10^{-5}% if $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 2$, to 2.6×10^{-4}% for the Cobb-Douglas specification. The equal rise in both rates of immigration generates small benefits for the unskilled population at the expense of the skilled, but only as long as capital and skill are relative complements. For the Cobb-

Douglas specification, the rise in undifferentiated immigration generates a surplus of $2.7 \times 10^{-4}\%$ for all natives in the economy.

Table 7 About Here

The lower the elasticity of substitution between capital and skilled labor, and the higher the elasticity of substitution between capital and unskilled labor, the more the impacts on the economy and the native population generated by the two types of immigration diverge. If $\sigma_{SK} = 0.5$ and $\sigma_{UK} = 2$, high skilled immigrants generate an immigration surplus that is about twenty times larger than that generated by unskilled immigration. If $\sigma_{SK} = 1$ and $\sigma_{UK} = 1$, the relative complementarity between skilled labor and capital is absent and the benefits from skilled immigration are only four times as large—still substantial, considering that the skilled workers are only 2.7 times more productive than the unskilled. In summary, these results demonstrate that for a wide range of elasticities, high-skilled immigrants not only generate surpluses greater than those generated by low-skilled immigrants, but the gap is potentially far greater than simple comparisons of their marginal products imply. All of this before even considering the likely differential impact of each type of immigrant on government expenditure and revenue.

7 Conclusion

Given the vast differences in income available to workers in the developing world and the industrialized West, the number of people seeking to improve their lives by migrating from the former to the latter will remain very large for the foreseeable future. How many, and which kinds, of immigrants Western countries will choose to absorb will depend on a number of considerations, not all of them economic. Within the realm of economics, policy makers will need to take into account how immigrants affect the distribution of income between capital and workers, the distribution of wages between different types of worker, the size and scale of the economy, and the variety and types of goods and services available in the market. In addition, given the low birth rates and the increase in life expectancy throughout the developed world, the immigration of young workers is likely to play an ever more important role in decisions regarding long-run fiscal policy, in particular as policy makers seek ways to sustain costly public pension schemes.

The model we presented in this paper abstracts from scale effects as well as externalities. Although we introduced a government sector to aid in calibrating the model, it is a deliberately simplified one—fiscal policy plays no role in the analysis. Instead, this paper demonstrates that even in a model with constant returns to scale, no external effects, and no change in the tax burden, small variations in immigration rates can have important welfare implications that are in turn heavily dependent on the type of immigrants admitted. Furthermore, these results obtain in a model in which capital is not fixed, but rather adjusts endogenously through changes in maximizing agents' choices of savings.

The presence of capital-skill complementarities has profound implications for how different types of immigrants affect the welfare of the population that absorbs them. Raising the number of skilled immigrants arriving in the United States by sixty-thousand per year (approximately doubling the size of the U.S. government's H1-B visa program), for one decade only, redistributes income worth close to \$255 billion in present value from the wealthier college-educated population to the less affluent non-college educated majority. Policies that lower wage inequality often generate a deadweight loss, but this policy would generate a welfare surplus equivalent to three billion dollars. By contrast, the same sized increase in the number of unskilled immigrants generates a welfare benefit only a tenth as large, while redistributing close to \$82 billion worth of consumption in the opposite direction.

There is a growing body of direct (Lindquist (2005)), and indirect (Skaksen and Sorensen (2005) and Winchester and Greenaway (2007)) evidence that capital-skill complementarities are a common feature of many developed economies. Having examined the behavior of the model for alternative choices of the elasticity of substitution, we can infer that large differences between the immigration surpluses generated by skilled and unskilled immigrants in the U.S. economy are likely to emerge if the model is calibrated to match the economies of other countries that absorb immigrants.

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Captions for Tables and Figures

Table 1: Paramaterization of Baseline Model. [†]Bureau of Economic Analysis. [‡]U.S. Census Bureau. [§]1998 Survey of Consumer Finances.

Table 2: Welfare effects generated by an increase in the rate of immigration from 3.2 to 3.4 per thousand per annum during one decade only.

Table 3: Compensating differentials generated by the influx of additional immigrants to the underlying immigration flow over the course of ten years.

Table 4: Compensating differentials generated by the influx of an additional six hundred thousand immigrants to the underlying immigration flow over the course of T years.

Table 5: Compensating differentials generated by the influx of an additional six hundred thousand thousand immigrants to the underlying immigration flow over the course of T years.

Table 6: The relationship between cross and own Allen-Hicks partial elasticities of complimentarity and the cross partial elasticities of substition for the two-level CES production function: $\mathsf{c}_{US} = \mathsf{c}_{UK} = \frac{1}{\sigma_{UK}}$, $\mathsf{c}_{SK} = \frac{(1-\phi_{SK})(\sigma_{UK}-\sigma_{SK})+\sigma_{UK}}{\sigma_{UK}(\phi_{SK}\sigma_{SK}-(1-\phi_{SK})\sigma_{UK})}$, $\mathsf{c}_{UU} = -\frac{1-\phi_U}{\phi_U\sigma_{UK}}$, $\mathsf{c}_{KK} = -\frac{1-\phi_K}{\phi_K\sigma_{UK}}$, $\mathsf{c}_{SS} = -\frac{\phi_S(1-\phi_{SK})(\sigma_{SK}-\sigma_{UK})+(1-\phi_S)\sigma_{UK}}{(\phi_{SK}\sigma_{SK}-(1-\phi_{SK})\sigma_{UK})\phi_S\sigma_{UK}}$. The difference between c_{SK} and c_{UK} is $\mathsf{c}_{SU}^{SK} = \frac{\sigma_{UK}-\sigma_{SK}}{\sigma_{UK}(\phi_{SK}\sigma_{SK}-(1-\phi_{SK})\sigma_{UK})}$.

Table 7: Compensating differentials generated by the influx of an additional six hundred thousand immigrants to the underlying immigration flow over the course of ten years, for different elasticities of substitution.

Figure 1: The Sources of Population Growth in OECD countries, net migration versus natural population growth, decade averages for 1991-2000. Source: Organization of Economic Co-operation Development, *Components of Total Population Growth,* Vol 2001.

Figure 2: The solid curves are the impulse responses of factor returns and per-capita output if the rate of immigration increases from 3.2 to 3.4 per thousand per annum for ten years, and all the additional immigrants are skilled. The curves with the short dashes are the impulse responses when the rates of immigration for the skilled and unskilled both rise at the same rate. The gray areas between the two curves isolate the overall influence of changes in the composition, rather than the size of the population. The curves with the long dashes represent the behavior of factor returns and per-capita output if capital flows freely from abroad.

Figure 3: The solid curves are the impulse responses of factor returns and per-capita output if the rate of immigration increases from 3.2 to 3.4 per thousand per annum for ten years, and all the additional immigrants are unskilled. The curves with the short dashes are the impulse responses when the rates of immigration for the skilled and unskilled both rise at the same rate. The gray areas between the two curves isolate the overall influence of changes in the composition, rather than the size of the population. The curves with the long dashes represent the behavior of factor returns and per-capita output if capital flows freely from abroad.

Figure 4: The compensating differentials, p_S and p_U from (12), and immigration surplus p from (14), generated by an increase in the rate of immigration from 3.2 to 3.4 per thousand, as a function of the fraction of the additional immigrants μ_S that are skilled.

Figure 5: The compensating differentials, p_S and p_U from (12), and immigration surplus p from (14), as a function of the changes in the rates of immigration ranging between a drop and a rise of 0.2 per thousand in the rate of immigration, and as a function of the fraction of the additional immigrants μ_S that are skilled.

Figure 6: A rise of six hundred thousand in the number of immigrants arriving over the course of T years. Solid curves: Baseline model where all six hundred thousand immigrants are skilled. Curves with long dashes: Capital flows freely from abroad where all six hundred thousand immigrants are skilled. Curves with short dashes: Baseline model where rates of immigration for skilled and unskilled are equal.

Figure 7: A rise of six hundred thousand in the number of immigrants arriving over the course of T years. Solid curves: Baseline model where all six hundred thousand immigrants are unskilled. Curves with long dashes: Capital flows freely from abroad where all six hundred thousand immigrants are unskilled. Curves with short dashes: Baseline model where rates of immigration for skilled and unskilled are equal.

Figure 8: Rate of immigration increases from 3.2 to 3.4 per thousand for ten years. Solid curves: Baseline model, all the extra immigrants are skilled, and they arrive with capital equal to 25%, 50%, 75%, or 100% of capital owned by skilled natives. Curves with long dashes: Capital flows freely from abroad and all the extra immigrants are skilled. Curves with short dashes: Baseline model and the rates of immigration for skilled and unskilled are equal.

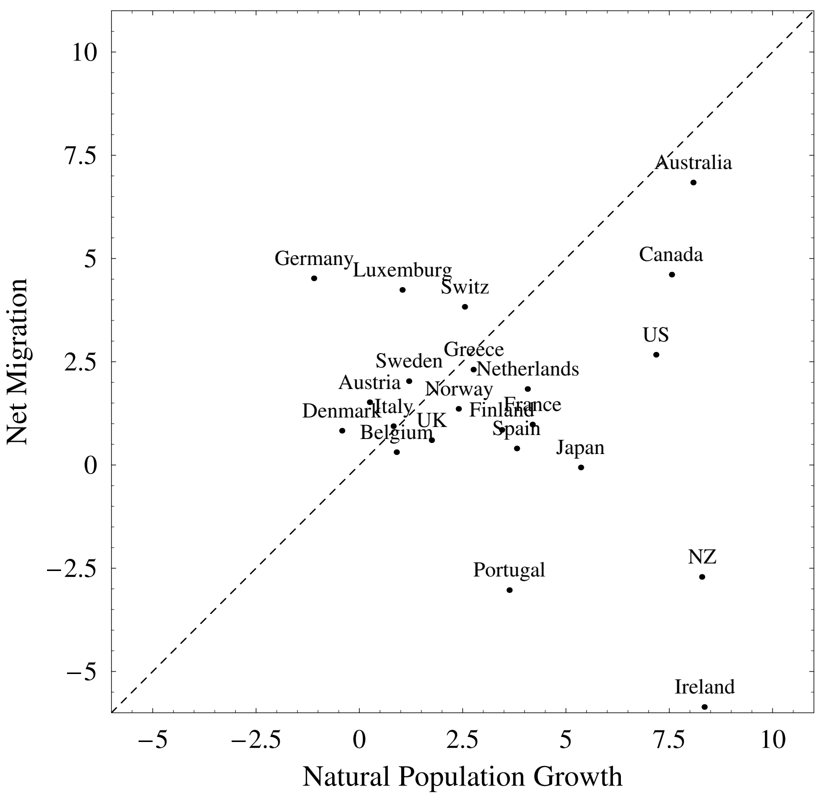
Figure 9: Rate of immigration increases from 3.2 to 3.4 per thousand for ten years. Solid curves: Baseline model, all the extra immigrants are unskilled, and they arrive with capital equal to 25%, 50%, 75%, or 100% of capital owned by unskilled natives. Curves with long dashes: Capital flows freely from abroad and all the extra immigrants are unskilled. Curves with short dashes: Baseline model and the rates of immigration for skilled and unskilled are equal.

Figure 10: Rate of immigration increases from 3.2 to 3.4 per thousand for ten years for different elasticities of substitution. Solid curves: Baseline model and all the extra immigrants are skilled. Curves with long dashes: Capital flows freely from abroad and all the extra immigrants are skilled. Curves with short dashes: Baseline model and the rates of immigration for skilled and unskilled are equal.

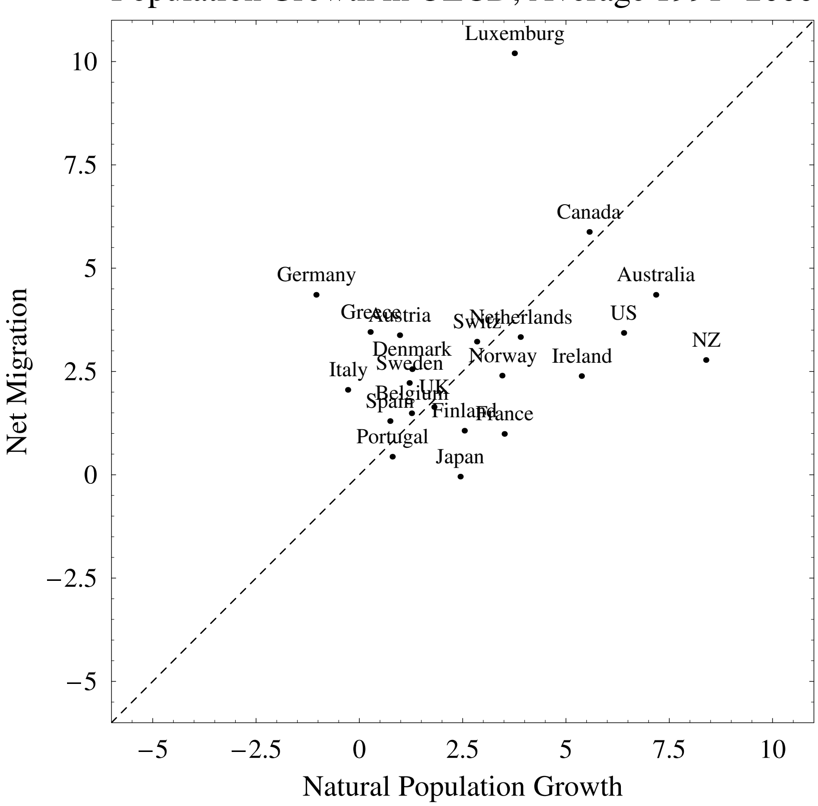
Figure 11: Rate of immigration increases from 3.2 to 3.4 per thousand for ten years for different elasticities of substitution. Solid curves: Baseline model and all the extra immigrants are unskilled. Curves with long dashes: Capital flows freely from abroad and all the extra immigrants are unskilled. Curves with short dashes: Baseline model and the rates of immigration for skilled and unskilled are equal.

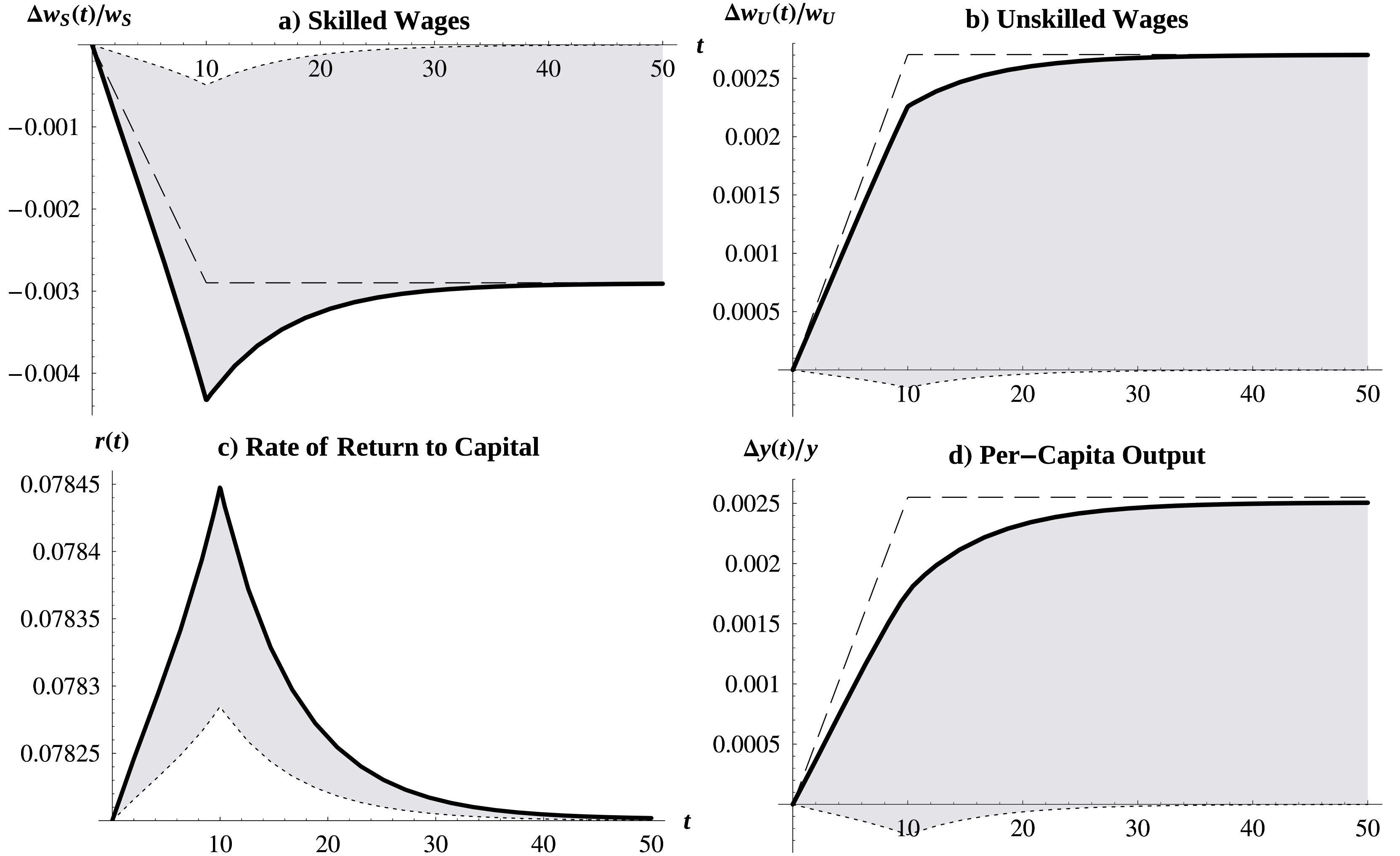
Figure 1

Population Growth in OECD, Average 1981−1990

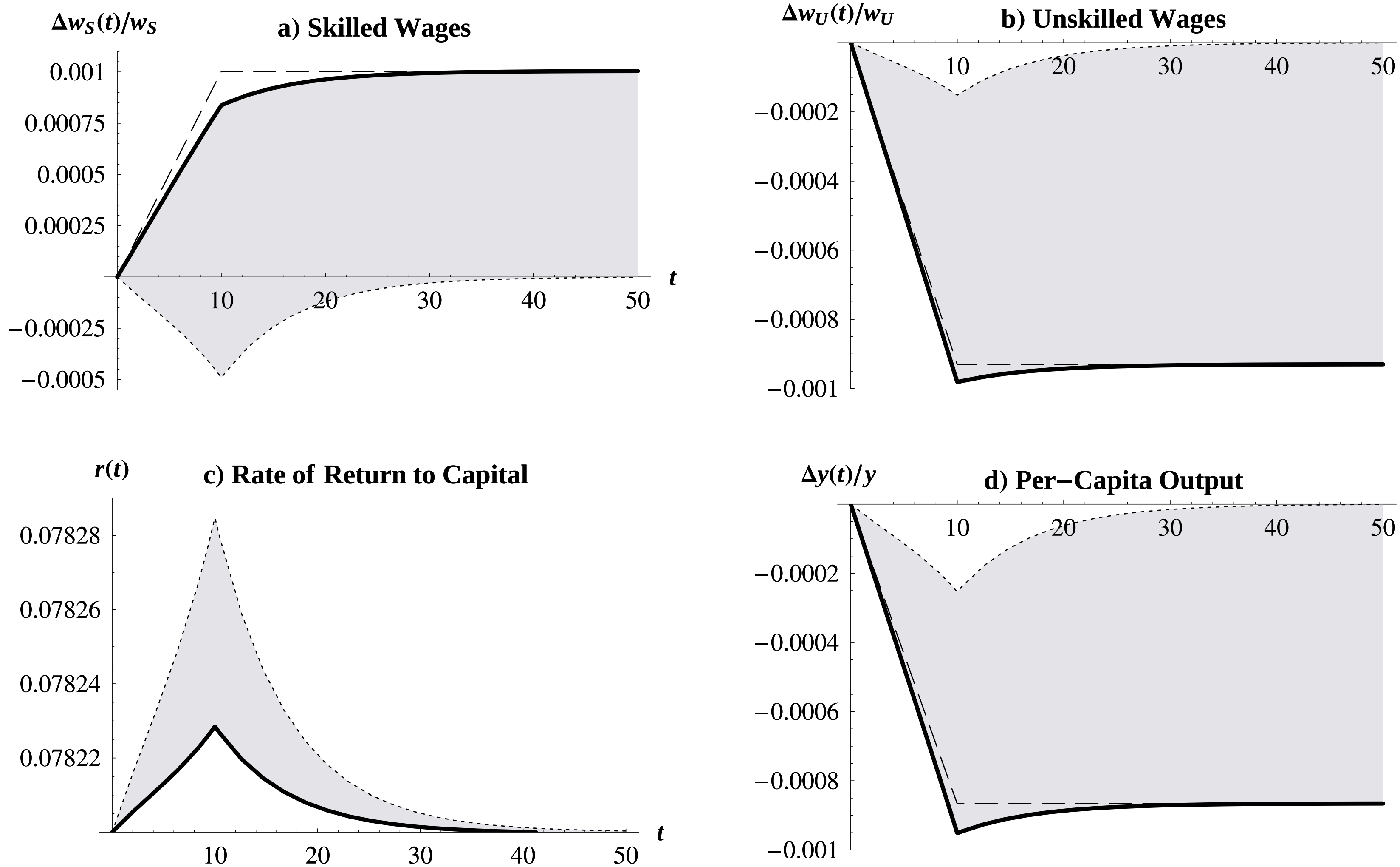


Population Growth in OECD, Average 1991−2000



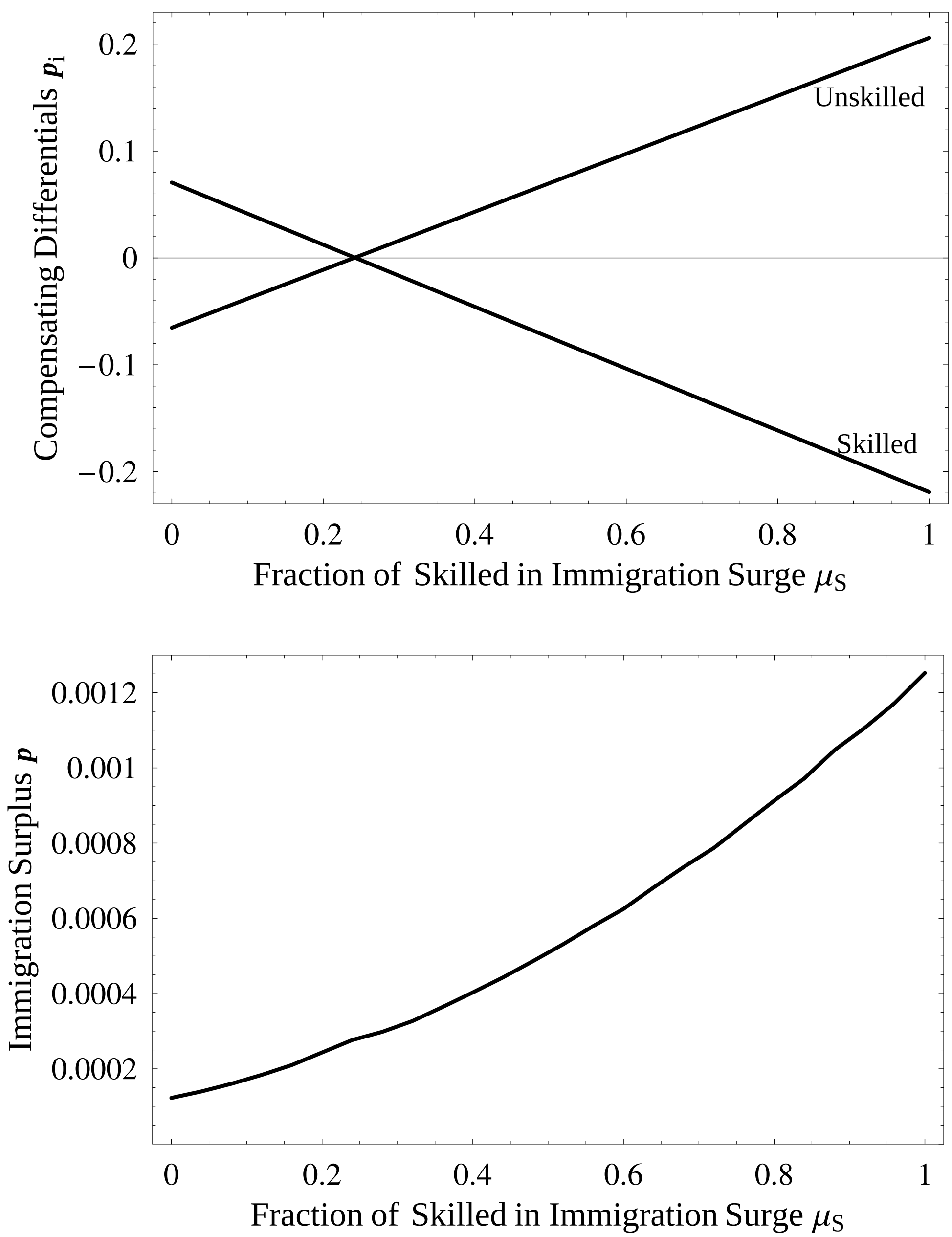


a) Skilled Wages
Δw_S(t)/w_S
t
10
20
30
40
50
−0.001
−0.002
−0.003
−0.004
b) Unskilled Wages
Δw_U(t)/w_U
0.0025
0.002
0.0015
0.001
0.0005
t
10
20
30
40
50
c) Rate of Return to Capital
r(t)
0.07845
0.0784
0.07835
0.0783
0.07825
t
10
20
30
40
50
d) Per−Capita Output
Δy(t)/y
0.0025
0.002
0.0015
0.001
0.0005
t
10
20
30
40
50



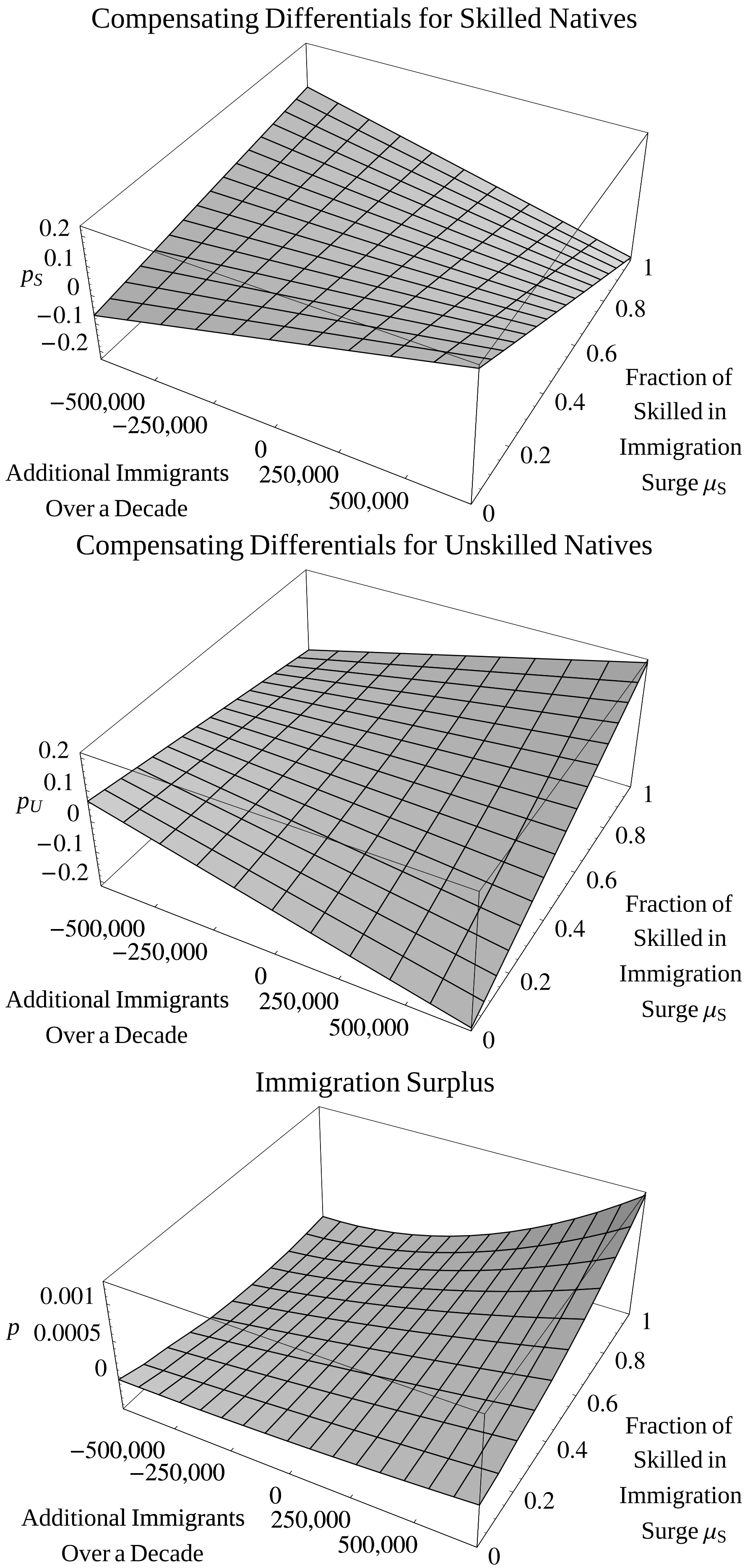
a) Skilled Wages
Δw_S(t)/w_S
0.001
0.00075
0.0005
0.00025
−0.00025
−0.0005
10
20
30
40
50
t
b) Unskilled Wages
Δw_U(t)/w_U
−0.0002
−0.0004
−0.0006
−0.0008
−0.001
c) Rate of Return to Capital
r(t)
0.07828
0.07826
0.07824
0.07822
d) Per−Capita Output
Δy(t)/y

Figure 4

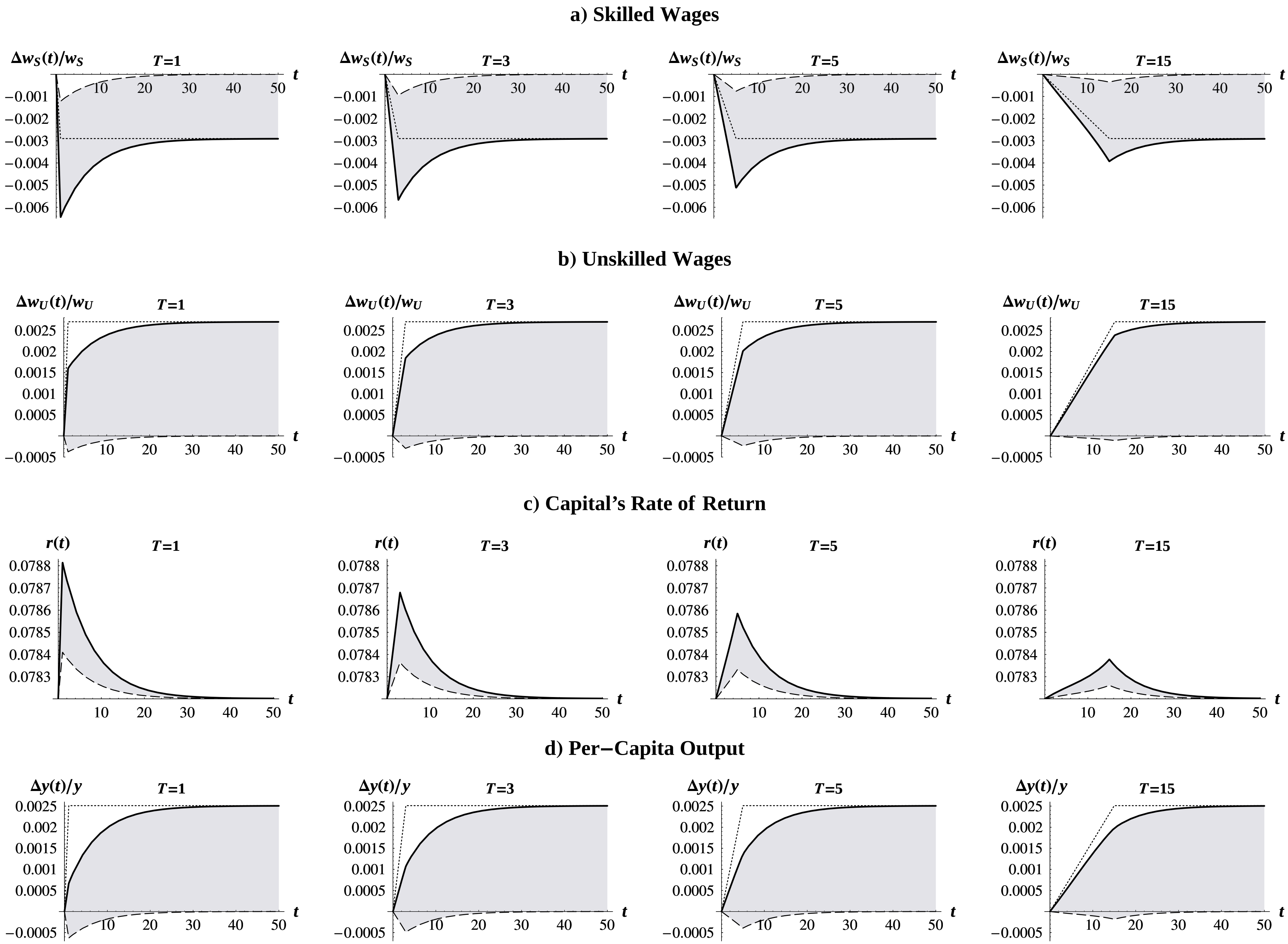


0.2
0.1
0
−0.1
−0.2
Compensating Differentials p_i
Unskilled
Skilled
0
0.2
0.4
0.6
0.8
1
Fraction of Skilled in Immigration Surge μ_S
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
Immigration Surplus p
0
0.2
0.4
0.6
0.8
1
Fraction of Skilled in Immigration Surge μ_S

Figure 5

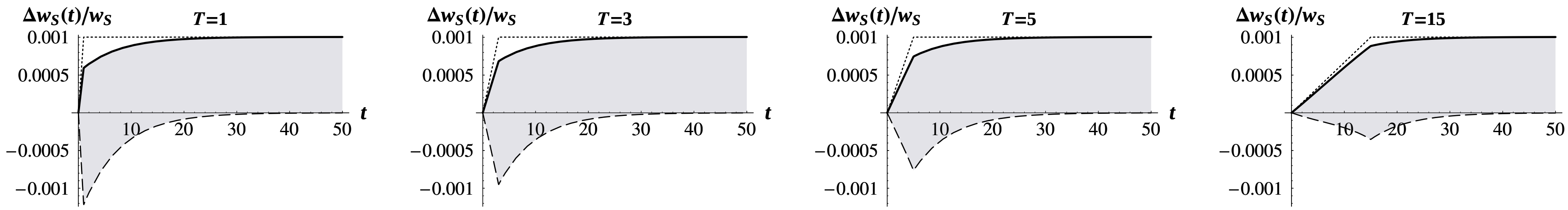


Compensating Differentials for Skilled Natives
p_S
0.2
0.1
0
−0.1
−0.2
−500,000
−250,000
0
250,000
500,000
Additional Immigrants Over a Decade
0
0.2
0.4
0.6
0.8
1
Fraction of Skilled in Immigration Surge μ_S
Compensating Differentials for Unskilled Natives
p_U
0.2
0.1
0
−0.1
−0.2
−500,000
−250,000
0
250,000
500,000
Additional Immigrants Over a Decade
0
0.2
0.4
0.6
0.8
1
Fraction of Skilled in Immigration Surge μ_S
Immigration Surplus
p
0.001
0.0005
0
−500,000
−250,000
0
250,000
500,000
Additional Immigrants Over a Decade
0
0.2
0.4
0.6
0.8
1
Fraction of Skilled in Immigration Surge μ_S

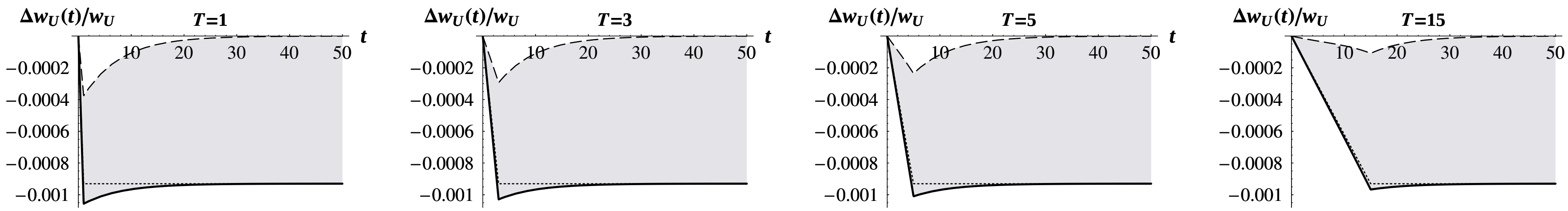


a) Skilled Wages
Δw_S(t)/w_S
T=1
T=3
T=5
T=15
t
10
20
30
40
50
−0.001
−0.002
−0.003
−0.004
−0.005
−0.006
b) Unskilled Wages
Δw_U(t)/w_U
0.0025
0.002
0.0015
0.001
0.0005
−0.0005
c) Capital's Rate of Return
r(t)
0.0788
0.0787
0.0786
0.0785
0.0784
0.0783
d) Per−Capita Output
Δy(t)/y

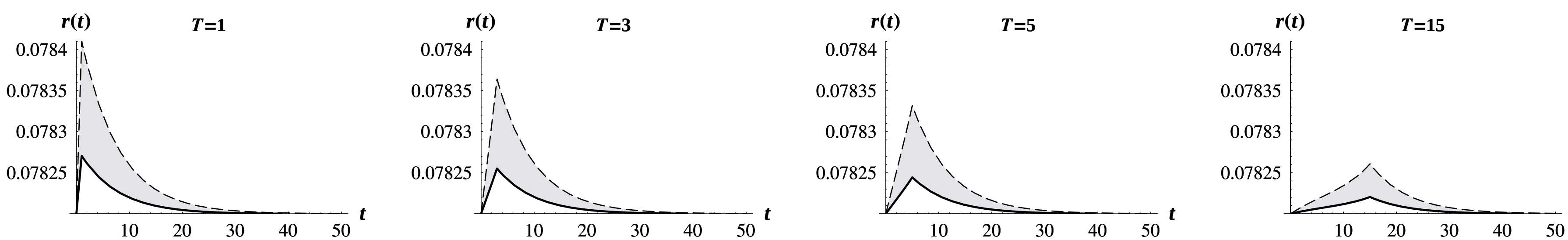
a) Skilled Wages



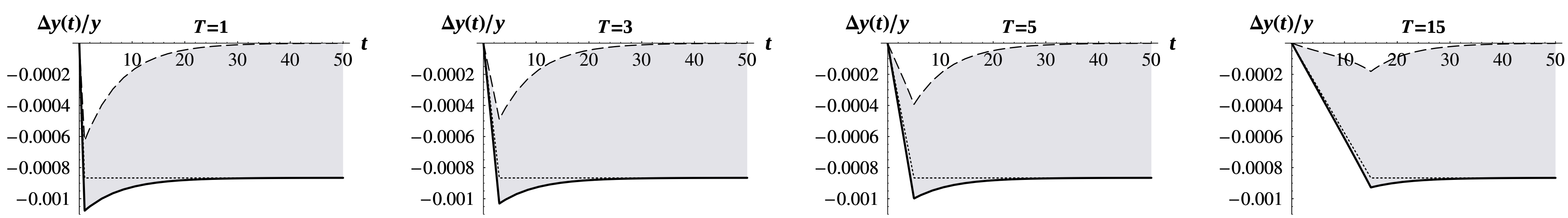
b) Unskilled Wages



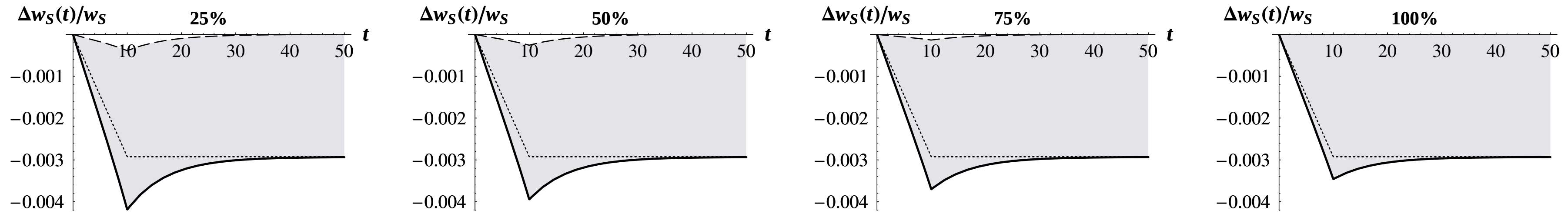
c) Capital's Rate of Return



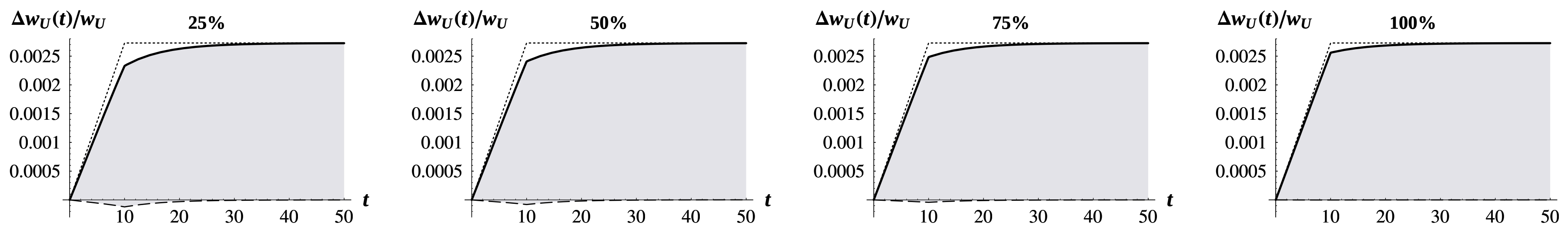
d) Per−Capita Output



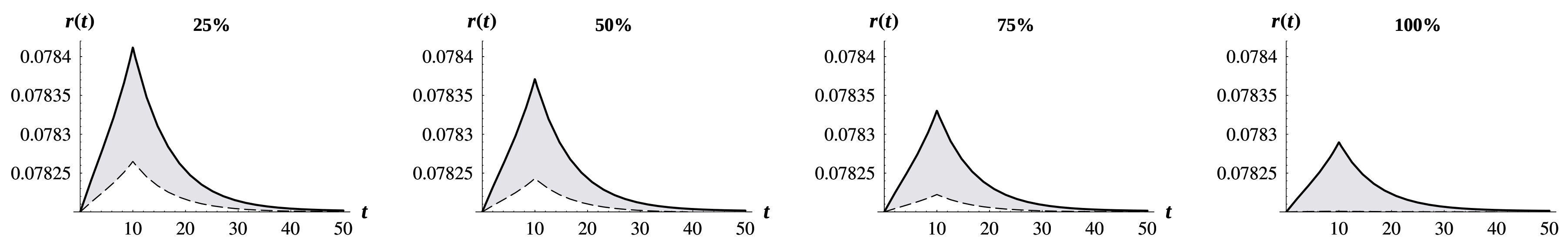
a) Skilled Wages



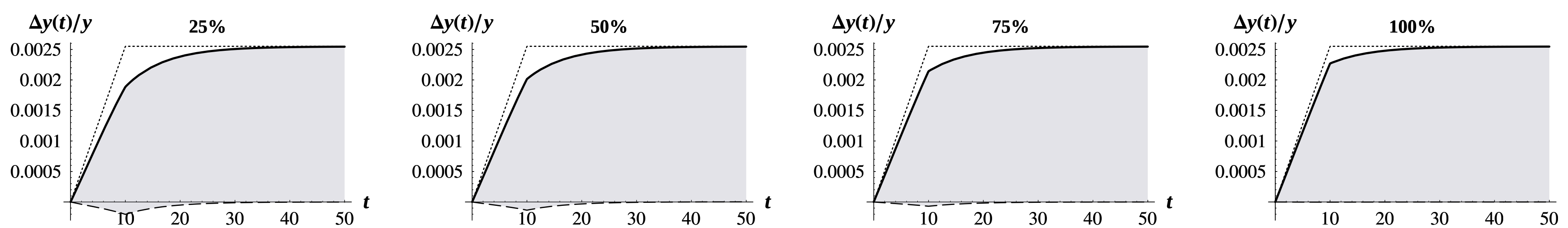
b) Unskilled Wages



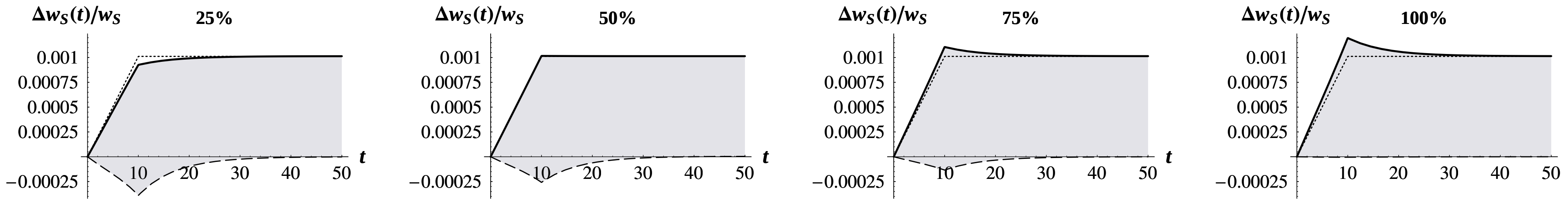
c) Capital's Rate of Return



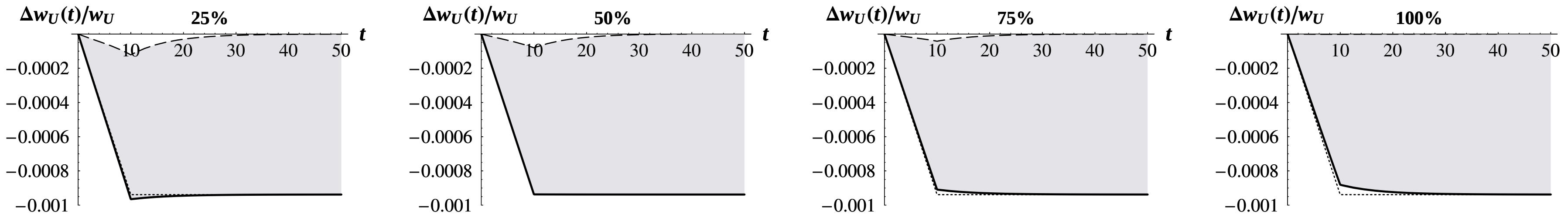
d) Per−Capita Output



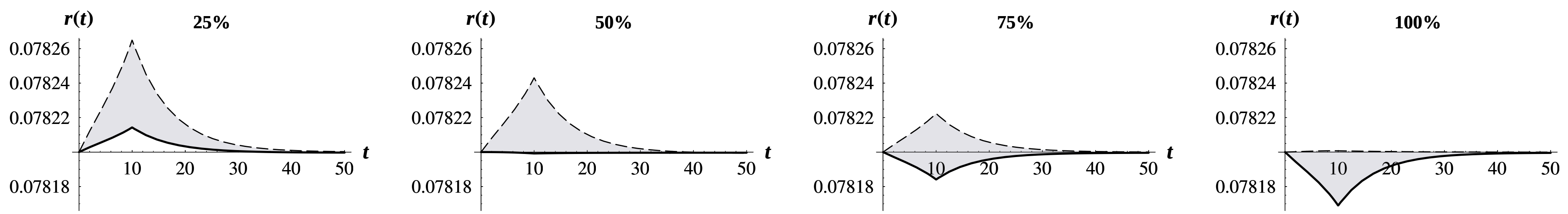
a) Skilled Wages



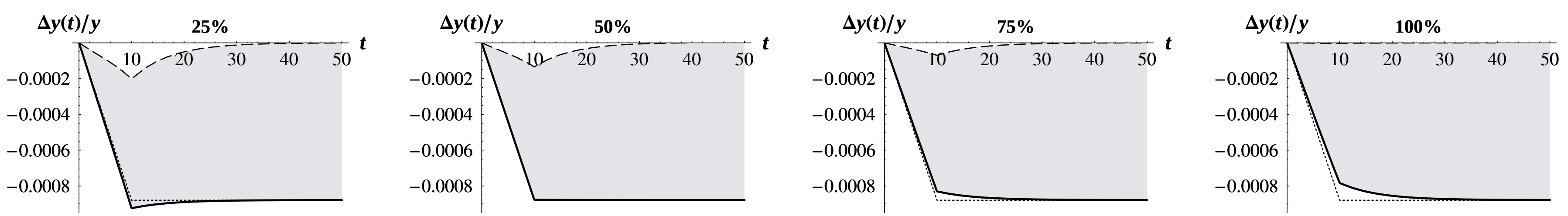
b) Unskilled Wages

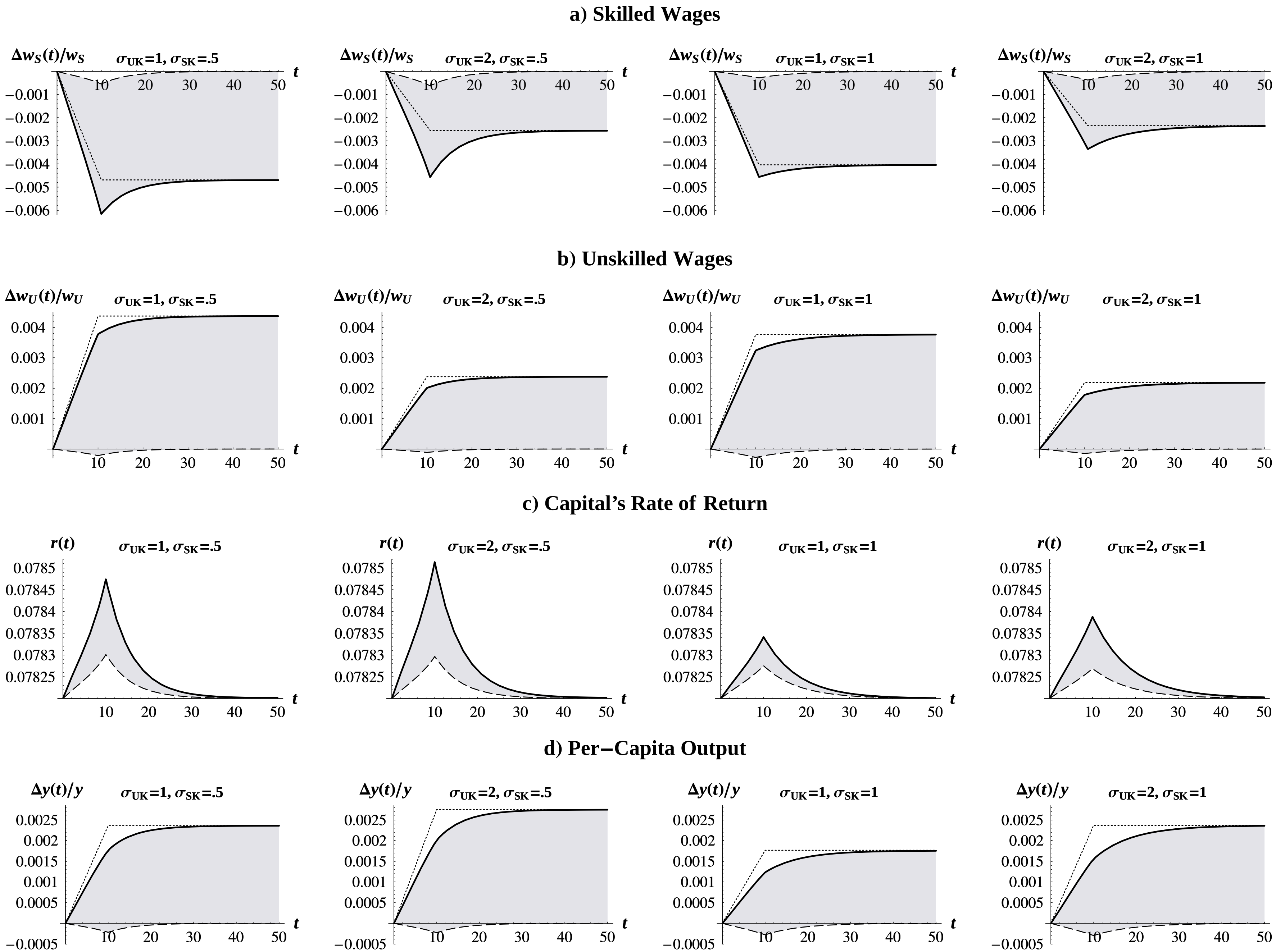


c) Capital's Rate of Return



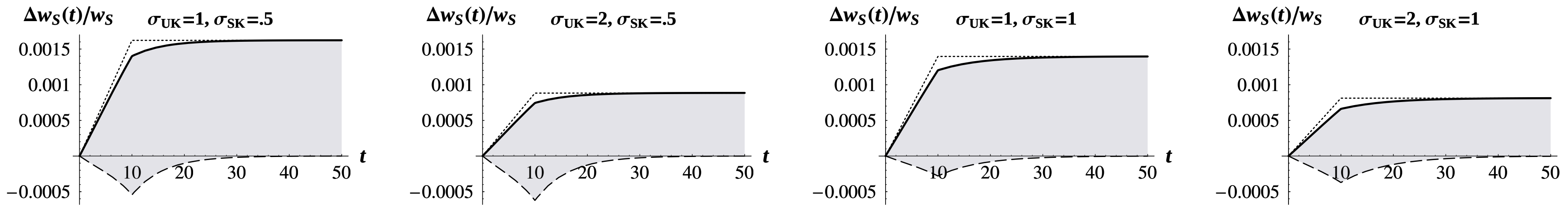
d) Per−Capita Output



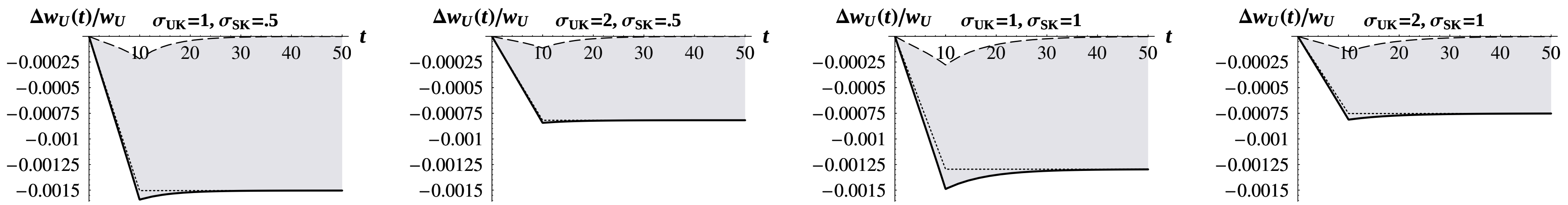


a) Skilled Wages
Δw_S(t)/w_S
σ_UK=1, σ_SK=.5
σ_UK=2, σ_SK=.5
σ_UK=1, σ_SK=1
σ_UK=2, σ_SK=1
t
10 20 30 40 50
−0.001 −0.002 −0.003 −0.004 −0.005 −0.006
b) Unskilled Wages
Δw_U(t)/w_U
0.004 0.003 0.002 0.001
c) Capital's Rate of Return
r(t)
0.0785 0.07845 0.0784 0.07835 0.0783 0.07825
d) Per−Capita Output
Δy(t)/y
0.0025 0.002 0.0015 0.001 0.0005 −0.0005

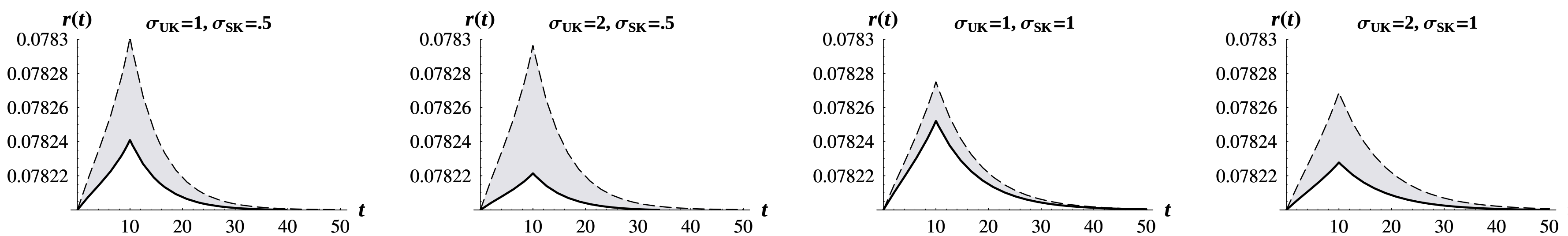
a) Skilled Wages



b) Unskilled Wages



c) Capital's Rate of Return



d) Per−Capita Output

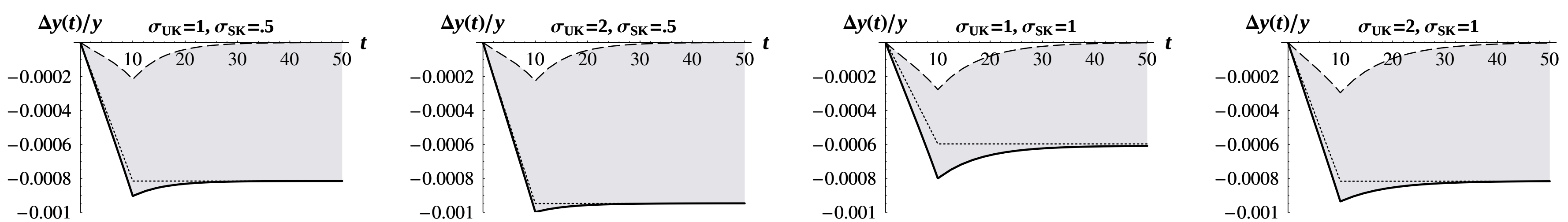


Table 1

	PREFERENCES, TECHNOLOGY AND FACTOR SHARES:
$x = 0.02$	Average U.S. per-capita growth rate in GDP: 1991-2000.†
γ=-0.495, ϑ=0.401	Krusell, Ohanian, Ríos-Rull, and Violante (2000).
$\phi_K = 0.36$	The average share of capital in U.S. GDP: 1991-2000.†
α=0.366, β=0.775	Matches the values of γ,ϑ, ϕ_K, and capital-output ratio of 2.38.
$\delta = 0.0731$	Rate of depreciation on fixed assets consistent with production function and baseline pre-tax interest rate of 7.82%.
τ=0.19	Share of government consumption as a fraction of U.S. NDP and implied services from consumer durables: 1991-2000.†
$\rho = 0.0429$	Matches interest rate, tax rate, growth rate and rate of immigration.
	POPULATION:
$n = 0.0067$	Average U.S. natural rate of population growth: 1991-2000.‡
$m_S = m_U = 0.0032$	Average U.S. rate of net migration: 1991-2000.‡
$\kappa_S = \kappa_U = 1$	Immigrants arrive without physical capital.
$\eta(0) = 0.344$	Ratio of population with/without college degrees.‡
$d = 2.7$	Ratio of initial earnings and wealth between households with/without college degrees.‡§

Table 2

	Compensating Differential, Percentage of Permanent Consumption	*Compensating Differential, Permanent Consumption in Millions of U.S. Dollars*	*Compensating Differential, Present Value Consumption in Millions of U.S. Dollars*	*Compensating Differential, Present Value Consumption per Immigrant in U.S. Dollars*
AN INCREASE IN SKILLED IMMIGRATION:				
Skilled Households	−0.2191	−\$9,224 mil.	−\$254,929 mil.	−\$424,882
Unskilled Households	0.2060	\$9,333 mil.	\$257,955 mil.	\$429,924
Immigration Surplus	0.0013	\$109 mil.	\$3,025 mil.	\$5,042
AN INCREASE IN UNSKILLED IMMIGRATION:				
Skilled Households	0.0706	\$2,970 mil.	\$82,100 mil.	\$136,834
Unskilled Households	−0.0653	−\$2,960 mil.	−\$81,804 mil.	−\$136,341
Immigration Surplus	1.2×10^{-4}	\$11 mil.	\$296 mil.	\$493
AN INCREASE IN UNDIFFERENTIATED IMMIGRATION:				
Skilled Households	−0.0039	−\$164 mil.	−\$4,540 mil.	−\$7,566
Unskilled Households	0.0042	\$188 mil.	\$5,206 mil.	\$8,677
Immigration Surplus	2.8×10^{-4}	\$24 mil.	\$666 mil.	\$1,110

Table 3 pdf file in landscape form

Overall Rate of Immigration Per Thousand During the Decade	3.0	3.05	3.1	3.15	3.25	3.3	3.35	3.4
Thousands of Additional (or Fewer) Immigrants During the Decade	*(600)*	*(450)*	*(300)*	*(150)*	*150*	*300*	*450*	*600*
AN INCREASE IN SKILLED IMMIGRATION:								
Skilled Households	0.2215	0.1659	0.1105	0.0552	−0.0550	−0.1099	−0.1646	−0.2191
Unskilled Households	−0.2065	−0.1548	−0.1032	−0.0516	0.0515	0.1031	0.1545	0.2060
Immigration Surplus	-3.8×10^{-4}	-3.7×10^{-4}	-3.0×10^{-4}	-1.8×10^{-4}	2.3×10^{-4}	5.1×10^{-4}	8.5×10^{-4}	0.0013
AN INCREASE IN UNSKILLED IMMIGRATION:								
Skilled Households	−0.0705	−0.0529	−0.0353	−0.0176	0.0176	0.0353	0.0529	0.0706
Unskilled Households	0.0655	0.0491	0.0327	0.0164	−0.0163	−0.0327	−0.0490	−0.0653
Immigration Surplus	-4.1×10^{-5}	-3.9×10^{-5}	-3.1×10^{-5}	-1.8×10^{-5}	2.3×10^{-5}	5.1×10^{-5}	8.4×10^{-5}	1.2×10^{-4}
AN INCREASE IN UNDIFFERENTIATED IMMIGRATION:								
Skilled Households	0.0039	0.0029	0.0020	0.0010	−0.0010	−0.0020	−0.0031	−0.0039
Unskilled Households	−0.0041	−0.0031	−0.0021	−0.0010	0.0010	0.0021	0.0033	0.0042
Immigration Surplus	-2.6×10^{-4}	-2.0×10^{-4}	-1.3×10^{-4}	-6.7×10^{-5}	6.8×10^{-5}	1.4×10^{-4}	2.1×10^{-4}	2.8×10^{-4}

Table 4

Duration of the Policy	$T = 1$	$T = 3$	$T = 5$	$T = 15$
Thousands of Additional Immigrants per Annum	*600*	*200*	*120*	*40*
AN INCREASE IN SKILLED IMMIGRATION:				
Skilled Households	-0.2664	-0.2541	-0.2431	-0.1993
Unskilled Households	0.2504	0.2389	0.2285	0.1873
Immigration Surplus	0.0015	0.0015	0.0014	0.0011
AN INCREASE IN UNSKILLED IMMIGRATION:				
Skilled Households	0.0817	0.0791	0.0766	0.0651
Unskilled Households	-0.0756	-0.0732	-0.0709	-0.0602
Immigration Surplus	1.4×10^{-4}	1.4×10^{-4}	1.3×10^{-4}	1.1×10^{-4}
AN INCREASE IN UNDIFFERENTIATED IMMIGRATION:				
Skilled Households	-0.0078	-0.0066	-0.0056	-0.0029
Unskilled Households	0.0078	0.0067	0.0058	0.0032
Immigration Surplus	3.0×10^{-4}	3.0×10^{-4}	2.9×10^{-4}	2.6×10^{-4}

Table 5

Percentage of Capital Additional Immigrants Import	25%	50%	75%	100%
An Increase in Skilled Immigration:				
Skilled Households	-0.2173	-0.2156	-0.2138	-0.2120
Unskilled Households	0.2040	0.2020	0.2001	0.1981
Immigration Surplus	0.0011	9.3×10^{-4}	7.7×10^{-4}	5.8×10^{-4}
An Increase in Unskilled Immigration:				
Skilled Households	0.0713	0.0719	0.0726	0.0733
Unskilled Households	-0.0661	-0.0668	-0.0675	-0.0682
Immigration Surplus	7.4×10^{-5}	2.6×10^{-5}	-2.2×10^{-5}	-7.3×10^{-5}
An Increase in Undifferentiated Immigration:				
Skilled Households	-0.0031	-0.0021	-0.0010	0
Unskilled Households	0.0033	0.0022	0.0011	0
Immigration Surplus	2.2×10^{-4}	1.5×10^{-4}	7.2×10^{-5}	0

Table 6

	All values of σ_{SK}			σ_{SK}=.5			σ_{SK}=.75			σ_{SK}=1		
	c_{UK}	c_{UU}	c_{KK}	c_{SK}	c_{SS}	c_{UK}^{SK}	c_{SK}	c_{SS}	c_{UK}^{SK}	c_{SK}	c_{SS}	c_{UK}^{SK}
σ_{UK}=1	1	-2.01	-1.78	1.75	-3.12	0.75	1.30	-2.59	0.30	1	-2.59	0
σ_{UK}=1.5	0.67	-1.34	-1.19	1.47	-2.43	0.80	1.17	-2.08	0.50	0.95	-1.83	0.29
σ_{UK}=2	0.50	-1.01	-0.89	1.25	-2.00	0.75	1.04	-1.75	0.54	0.88	-1.56	0.38

Table 7

		$\sigma_{SK} = 0.5$	$\sigma_{SK} = 0.75$	$\sigma_{SK} = 1$
AN INCREASE IN SKILLED IMMIGRATION:				
	Skilled Households	-0.3396	-0.3132	-0.2883
$\sigma_{UK} = 1$	*Unskilled Households*	0.3179	0.2932	0.2698
	Immigration Surplus	0.0013	0.0012	0.0010
	Skilled Households	-0.2513	-0.2318	-0.2161
$\sigma_{UK} = 1.5$	*Unskilled Households*	0.2359	0.2177	0.2028
	Immigration Surplus	0.0013	0.0012	0.0011
	Skilled Households	-0.2005	-0.1866	-0.1752
$\sigma_{UK} = 2$	*Unskilled Households*	0.1894	0.1758	0.1648
	Immigration Surplus	0.0016	0.0013	0.0011
AN INCREASE IN UNSKILLED IMMIGRATION:				
	Skilled Households	0.1131	0.1066	0.1001
$\sigma_{UK} = 1$	*Unskilled Households*	-0.1046	-0.0983	-0.0925
	Immigration Surplus	2.2×10^{-4}	2.1×10^{-4}	2.6×10^{-4}
	Skilled Households	0.0804	0.0761	0.0725
$\sigma_{UK} = 1.5$	*Unskilled Households*	-0.0745	-0.0705	-0.0670
	Immigration Surplus	1.2×10^{-4}	1.5×10^{-4}	1.8×10^{-4}
	Skilled Households	0.0619	0.0592	0.0569
$\sigma_{UK} = 2$	*Unskilled Households*	-0.0574	-0.0548	-0.0526
	Immigration Surplus	8.0×10^{-5}	1.1×10^{-5}	1.4×10^{-4}
AN INCREASE IN UNDIFFERENTIATED IMMIGRATION:				
	Skilled Households	-0.0033	-0.0013	2.7×10^{-4}
$\sigma_{UK} = 1$	*Unskilled Households*	0.0036	0.0017	2.7×10^{-4}
	Immigration Surplus	2.7×10^{-4}	2.8×10^{-4}	2.7×10^{-4}
	Skilled Households	-0.0051	-0.0032	-0.0017
$\sigma_{UK} = 1.5$	*Unskilled Households*	0.0053	0.0035	0.0022
	Immigration Surplus	3.0×10^{-4}	2.9×10^{-4}	2.8×10^{-4}
	Skilled Households	-0.0059	-0.0042	-0.0029
$\sigma_{UK} = 2$	*Unskilled Households*	0.0060	0.0044	0.0032
	Immigration Surplus	3.0×10^{-4}	2.9×10^{-4}	2.8×10^{-4}

Table 3 LaTeX file

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AN INCREASE IN SKILLED IMMIGRATION:					
Skilled Households	0.2215	0.1659	0.1105	0.0552	−0.05
Unskilled Households	−0.2065	−0.1548	−0.1032	−0.0516	0.05
Immigration Surplus	-3.8×10^{-4}	-3.7×10^{-4}	-3.0×10^{-4}	-1.8×10^{-4}	2.3×10
AN INCREASE IN UNSKILLED IMMIGRATION:					
Skilled Households	−0.0705	−0.0529	−0.0353	−0.0176	0.01
Unskilled Households	0.0655	0.0491	0.0327	0.0164	−0.01
Immigration Surplus	-4.1×10^{-5}	-3.9×10^{-5}	-3.1×10^{-5}	-1.8×10^{-5}	2.3×10
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Skilled Households	0.0039	0.0029	0.0020	0.0010	−0.00
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