Essays on Social Mobility, Immigration and the Skill Premium

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Thesis Declaration

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Abstract

This thesis is formed of three chapters. The first chapter examines the effect on social mobility and economic growth following the introduction of reprogenetic technology such that parents can choose to invest in the talent or ability of their unborn children. I find that if the economy is initially in a steady state such that social mobility is low, the introduction of such technology can increase social mobility and economic growth. If the economy is initially in a steady state such that social mobility is high, then the introduction of such technology will not increase (and may decrease) social mobility and will not affect economic growth.

The second chapter is a review of the literature on how immigration affects wages focusing on studies of the US and UK labour markets.

The third chapter analyses how the skill premium depends on the relative supply of high and low skilled workers in the economy, and the size of the economy. Using a two-sector model where one sector is more skill-intensive than the other, and returns to scale are larger in the skill-intensive sector, I find that the skill premium depends positively on the size of the economy. I consider the effect of an exogenous increase in the number of skilled workers (perhaps due to immigration) on the skill premium and find that under certain conditions the skill premium may increase. I then analyse the effect on the skill premium and the relative price of the skill intensive good in the short and long run and compare the models predictions to the data.

The Economics of Reprogenetics: Growth and Social Mobility in a Brave New World

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Abstract

This paper examines the effect on economic growth and social mobility following the introduction of reprogenetic technology such that parents can invest in the intelligence of their unborn child. If the economy is in a steady state such that social mobility is low, the introduction of such technology may increase social mobility and economic growth.

1 Introduction

The term "Reprogenetic" was coined by Lee M Silver, a Princeton University molecular biology professor, in his 1997 book *Remaking Eden*. The term refers to the creation and manipulation of embryos for reproductive purposes. There has been much debate in the popular press recently about the ethics of "designer babies" as genetic enhancement technology improves. In 2009, *The Fertility Institutes*, based in LA, began offering parents the chance to choose their child's eye and hair colour, but the program was shut down the same year after public outcry.

A powerful genome editing technology known as Crispr, which allows manipulation of DNA in cell nuclei, was developed in 2012 and shown to be effective in human cells in 2013. Last year it was used to alter the genes for fur colour in mice.[1] Unsurprisingly, use of this technology has proved contoversial. On one hand, it raises the possibility of eradicating some genetic diseases. On the other hand, concerns about the safety and ethics of Crispr technology have led to a group of scientists publishing in *Nature* calling for a moratorium on the use of genome editing tools on human embryos.[2] Unesco's *Uni-*

[1] http://www.theguardian.com/science/2015/may/10/crispr-genome-editing-dna-upgrade-technology-genetic-disease

[2] http://www.nature.com/news/don-t-edit-the-human-germ-line-1.17111

versal Declaration on the Human Genome and Human Rights describes reproductive cloning of human beings as "contrary to human dignity".[3]

Despite apparent widespread distaste for use of gene altering techniques on human embryos, Crispr developer Jennifer Doudna expects that over time people will become more comfortable with the use of such technology.[4] She cites IVF as an example of a technology that has become increasingly accepted by society following initial reservations. Within a decade or two it may be possible to screen embryos for genes related to particular abilities or intelligence, or even to use gene therapy to add genes for a high IQ.

My research aims to investigate the rationality of fears that a two tiered society of genetically engineered "haves" and "have nots" could emerge if access to such technology is unequal. I am not attempting to address directly the ethical concerns surrounding this issue. Instead I will focus on what effect the existence of such a technology, which in effect can to some degree be seen as enabling parents to invest in their child's genetic component of IQ or ability, has on overall economic growth as well as on social mobility.

Disregarding ethical and other social concerns and possible feedback effects from these on economic growth, it is difficult to see how the ability to screen embryos and add genes to increase IQ could not have a positive effect on productivity and hence growth. While I show this to certainly be the case in the model considered here, the analysis of the effects on social mobility is much more complicated and depends on several parameters and initial conditions.

The model is based on Hassler and Rodriguez Mora (2000). In this paper an individual's success as an entrepreneur depends on his innate ability and on his background. If his parents are entrepreneurs he inherits an advantage unrelated to ability: easier access to capital, better education, a network of contacts, and specific knowledge about his parents' industry. When the rate of growth of technology is high, the world is changing rapidly and the return to ability is higher. The value of knowledge inherited from one's parents is lower because the technology has changed more. Social mobility is defined within this paper as the degree to which ability, rather than parental background or upbringing, determines an individual's social position and economic success.

I am adding parental investment, or more specifically parental investment into the genetic component of ability, to the framework of Hassler and Rodriguez Mora (2000). The question is then who will actually find it optimal to invest and how these investment decisions affect results on economic growth and social mobility.

The relationship between social mobility and economic growth has been studied

[3] http://portal.unesco.org/en/ev.php-URL_ID=13177&URL_DO=DO_TOPIC&URL_SECTION=201.html

[4] http://www.theguardian.com/science/2015/may/10/crispr-genome-editing-dna-upgrade-technology-genetic-disease

extensively by both sociologists and economists. The consensus is that high levels of social mobility foster economic growth through more efficient allocation of resources. A key assumption in this paper is that an increase in the growth rate reduces the relative return to family background and increases the return to innate ability. This assumption is also key to models of Galor and Tsiddon (1997) and Galor and Moav (2000), the later find empirical support for this assumption. Galor and Tsiddon (1997) find that major technological inventions increase inequality and mobility and lead to a higher proportion of high ability individuals in technologically advanced sectors, stimulating further technological progress. Further empirical support for this assumption comes from Eriksson and Goldthorpe (1992) who construct an index of intergenerational social mobilty for nine major economies. They divide these into two groups; high and low mobility, and find that the average growth rate between 1870 and 1979 is significantly higher in the high mobility group.

2 The Model

Individuals are of type {j,k} where j represents social background and k represents ability. Individuals can be children of workers (j=w) or children of entrepreneurs (j=e). Ability can be high (k=h) or low (k=l). Children are born with high ability with probability q. Individuals are economically active for one period. Their children are economically active in the following period. For simplicity, reproduction is asexual and each adult has one child.

Individuals care about their immediate offspring's income and hence an individual's utility is a function of their own income and their child's income in the next period, i.e.

$$u = I^o + \delta I^c, \tag{1}$$

where I^o is their own income. I^c is their child's income. δ is a parameter which captures both the discount rate and the value a parent places on their child's income relative to their own income.[5]

Individuals choose whether to become entrepreneurs or workers. A worker earns the market determined wage, w_t, which is not firm specific and independent of ability. Hence, the wage of high and low ability workers is identical. An entrepreneur creates a firm and earns that firm's profits, π.

[5]Note that the model could easily be extended to the case in which the individual's utility depends on the income of grand-children, grand-grand-children and so on. However, apart from complicating the model, this will merely change things quantitatively, but not change the underlying qualitative results.

The profits of firm i in period t is given by:

$$\pi_{i,t} = \left(1 - a_{i,t}^{-\beta_{i,t}}\right)\left(2e^{r_t+\chi_{i,t}} l_{i,t}^{1/2} - w_t l_{i,t}\right) \tag{2}$$

where r_t = log of the level of technology, $\chi_{i,t}$ = chosen level of innovation, w_t = wage, $l_{i,t}$ = labour and $a_{i,t} \in (1, \infty)$ is the business outcome and relates to the entrepreneur's (or firm's) productivity and is the realisation of a Pareto distributed random variable a with parameter $\theta_{i,t}$ and minimum 1. Hence, the pdf of the random variable a is given by:

$$f(a) = \begin{cases} 0 & \text{if } a < 1 \\ \theta_{i,t} a^{-(\theta_{i,t}+1)} & \text{if } a \geq 1, \end{cases} \tag{3}$$

where

$$\theta_{i,t} = 4e^{\frac{\chi_{i,t}^2}{\alpha_i}} - \beta_{i,t} \geq 1. \tag{4}$$

The parameter $\beta_{i,t}$ is given by

$$\beta_{i,t} = \alpha_i + \frac{\gamma_i}{1 + g_{t-1}}, \tag{5}$$

where $\gamma_i = \{0 \text{ if } j = w,\ 1 \text{ if } j = e\}$, $\alpha_i = \{0 \text{ if } k = l,\ 0 < \alpha < 1 \text{ if } k = h\}$ and g_{t-1} is the growth rate of technology in the previous period i.e. $r_t = r_{t-1} + g_{t-1}$. Hence, $\beta_{i,t}$ reflects all the positive or negative effects on productivity an entrepreneur faces either due to social background (which is reflected by γ_i) or ability (reflected by α_i).

The relative sizes of α_i and γ_i reflect the relative returns to ability and background respectively. γ_i is normalised to 1 when $j = e$. α is determined by the institutions prevalent in the economy. For example, α will be higher in an economy with high quality, free public education than in an economy with poor quality or no public education.

This model is not qualitatively different from that presented by Hassler and Rodriguez Mora (2000). This set up makes it far easier do derive an explicit expression for the wage rate which will become the focus of attention later on in the paper.

We can see that the advantage an entrepreneur has due to social background is decreasing in the growth rate, while the advantage due to ability is independent of the growth rate. As mentioned earlier, part of the advantage of having entrepreneurs as parents might be skills directly passed on from parents to their children. However, in a rapidly changing world of high growth the necessary skillset changes very quickly as well and so skills passed on from parents to their children are less useful.

Individuals choose to become an entrepreneur or a worker at the ex-ante stage, i.e. before the realisation of $a_{i,t}$.

An entrepreneur will maximise expected profits with respect to his two choice variables, labour input $l_{i,t}$ and innovation level $\chi_{i,t}$. Applying expectations to the profit function given by (2) we can write expected profits (after basic simplification) as:

$$E[\pi_{i,t}] = \frac{\beta_{i,t}}{\beta_{i,t}+\theta_{i,t}} \left(2e^{r_t+\chi_{i,t}} l_{i,t}^{1/2} - w_t l_{i,t}\right). \tag{6}$$

The first order condition with respect to labour yields

$$l_{i,t} = (e^{r_t+\chi_{i,t}}/w_t)^2. \tag{7}$$

As can be seen labour demand of entrepreneurs is independent of $a_{i,t}$.

Substituting the entrepreneur's labour demand into the respective profit functions we get

$$\pi_{i,t} = \left(1 - a_{i,t}^{-\beta_{i,t}}\right)\left(e^{2(r_t+\chi_{i,t})}/w_t\right) \tag{8}$$

$$E[\pi_{i,t}] = \frac{\beta_{i,t}}{\beta_{i,t}+\theta_{i,t}} \left(e^{2(r_t+\chi_{i,t})}/w_t\right). \tag{9}$$

Entrepreneurs of type {e,h} clearly make the highest expected profits and type {w,l} the lowest. At low growth rates, type {e,l} have an advantage over type {w,h}. This position is reversed when the rate of growth is high. Let the threshold growth rate where types {e,l} and {w,h} make equally good entrepreneurs be denoted by g^*.

Innovation increases the maximum possible profit but also increases the variance of profits through the parameter $\theta_{i,t}$.

The first order condition with respect to innovation yields the profit maximising level of innovation

$$\chi_{i,t} = \alpha_i. \tag{10}$$

The level of innovation by an entrepreneur is independent of his social background. Entrepreneurs with high ability innovate more than entrepreneurs with low ability.

Therefore, we assume the growth rate to be depending positively on the proportion of entrepreneurs who are of high ability:

$$g_t = \alpha \frac{m_t^h}{m_t}, \tag{11}$$

where m_t is the total number of entrepreneurs and m_t^h is the number of high ability entrepreneurs at time t. The growth rate is higher in an allocation where only high ability individuals become entrepreneurs. An increase in the proportion of entrepreneurs who are high ability has an effect on the growth rate similar to that of increasing the level of human capital used in research in the Romer (1990) model of endogenous growth.

Having established optimal decisions of entrepreneurs, their (expected) profits and how the growth rate depends on the types of entrepreneurs, let us now focus our attention on the individual's decision whether to become an entrepreneur or a worker in the first place.

Let $w_{j,k,t}$ be the wage at which an individual of type {j,k} is indifferent between being an entrepreneur or a worker at time t. Solving $E[\pi_{i,t}] = w_t$ for the wage we get:

$$w_{j,k,t} = \frac{1}{2} e^{r_t + \frac{\alpha_k}{2}} \left(\beta_{j,k,t}\right)^{\frac{1}{2}}. \tag{12}$$

Expressed in real terms, the wage at which type {j,k} is indifferent between occupations is:

$$z_{j,k,t} = \frac{w_{j,k,t}}{e^{r_t}} = \frac{1}{2} e^{\frac{\alpha_k}{2}} \left(\beta_{j,k,t}\right)^{\frac{1}{2}}. \tag{13}$$

When z_t is low, everyone prefers to be an entrepreneur. As z_t rises, type {w,l} are the first and type {e,h} are the last to choose to be workers. Whether type {w,h} or type {e,l} prefer to be workers first as z_t rises depends on g_{t-1}. As defined earlier, let g^* be the growth rate at which $z_{w,h,t} = z_{e,l,t}$. Using our definition for β given by (5) and solving the equation for the growth rate yields

$$g^* = \frac{1}{\alpha e^{\alpha}} - 1. \tag{14}$$

g^* is positive for $\alpha < 0.56$. Intuitively, if $g > g^*$, then high ability children of workers would make higher expected profits than low ability children of entrepreneurs if they chose to become entrepreneurs and vice versa for $g < g^*$.

Equilibrium conditions

There are two conditions that must hold for the economy to be in equilibrium. First, given the allocation of entrepreneurs and workers, the labour market must clear. Second, given the wage established in the labour market, utility maximising individuals choose their occupations optimally.

Combining optimal labour demand given in (7) with optimal innovation levels for the different types of entrepreneurs given by (10), we can say that aggregate labour demand as a function of the real wage $z_t = \frac{w_t}{e^{r_t}}$ is given by

$$l^d(z_t) = m_t^h \left(\frac{e^{r_t+\alpha}}{w_t}\right)^2 + m_t^l \left(\frac{e^{r_t+}}{w_t}\right)^2, \tag{15}$$

where the first part is aggregate labour demand by high ability entrepreneurs and the second aggregate labour demand by low ability entrepreneurs.

Aggregate labour supply is given by

$$l^s(z_t) = 1 - m_t^h - m_t^l, \tag{16}$$

which depends on the real wage, because the numbers of entrepreneurs m_t^h and m_t^l depend on the real wage.

After some basic simplification solving $l^d(z_t) = l^s(z_t)$ yields a market clearing equilibrium wage of:

$$z_t = \left(\frac{m_t^h e^{2\alpha} + m_t^l}{1 - m_t^h - m_t^l} \right)^{\frac{1}{2}}. \tag{17}$$

The number of entrepreneurs $m_t = m_t(z_t) = m_t^h + m_t^l$ is a step function such that $m_t = 1$ if $z_t < z_{w,l,t}$ and $m_t = 0$ if $z_t > z_{e,h,t}$. The discontinuities occur at the wage where one type {j,k} is indifferent between occupations.

Suppose that the economy is initially in a steady state such that $\overline{g} < g^*$. This is a world of low social mobility since only types {e,h} and {e,l} can be entrepreneurs. To be in a steady state equilibrium, we require the number of entrepreneurs to be constant, $m_{t-1} = m_t = \overline{m}$.[6] There is one segment of the $m_t(z_t)$ function where $m_{t-1} = m_t$, marked by a thicker line in figure 1. This is where all children of entrepreneurs become entrepreneurs in the next period. The intersection of $z_t(m_t)$ and $m_t(z_t)$ can by definition not be at another part of the stepwise function $m_t(z_t)$ as the number of entrepreneurs would be increasing if the intersection was to the left and decreasing if it was to the right of the thick area. This case is depicted in figure 1 below.

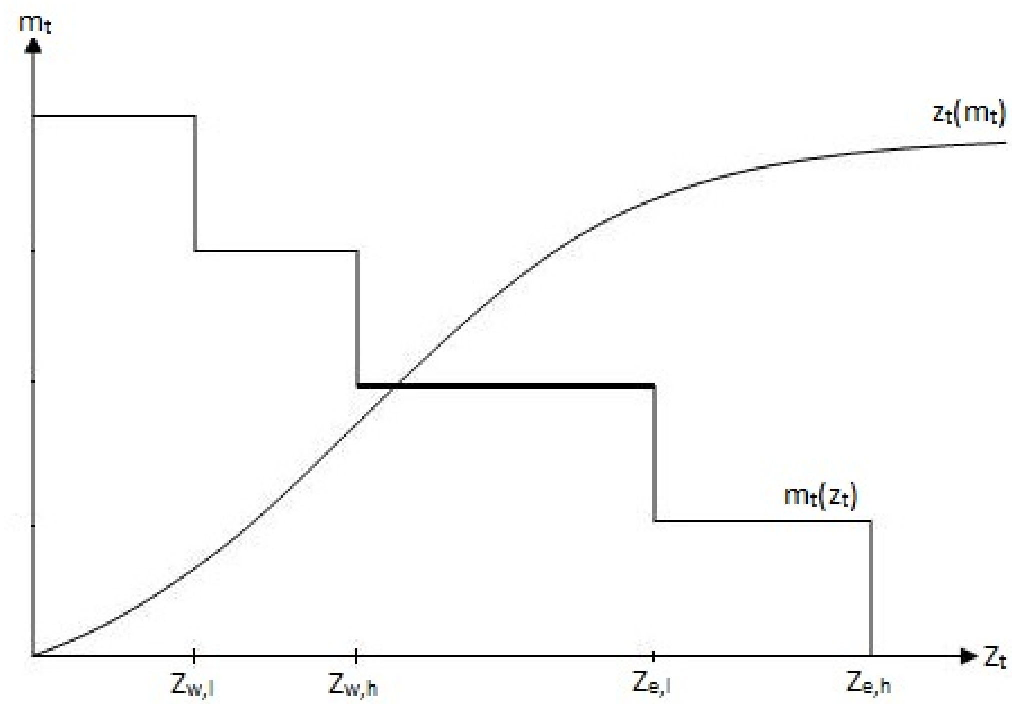

Figure 1: $\overline{g} < g^*$, low social mobility

If $\overline{g} > g^*$, there are three possible steady state allocations of individuals: types {e,h} and {w,h} are entrepreneurs; type {e,h} and a constant fraction of type {w,h}

[6]In general, in terms of notation, I use $\overline{x}$ as the steady state value for the variable x_t.

are entrepreneurs; types {e,h} and {w,h} and a constant fraction of type {e,l} are entrepreneurs. Which steady state prevails depends on the value of q. The segments of the $m_t(z_t)$ function where $m_{t-1} = m_t$ are marked by a thicker line in figure 2.

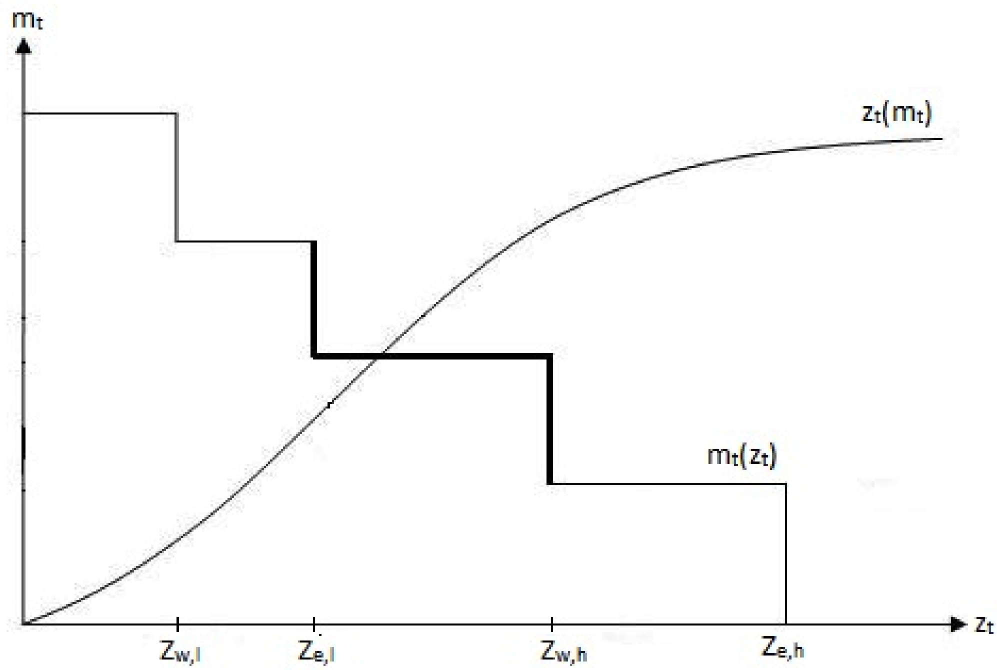

Figure 2: $\overline{g} > g^*$, high social mobility

2.1 Reprogenetic Technology

At some time s, the technology increasing the probability of a child being high ability from q to q' becomes available at cost c_s. Any parent may choose to invest, as long as their income exceeds the cost since we do not allow for borrowing in this economy. The results about who finds it optimal to make use of the technology, growth and social mobility will depend on whether we are in a low or high social mobility economy. Let us first consider the scenario in which the economy is initially in a low mobility steady state.

2.1.1 Low Social Mobility Economy

Consider an economy initially in a steady state such that $\overline{g} < g^*$, i.e. low social mobility, before the introduction of the reprogenetic technology at time s. As shown earlier, at time $s+1$ only types {e,h} and {e,l} will be entrepreneurs, so only entrepreneurs have an incentive to invest. Entrepreneurs at t will find it optimal to invest if the expected benefit of the investment outweighs the costs, which we can write as:

$$\delta(q' - q)E\{\pi_{e,h,t+1} - \pi_{e,l,t+1}\} > c_t. \tag{18}$$

The expected benefit from making use of the reprogenetic technology is that the entrepreneur's child is more likely to be of high ability and hence derive larger profits. Since the child's payoff enters the entrepreneur's utility function adjusted with δ we get the above equation.

We can rewrite this condition by substituting in the profits derived earlier as:

$$\delta(q' - q)\frac{e^{r_t}}{4}\left(\frac{1 - m_t}{m_t^h e^{2\alpha} + m_t - m_t^h}\right)^{\frac{1}{2}}\left[\alpha e^{\alpha} + \frac{1}{1 + g_{t-1}}\left(e^{\alpha} - 1\right)\right] > c_t. \tag{19}$$

This equation (19) can be thought of as the entrepreneurs incentive compatibility constraint for investing.

However, parents can only invest if their profits exceed the cost, $\pi_{e,k,t} > c_t$, which can be thought of as the participation constraint. This proportion of type {e,k} that invests is given by:

$$\lambda_{e,k,t} = \Pr\left(\pi_{e,k,t} > c_t\right). \tag{20}$$

Substituting profits derived earlier, we can write this as

$$\lambda_{e,k,t} = max\left\{\left[1 - \frac{c_t}{e^{2r_t}}w_t\right]^{\frac{\theta_{k,e,t}}{\beta_{k,e,t}}}, 0\right\}. \tag{21}$$

Finally, using the equilibrium wage defined by (17), the proportion of type {e,k} that invests investors can be written as:

$$\lambda_{e,k,t} = max\left\{\left[1 - \frac{c_t}{e^{r_t}}\left(\frac{m_t^h e^{2\alpha} + m_t - m_t^h}{1 - m_t}\right)^{\frac{1}{2}}\right]^{\frac{\theta_{k,e,t}}{\beta_{k,e,t}}}, 0\right\}. \tag{22}$$

Assume that the cost c_t is constant over time in nominal terms, i.e. $c_t = c$. Investment by parents increases the number of high ability entrepreneurs in the next period, which increases demand for labour and pushes up wages. Since in a world of low social mobility only children of entrepreneurs can become entrepreneurs in the next period, i.e. m_t is fixed, then the real wage, $\frac{w_t}{e^{r_t}}$, has an upper bound of $\left(\frac{[q'e^{2\alpha}+(1-q')m_t]}{1-m_t}\right)^{\frac{1}{2}}$. Economic growth means that $\frac{c_t}{e^{r_t}}$ is falling over time and $\lambda_{e,k,t}$ approaches 1. Similarly since $\frac{e^{r_t}}{w_t}$ has a lower bound of $\left(\frac{1-m_t}{[q'e^{2\alpha}+(1-q')m_t]}\right)^{\frac{1}{2}}$ and $g_{t-1} \leq \alpha$, the left hand side of equation (19) increases as r_t increases. Even if the technology is very costly when first introduced, eventually equation (18) will be satisfied as r_t rises and the "real" cost of the technology falls.

Intuitively, assuming that the nominal cost for the reprogenetic technology remains constant over time implies that the real costs of it decreases over time since productivity is increasing. When entrepreneurs make the decision about whether to invest into their child's genetic component of ability what matters is how profits compare to c. Hence, over time the fraction of investors will increase until it finally reaches one. This assumption is not entirely realistic, however the cost of high-tech goods or services such as computers, air travel or IVF treatment does tend to fall in real terms over time. Even if the cost was increasing over time in nominal terms, as long as it is falling in real terms (even if it is very slowly) the economy will converge to the steady states described in this paper.

Using our results about who invests in a world of low social mobility we can say that the growth rate, defined in (11), is given by

$$g_t = \frac{q + \lambda_{e,l,t-1}\left(q' - q\right)}{1 - \left(q' - q\right)\left(\lambda_{e,h,t-1} - \lambda_{e,l,t-1}\right)}\alpha \tag{23}$$

We can also say that g_t approaches $q'\alpha$ as $\lambda_{e,h,t-1}$ and $\lambda_{e,l,t-1}$ approach 1.

Interestingly, if $q'\alpha > g^* = \frac{1}{\alpha e^{\alpha}} - 1$, then as more entrepreneurs invest, the economy will eventually reach the point where the growth rate of technology is high enough that entrepreneurs of type {w,h} have higher expected profits than entrepreneurs of type {e,l} and the economy switches to the high social mobility state. So, for α low enough the introduction of the reprogenetic technology can sufficiently increase growth over time and turn a low social mobility economy into a high social mobility economy for given institutional factors. This result is surprising as a common criticism of such a technology is that it would widen gaps between "haves" and "have nots" and make it increasingly difficult for "have nots" to improve their social and economic status and this result shows that actually exactly the opposite could happen.

Multiplying equation (17) by e^{r_t} we get an expression for the wage at time t:

$$w_t = e^{r_t}\left(\frac{m_t^h e^{2\alpha} + m_t^l}{1 - m_t^h - m_t^l}\right)^{\frac{1}{2}}. \tag{24}$$

Consider an increase in the proportion of entrepreneurs who are high ability such that the total number of entrepreneurs remains constant i.e. $dm_t^h = dm_t^l$.

$$\frac{dw_t}{dm_t^h} = \frac{1}{2} z_t^{-\frac{1}{2}}\left(e^{2\alpha} - 1\right) > 0 \tag{25}$$

Thus an increase in the proportion of high ability entrepreneurs, who demand more labour, raises the level of the wage. Additionally, since $r_t = r_{t-1} + g_{t-1}$, the resulting increase in the growth rate increases the growth rate of wages. This resembles the models from the literature on 'trickle down' such as Aghion and Bolton (1997).

2.1.2 High Social Mobility Economy

There are three possible steady state allocations of entrepreneurs and workers in the high social mobility economy: types $\{e,h\}$ and $\{w,h\}$ are entrepreneurs; type $\{e,h\}$ and a proportion $\psi_{w,h}$ of type $\{w,h\}$ are entrepreneurs; types $\{e,h\}$, $\{w,h\}$ and a proportion $\psi_{e,l}$ of type $\{e,l\}$ are entrepreneurs.

Adjusting our incentive compatibility constraint (18) to this setting, we can say that entrepreneurs will want to invest at time t if:

$$\delta(q'-q)\left\{E\left[\pi_{e,h,t+1}\right]-\psi_{e,l,t+1}E\left[\pi_{e,l,t+1}\right]-(1-\psi_{e,l,t+1})w_{t+1}\right\}>c_t. \tag{26}$$

Since in a steady state where $0<\psi_{e,l}<1$, type $\{e,l\}$ are indifferent between being entrepreneurs or workers, i.e. the expected profit of an entrepreneur of type $\{e,l\}$ equals the wage, the above equation simplifies to:

$$\delta(q'-q)\left\{E\left[\pi_{e,h,t+1}\right]-w_{t+1}\right\}>c_t. \tag{27}$$

In the world of high social mobility workers might also find it optimal to invest into their child's genetic ability, since children of workers can become entrepreneurs and being of high ability is beneficial to entrepreneurs. Workers will choose to invest if the increase in the child's expected income due to an increase in the probability of becoming an entrepreneur and hence derive the profits of a high ability entrepreneur rather than a worker is sufficiently large. Hence, workers want to invest if:

$$\delta(q'-q)\psi_{w,h,t+1}\left\{E\left[\pi_{w,h,t+1}\right]-w_{t+1})\right\}>c_t. \tag{28}$$

Since the left hand side of equation (25) is greater than the left hand side of equation (26) and hence the constraint is stricter for workers, one of the following occurs:

- All entrepreneurs and workers invest
- Entrepreneurs and a proportion of workers invest
- All entrepreneurs but no workers invest
- Only a proportion of entrepreneurs invest
- Nobody invests

Since the "real" cost of investment is falling over time, eventually any parent wanting to invest will be able to do so and the economy will converge to one of the following steady states, provided $\overline{g}>g^*$, which we are going to analyse case by case.

1. Steady state when types $\{e,h\}$ and $\{w,h\}$ are entrepreneurs

This case of a high social mobility economy in which all high ability individuals, whether they are children of workers or entrepreneurs, become entrepreneurs and no low ability individuals become entrepreneurs is summarised in figure 3 below.

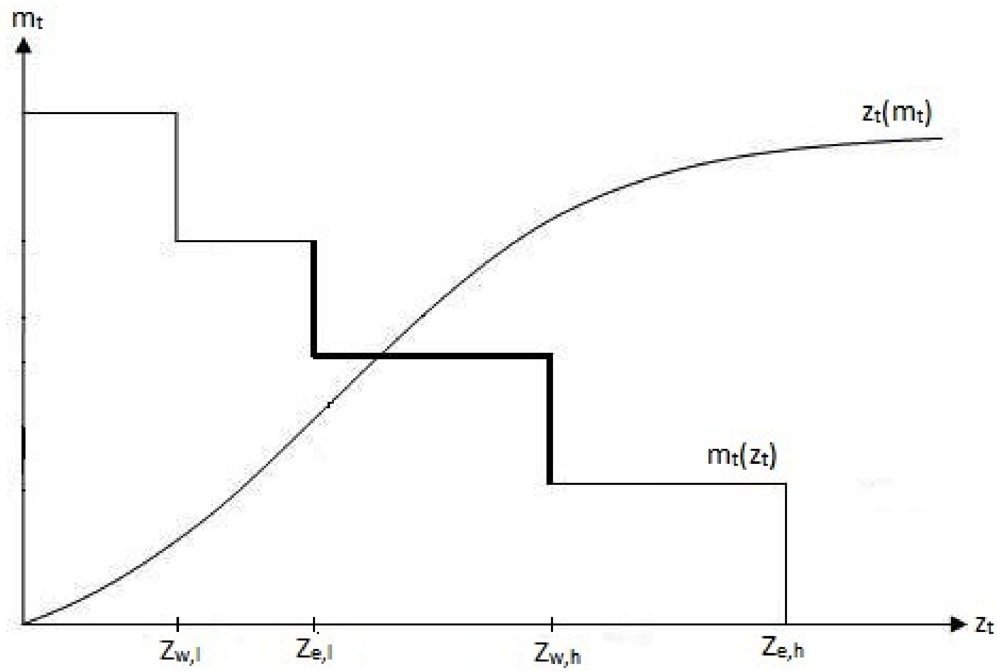

Figure 3: $\overline{g} > g^{*}$, high ability individuals are entrepreneurs

Let ϕ_e be the fraction of entrepreneurs who invest and ϕ_w be the fraction of workers who invest, where we know that $0 \leq \phi_w \leq \phi_e \leq 1$.

Using this, we can write the number of entrepreneurs in steady state as:

$$\overline{m} = \frac{q + \phi_w \left(q' - q\right)}{1 - \left(\phi_e - \phi_w\right)\left(q' - q\right)}. \tag{29}$$

Using the steady state value for m and m^h we can see that the growth rate in this steady state is given by

$$\overline{g} = g_t\Big|_{m_t^h = \overline{m}^h, m_t = \overline{m}} = \alpha. \tag{30}$$

The existence of this steady state requires that $\alpha > g^{*} = \frac{1}{\alpha e^{\alpha}} - 1$ as our condition for the high social mobility economy.

The wage in this steady state is:

$$\overline{w} = e^{r_t + \alpha}\left(\frac{q + \phi_w \left(q' - q\right)}{1 - q - \phi_e \left(q' - q\right)}\right)^{\frac{1}{2}}. \tag{31}$$

The wage is increasing in q, q', ϕ_e and ϕ_w, since higher values of any of these variables increase the equilibrium number of entrepreneurs, pushing up demand for labour. Higher values of α increase the growth rate, labour productivity and therefore wages.

Expected profits of entrepreneurs of type $\{e,h\}$ and $\{w,h\}$ are:

$$E\left[\overline{\pi}_{e,h}\right]=\frac{1}{4}\left(\alpha+\frac{1}{1+\alpha}\right)e^{r_t}\left(\frac{1-q-\phi_e\left(q'-q\right)}{q+\phi_w\left(q'-q\right)}\right)^{\frac{1}{2}}, \tag{32}$$

$$E\left[\overline{\pi}_{w,h}\right]=\frac{\alpha}{4}e^{r_t}\left(\frac{1-q-\phi_e\left(q'-q\right)}{q+\phi_w\left(q'-q\right)}\right)^{\frac{1}{2}}. \tag{33}$$

Expected profits for both types are decreasing in q, q', ϕ_e and ϕ_w, due to the positive effect on wages of an increase in any of these variables. Since both types are high ability, expected profits for both are increasing in α which represents the return to ability.

This steady state furthermore requires that $E\left[\overline{\pi}_{w,h}\right]>\overline{w}$, so that high ability children of workers actually want to become entrepreneurs, i.e.

$$\frac{\alpha}{4}>e^{\alpha}\left(\frac{q+\phi_w\left(q'-q\right)}{1-q-\phi_e\left(q'-q\right)}\right) \tag{34}$$

and $E\left[\overline{\pi}_{e,l}\right]<\overline{w}$, so that low ability children of entrepreneurs will not want to become entrepreneurs, i.e.

$$\frac{1}{4(1+\alpha)}<e^{2\alpha}\left(\frac{q+\phi_w\left(q'-q\right)}{1-q-\phi_e\left(q'-q\right)}\right). \tag{35}$$

2. Type $\{e,h\}$ and a proportion $\psi_{w,h}$ of type $\{w,h\}$ are entrepreneurs

This case of a high social mobility economy in which all high ability children of workers and some high ability children of workers become entrepreneurs, is summarised in figure 4 below.

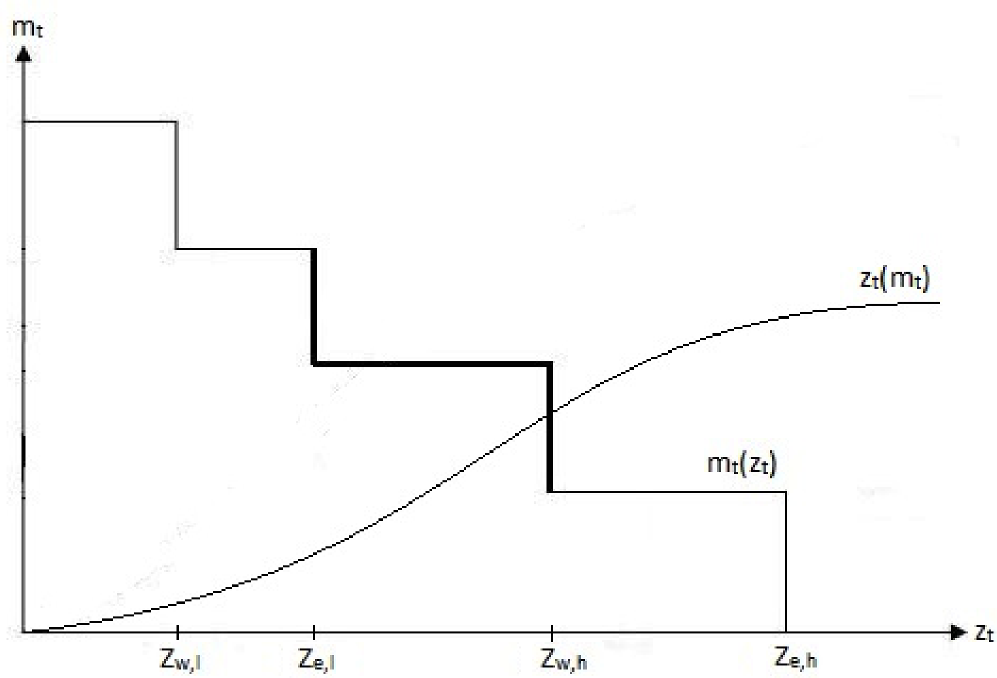

Figure 4: $\overline{g}>g^{*}$, $\{e,h\}$ and some $\{w,h\}$ are entrepreneurs

Since type $\{w,h\}$ are indifferent between being entrepreneurs and workers in this steady state, the left hand side of equation (26) equals zero, so no workers will invest.

The number of entrepreneurs in steady state is:

$$\overline{m} = \frac{\psi_{w,h} q}{1 - (1 - \psi_{w,h}) q - \phi_e (q' - q)} \tag{36}$$

Since all entrepreneurs are of high ability (but not vice versa like in the first case) the steady state growth rate is the same as in the previous case and given by:

$$\overline{g} = \alpha. \tag{37}$$

Again, for the economy to be in the state of high social mobility, the existence of this steady state requires that $\alpha > g^* = \frac{1}{\alpha e^{\alpha}} - 1$.

The wage in this steady state is:

$$\overline{w} = e^{r_t + \alpha} \left(\frac{\psi_{w,h} q}{1 - q - \phi_e (q' - q)} \right)^{\frac{1}{2}}. \tag{38}$$

Since $\psi_{w,h}$ is endogenous, changes in q, q', ϕ_e, ϕ_w and α, do not affect the wage, only the value of $\psi_{w,h}$. This can be seen as a shift in the $m_t(z_t)$ line. Only if the changes are so large that the economy moves to an equilibrium as described in case 1, will the wage change.

Expected profits of entrepreneurs of type $\{e,h\}$ and $\{w,h\}$ are:

$$E[\overline{\pi}_{e,h}] = \frac{1}{4} \left(\alpha + \frac{1}{1+\alpha} \right) e^{r_t} \left(\frac{1 - q - \phi_e (q' - q)}{\psi_{w,h} q} \right)^{\frac{1}{2}}, \tag{39}$$

$$E[\overline{\pi}_{w,h}] = \frac{\alpha}{4} e^{r_t} \left(\frac{1 - q - \phi_e (q' - q)}{\psi_{w,h} q} \right)^{\frac{1}{2}}. \tag{40}$$

Again, changes in q, q', ϕ_e and ϕ_w are absorbed by changes in $\psi_{w,h}$. Wages and therefore expected profits are unaffected, unless the changes are large enough that the economy switches to an equilibrium where all individuals of type $\{e,h\}$ and $\{e,h\}$ are entrepreneurs. Changes in α do not affect wages in this case but do affect labour productivity. Intuitively an increase in α increases labour productivity in firms owned by high ability entrepreneurs, and therefore increases expected profits of both type $\{e,h\}$ and $\{w,h\}$.

The existence of this steady state allocation requires that $E[\overline{\pi}_{w,h}] = \overline{w}$, so that high ability children of workers are indifferent between becoming an entrepreneur or a worker, i.e.

$$\frac{\alpha}{4} > e^{\alpha} \left(\frac{\psi_{w,h} q}{1 - q - \phi_e (q' - q)} \right) \tag{41}$$

3. Types $\{e,h\}$, $\{w,h\}$ and a proportion $\psi_{e,l}$ of type $\{e,l\}$ are entrepreneurs

The case of a high social mobility economy in which all high ability children and some low ability children of entrepreneurs become entrepreneurs, is summarised in figure 5 below.

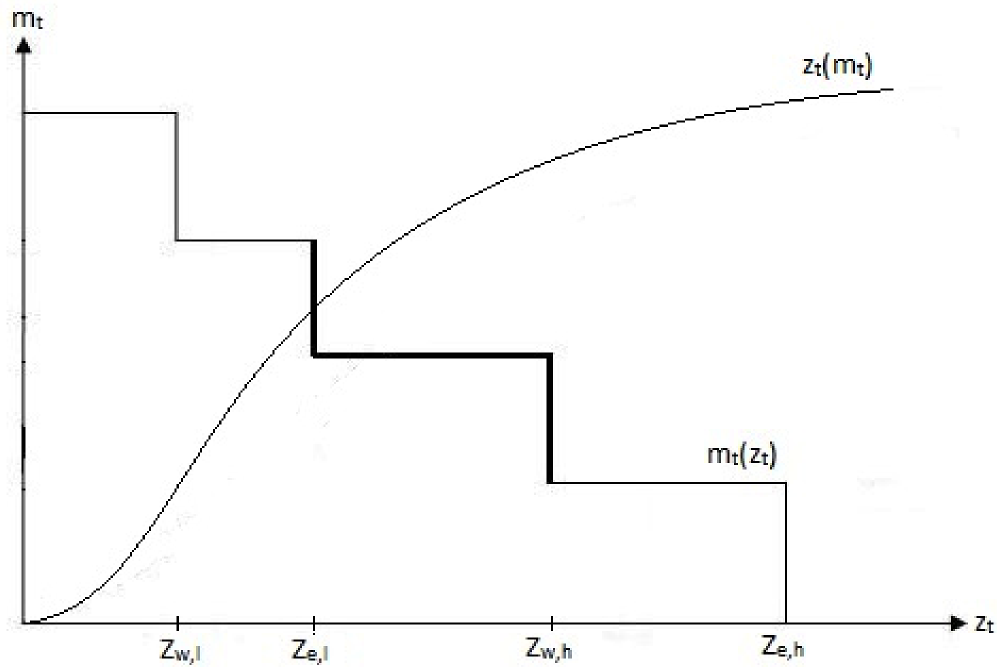

Figure 5: $\overline{g} > g^{*}$, $\{e,h\}$, $\{w,h\}$ and a proportion and some $\{e,l\}$ are entrepreneurs

The number of entrepreneurs in steady state is:

$$\overline{m} = \frac{q + \phi_w \left(q' - q\right)}{1 - \left(\phi_e - \phi_w\right)\left(q' - q\right) - \psi_{e,l}\left[1 - q - \phi_e \left(q' - q\right)\right]} \tag{42}$$

The fraction of entrepreneurs who are high ability in steady state is:

$$\frac{\overline{m}^h}{\overline{m}} = 1 - \psi_{e,l}\left[1 - q - \phi_e \left(q' - q\right)\right] \tag{43}$$

Hence the steady state growth rate $\overline{g} = \alpha \frac{\overline{m}^h}{\overline{m}}$ is given by:

$$\overline{g} = \alpha \left[1 - \psi_{e,l}\left[1 - q - \phi_e \left(q' - q\right)\right]\right]. \tag{44}$$

The growth rate is increasing in q, q', ϕ_e since the number of high ability entrepreneurs, who innovate more, is increasing in these variables. An increase in the proportion of type $\{e,l\}$ who are entrepreneurs in equilibrium, $\psi_{e,l}$, decreases the proportion of entrepreneurs who are high ability, lowering the average level of innovation and decreasing the growth rate.

The wage in this steady state is:

$$\overline{w} = e^{r_t + \alpha} \left(\frac{[q + \phi_w(q' - q)][e^{2\alpha} - \psi_{e,l}[1 - q - \phi_e(q' - q)](e^{2\alpha} - 1)]}{(1 - \psi_{e,l})(1 - q - \phi_e(q' - q))} \right)^{\frac{1}{2}}. \tag{45}$$

Similarly to case 2, changes in q, q', ϕ_e and $\alpha$are absorbed by changes in $\psi_{e,l}$, unless the changes are so large that the economy shifts to an equilibrium as in case 1.

Expected profits of entrepreneurs of type $\{e,h\}$, $\{w,h\}$ and $\{e,l\}$ are:

$$\begin{aligned} E\left[\overline{\pi}_{e,h}\right] =& \frac{1}{4}\left(\alpha+\frac{1}{1+\alpha\left[1-\psi_{e,l}\left[1-q-\phi_e\left(q'-q\right)\right]\right]}\right)e^{r_t+\alpha} \\ &\times\left(\frac{\left(1-\psi_{e,l}\right)\left(1-q-\phi_e\left(q'-q\right)\right)}{\left[q+\phi_w\left(q'-q\right)\right]\left[e^{2\alpha}-\psi_{e,l}\left[1-q-\phi_e\left(q'-q\right)\right]\right]\left(e^{2\alpha}-1\right)}\right)^{\frac{1}{2}} \end{aligned} \tag{46}$$

$$E\left[\overline{\pi}_{w,h}\right] = \frac{\alpha}{4}e^{r_t+\alpha}\left(\frac{\left(1-\psi_{e,l}\right)\left(1-q-\phi_e\left(q'-q\right)\right)}{\left[q+\phi_w\left(q'-q\right)\right]\left[e^{2\alpha}-\psi_{e,l}\left[1-q-\phi_e\left(q'-q\right)\right]\right]\left(e^{2\alpha}-1\right)}\right)^{\frac{1}{2}} \tag{47}$$

$$\begin{aligned} E\left[\overline{\pi}_{e,l}\right] =& \frac{1}{4}\left(\frac{1}{1+\alpha\left[1-\psi_{e,l}\left[1-q-\phi_e\left(q'-q\right)\right]\right]}\right)e^{r_t} \\ &\times\left(\frac{\left(1-\psi_{e,l}\right)\left(1-q-\phi_e\left(q'-q\right)\right)}{\left[q+\phi_w\left(q'-q\right)\right]\left[e^{2\alpha}-\psi_{e,l}\left[1-q-\phi_e\left(q'-q\right)\right]\right]\left(e^{2\alpha}-1\right)}\right)^{\frac{1}{2}} \end{aligned} \tag{48}$$

Since wages are unaffected by small changes in q, q', ϕ_e, profits are also unaffected. As in case 2, an increase in α increases labour productivity in firms owned by high ability entrepreneurs, and therefore increases expected profits of types $\{e,h\}$, $\{w,h\}$ but not of type $\{e,l\}$.

The existence of this steady state allocation requires that $E\left[\overline{\pi}_{e,l}\right] = \overline{w}$, so that low ability children of entrepreneurs are indifferent between becoming an entrepreneur and a worker, i.e.

$$\frac{1}{4(1+\alpha)} > e^{2\alpha}\left(\frac{\left[q+\phi_w\left(q'-q\right)\right]\left[e^{2\alpha}-\psi_{e,l}\left[1-q-\phi_e\left(q'-q\right)\right]\left(e^{2\alpha}-1\right)\right]}{\left(1-\psi_{e,l}\right)\left(1-q-\phi_e\left(q'-q\right)\right)}\right) \tag{49}$$

Which steady state allocation the economy converges to depends on the real wage function. Higher values of α, q, q' ϕ_e and ϕ_w all raise the wage for a given number of entrepreneurs, reducing the number of entrepreneurs in steady state.

3 Conclusion

Starting from a low social mobility steady state, investment in technology which increases the probability of a parent producing a high ability child increases the number of high ability entrepreneurs in the economy. This increases wages since high ability entrepreneurs hire more labour and increases the growth rate since high ability entrepreneurs innovate more. This increase in the growth rate reduces the advantage inherited from parents who are entrepreneurs relative to the advantage of being high ability. If the growth rate is sufficiently high, the economy will switch into a high social mobility allocation. In the high mobility economy, investment by parents increases the wage rate and reduces profits of entrepreneurs. Once the economy has switched from a low mobility to a high mobility steady state it will stay there, even if nobody invests.

We have therefore seen that contrary to popular belief a technology enabling parental investment into the genetic component of their child's ability can enhance not only economic growth but also social mobility even if parents cannot borrow. Positive effects with regards to a potential increase are self-enforcing in the sense that social mobility is increasing in growth and growth is increasing in parental investment into innate ability. Overall, because it increases growth, this technology reduces the relative importance of social background compared to innate ability and hence can enhance social mobility.

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A literature review on the effects of migration on wages

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Abstract

This paper summarises and critiques the literature on the effects of migration on wages.

1 Introduction

This first section of this paper addresses the potential problems with estimating the effect of immigration on wages and offers possible ways around these problems. Section two compares the literature surrounding the effect on immigration on wages focusing on papers which use a methodology other than cross-city comparisons. The final section discusses high-skilled migration driven endogenous technological change, a branch of the literature which is relatively new and not much studied.

Card (2009) includes a fairly comprehensive review of the literature on the effect of immigration on the distribution of wages in the US, focusing on papers using cross city comparisons. This paper is supportive of the conclusions drawn by Card (2009) and extends the literature review to include more recent papers that employ a different methodology including one which focuses on the UK labour market. Additionally, I will relate the literature on immigration to the literature on productivity externalities and endogenous technical change.

2 Potential problems when estimating the effect of immigration on wages

2.1 Problems with cross city or cross state comparisons

Much of the literature on the effect of immigration on wages tends to focus on cross city or cross state comparisons. There are a number of problems with such analysis. Firstly, immigrants may not be randomly distributed across labour markets. Rather, they may endogenously be located in in cities or states with thriving economies. In this case, such studies are likely to find a spurious positive correlation between immigration and wages. Secondly, natives may take their labour out of a local labour market in response to immigration flows, offsetting any wage effects. For example, Borjas, Freeman and Katz (1997) find that the native flow of labour to California has been greatly reduced by the influx of immigrants since 1970. As a result, immigration affects every city or state, not only the ones receiving immigrants.

A potential solution to the endogenous allocation of immigrants is to use instrumental variables estimation. A standard instrument in the literature which has been used in various studies following Altonji and Card (1991) is the settlement pattern of previous immigrants. A number of studies including Bartel (1989) and Munshi (2003) show that settlement patterns of previous immigrants are a key determinant of immigrants location decisions. Estimation in differences can be used to eliminate location specific fixed effects that are correlated with both immigrant settlement patterns and economic conditions.

The problem of reallocation of natives can be reduced by using large regional definitions making it more likely that any movements will be internalised. Card (2001) offers a methodology for testing how sensitive mobility flows of natives and earlier migrants are to inflows of new immigrants. This methodology involves estimating the following equation

$$y_{ic} = Z_{jc}\beta + \gamma R_{jc} + d_j + \theta_c + e_{jc} \tag{1}$$

where y_{ic} is a component of population growth for skill group j in city c e.g. the outmigration rate of natives. Z_{jc} is a set of group level characteristics, d_j is a skill group dummy, θ_c is a city dummy, R_{jc} is the inflow rate of immigrants in occupation group j to city c, and e_{jc} is an error term.

It is possible that unobserved city and skill group specific shocks may attract recent immigrants as well as reduce the outflow of natives and earlier immigrants. To get around this, Card uses settlement pattern of previous immigrants as an instrument for current migration flows. He defines the supply-push component of recent immigration flows as

$$SP_{jc} = \sum_g \tau_{gj} \lambda_{gc} M_g \tag{2}$$

where M_g is the total number of immigrants from source country g who arrived in the US between 1985 and 1990. λ_{gc} is the fraction of immigrants from an earlier cohort from country g who live in city c. τ_{gj} is the fraction of immigrants from country g who arrived between 1985 and 1990 and who are in skill group j. This measure is independent of any occupation specific shocks in city c as long as M_g, λ_{gc}, and τ_{gj} are all independent of any occupation specific shocks in city c.

Card (2001) estimates the effect of immigration flows on the inflows and outflows of natives and earlier immigrants by skill group for the 175 largest US cities during the period 1985-90 and finds that the estimates for γ are mostly small and statistically insignificant. It is important to note that Card is measuring the average effect of immigration flows on native migration flows across cities. These results should not be generalised to other time periods and may not hold when looking at more specific groups of cities such as cities in California. This methodology may be useful to check if region size is large enough that movements of natives in response to inflows of immigrants are internalised.

2.2 Skill downgrading

When estimating a model that relates changes in relative wages to migration flows of particular skill or experience groups, one potential problem is that immigrants tend to "downgrade" upon arrival in a foreign labour market. According to Dustmann, Frattini, and Preston (2013), immigrants tend to be found lower down in the wage distribution than one would predict based on their measured skill and experience levels. Possible explanations for this include discrimination by employers or differing productivities in the same jobs due to language difficulties or cultural differences.

Using UK labour force survey data from 2004-2005, Dustmann et al. find that recent immigrants i.e. those who arrived within two years of the interview are disproportionately represented in the lower occupational categories despite being on average much better educated than natives. 47 percent of recent immigrants are in the lowest three occupational categories compared to 27 percent of natives. However they are also slightly better represented than natives in the highest occupational category, higher managerial and professional occupations (16 percent versus 15 percent).

Looking at this data it becomes apparent that after arrival immigrants "upgrade", that is they move higher up the wage distribution perhaps as their language skill improve or they accumulate human or social capital complimentary to their existing skills. Dustmann et al. find that earlier immigrants i.e. those who arrived more than two years prior to the interview, are underrepresented compared to natives in all but the top two occupational categories. They are equally well represented in the second category (lower managerial and professional occupations) at around 31 percent, and overrepresented in the highest category (22 percent versus 15 percent). These findings are mirrored by Eckstein and Weiss (2004), who look at data on the wages of natives and immigrants in Israel and find evidence of considerable skill downgrading on arrival, following which wages of immigrants approach, but do not converge to, the wages of natives.

This skill downgrading and subsequent upgrading has important consequences for the estimation of the elasticity of substitution between immigrants and natives. If recent immigrants who downgrade upon arrival are classified into skill groups according to their education and experience levels, this misclassification would suggest that there are more immigrants working in higher occupation categories than is actually the case. The estimated wage for immigrants in higher occupation categories would be lower than the true wage since many of these immigrants are actually working in lower occupational categories. This leads to a downward bias in estimates of the elasticity of substitution of immigrants and natives. This estimation error is worse when using data with smaller time intervals. For example, when measuring the changes in the number of immigrants and in relative wages of immigrants over a 10 year period, the misclassification error will be much smaller than when measuring changes in the same variables over a two year period since upgrading after arrival means that fewer immigrants are misclassified in the 10 year model.

To get around the problem of skill downgrading by immigrants, one strategy would be to use data aggregated such that the time periods are defined as decades rather than years. This does not completely get rid of the downward bias in estimates of the substitutability of immigrants and natives but it would minimise it. Another approach, as in Dustmann et al. (2013), is to allocate immigrants to skill groups according to their observed position in the income distribution rather than their levels of education or experience, more details of which will follow in the next section.

3 A summary of the literature on the effect of immigration on wages

In light of the problems with cross-city comparisons discussed above, this section will focus on other methodologies for investigating the effect of immigration on wages. There is a distinct lack of consensus in the literature surrounding the effects of immigration on wages. Borjas (2003) uses US population data from 1960 to 2001 and finds that immigration lowers the wages of competing workers; a 10 percent increase in the supply of labour reduces wages by 3 to 4 percent, depending on education and experience level. Ottaviano and Peri (2012) and Manacorda, Manning and Wadsworth (2012) examine the impact of immigration on the wages of native workers for the US and UK respectively and find that it is very small.

Borjas (2003) sorts workers according to education level and labour market experience. Workers are classified into four distinct education groups: high school dropout, high school graduates, workers with some college education, and college graduates. The data is aggregated into five-year experience intervals to group workers with similar levels of experience together. Aggregate production is modelled using a 3-level CES production technology which allows technology to be summarised in terms of three elasticities of substitution: between capital and labour, between workers of different education levels and between workers in different labour market experience groups. The aggregate production function is given by

$$Q_t = [\lambda_{Kt} K_t^{\upsilon} + \lambda_{Lt} L_t^{\upsilon}]^{\frac{1}{\upsilon}} \tag{3}$$

where Q is output, K is capital, L is aggregate labour input. $\upsilon = 1 - \frac{1}{\sigma_{KL}}$ where σ_{KL} is the elasticity of substitution between capital and labour. $-\infty < \upsilon \leq 1$, $\lambda_{Kt} + \lambda_{Lt} = 1$. The aggregate labour input is composed of workers who differ in education and experience.

$$L_t = \left[\sum_i \theta_{it} L_{it}^{\rho} \right]^{\frac{1}{\rho}} \tag{4}$$

where L_{it} is the number of workers with education i at time t and $\rho = 1 - \frac{1}{\sigma_E}$ where σ_E is the elasticity of substitution across different education aggregates. $-\infty < \rho \leq 1$, $\sum_i \theta_{it} = 1$.

$$L_{it} = \left[\sum_j \alpha_i j L_{ijt}^{\eta} \right]^{\frac{1}{\eta}} \tag{5}$$

where L_{ijt} is the number of workers with experience level j in education class i. $\eta = 1 - \frac{1}{\sigma_x} +$ where σ_x is the elasticity of substitution across experience classes within an education group. $\sum_j \alpha_{ij} = 1$.

Borjas takes the elasticity of substitution between capital and labour to be 1 and estimates the elasticities of substitution between workers with different education levels and between workers with different experience levels. These estimates are then used to simulate the effects of immigration to the US between 1980 and 2000 on wages of workers by skill and education group. Note that capital is assumed to be inelastically supplied. The elasticity of substitution between workers in different education groups does not depend on which education groups are being compared i.e. it is the same between high school dropout and high school graduates as between high school dropouts and college graduates. Similarly the elasticity of substitution between workers with different levels of experience is the same whether these workers differ by 5 years of experience or 25.

Ottaviano and Peri (2012) perform a similar exercise but allow for the possibility of imperfect substitution between immigrants and natives within the same education and experience group. The degree of imperfect substitutability has important implications since it affects the impact immigration has on wages of natives with similar education and experience. Smaller substitutability means that the arrival of immigrants of a particular skill and experience group affects the wages of earlier immigrants more than the wages of natives. The authors find a small but significant degree of imperfect substitutability between immigrant and native workers within the same education and experience group. Their estimated substitution elasticity is around 20. Even this small degree of imperfect substitutability makes a significant difference when simulating the effect of immigration on native wages. When they allow the elasticity to vary across education groups, their estimate is significantly lower among less educated workers (around 11.1).

These estimates, combined with other estimated elasticities, imply that immigration to the US between 1990 and 2006 had a small positive effect on average native wages (+0.6%) and a larger negative effect (-6.7%) on wages of previous immigrants with the effect. This is not necessarily inconsistent with Card (2001) who finds that immigration during the 1980s reduced the wages of low-skilled natives in traditional gateway cities such as Miami and Los Angeles by 1-3 percent. It is possible that immigrants to the cities studied by Card during the 1980s may be disproportionately low-skilled compared to immigrants to the country as a whole between 1990 and 2006. In this case, low-skilled immigration flows to these cities may depress the wages of natives even if natives and immigrants are not perfect substitutes.

Unlike Borjas (2003), Ottaviano and Peri (2012) focus on the effect on wages in the long run after capital has fully adjusted to the labour supply shock due to the inflow of foreign-born workers. They assume that in the long run the economy follows a balanced growth path along which the real interest rate and aggregate capital-output ratio are both constant while the capital-labour ratio grows at a constant rate. This is consistent with data since the real return to capital and the capital-output ratio in the US do not show any long run trend, and the capital-labour ratio grows at a constant rate. This implies that the average wage does not depend on labour supply and therefore immigration in the long run. However immigration can still have distributional effects if different types of labour are imperfect substitutes and the composition of the immigrant population differs from that of the native population in terms of education and/or labour market experience.

As in Borjas (2003), Ottaviano and Peri (2012) use a three-level CES production technology. Imposing such a structure is restrictive since it relies on assumptions about the nesting structure and imposes assumptions about the separability of inputs. The authors reduce this problem by testing the empirical fit of four alternative specifications of the production technology. Model A an augmented version of that in Borjas (2003) allowing for imperfect substitutability between US and foreign born workers with equal education and experience. Model B sorts workers into two broad education classes rather than four: workers with at least some college education and workers with high school education or less. Model C allows for the elasticity of substitution across broad experience groups to differ from the elasticity of substitution across narrow experience groups. Model D is as in model A, but the nesting order of education and experience is reversed.

Using data from the Current Population Survey, the sample is large enough to estimate separately the elasticity of substitution between broad education groups and between narrow education groups. These are found to be quite different from each other with the former estimated to be around 2 and the latter above 10. Since workers within broad education groups are estimated to be close substitutes the data suggest that model B should be preferred. Choice of model B over any model with four distinct education groups significantly alters estimation of the effect of immigration on the wages of workers in the lowest education groups. This is because, according to Card (2009), US immigrants are disproportionately represented in the high school dropout education group (31 percent versus 11 percent for natives).

Card (2009) uses data from the 2005/6 American Community Survey to calculate the proportions of the immigrant and native populations that are high school equivalents in the two education group model. It is assumed that each dropout supplies 0.7 units of high school labour and half of workers with some college education supply 1.2 units of high school labour. The other half supplies 0.8 units of college equivalent labour. This results in similar proportions of the immigrant and native populations that are high school equivalents (63 percent versus 59 percent). In the four education group model, immigration significantly increases the proportion of high school dropouts in the labour force, lowering their wage relative to other education groups. In the two education group model, immigration does not have a significant effect on the proportion of high school equivalents so their relative wage does not change significantly. A number of papers attempt to estimate the inverse elasticity of substitution between different education groups in a four skill group model. The results are not consistent between papers, for example Raphael and Ronconi (2008) estimate the elasticity to be close to 0 while Borjas (2003) reports two estimates, 0.74 and 0.76 with standard errors of 0.65 and 0.58 respectively. Card (2009) conjectures that the inconsistency and imprecision of these estimates is because the four skill group model is misspecified. This supports the finding by Ottaviano and Peri (2012) that the two skill group model is a better fit for the data than the four skill group model.

Manning, Manacorda and Wadsworth (2012) use UK wage and employment data from the mid-1970s to the mid-2000s to study the impact of immigration on wages. Their approach is very similar to Ottaviano and Peri (2012) in that they use a three-level CES production function using as inputs two types of labour: skilled and unskilled. They allow for imperfect substitution between immigrants and natives and between labour from different age or education groups. The baseline estimate for the elasticity of substitution between immigrants and natives in a given age-education group is 7.81, which is lower than that found by Ottaviano and Peri. When they estimate this elasticity for recent (less than 5 years) and long-term immigrants separately, they estimate a higher degree of substitutability for immigrants who arrived earlier (10.1 versus 4.6).

Additionally, the authors find that the degree of substitutability is increasing in the age of immigrants (7.5 for those aged 26-35, 12.7 for those aged 36-50, and 90.9 for those aged 51 to 60). A possible reason for the higher estimate for the degree of substitution in the US is that Ottaviano and Peri use between-census i.e long-run changes in wages to form their estimates. Given that migrants become more substitutable with natives the longer they have been in the country, as confirmed by Manacorda, Manning and Wadsworth's estimates, this could explain, at least in part, the difference between the UK and US estimates. Alternatively, as explained earlier, skill downgrading by recent immigrants biases estimates of the elasticity of substitution between immigrants and natives downwards. The differences in the two estimates could be due to a larger degree of downgrading in the UK compared to the US (Dustmann, Frattini and Preston, 2011) or it could be due to the use of decennial census data for the US but data grouped into 5 year intervals for the UK. As explained earlier, shorter time periods between observations are likely to bias the estimation downwards more strongly.

Based on their estimates of the various elasticities of substitution, Manacorda et al simulate the effect of migration to the UK between 1975 and 2005 on wages of different groups. They find that the only sizeable effect of immigration to the UK over the last 30 years was on the wages of university educated immigrants. Given fixed demand for labour, these estimates imply a fall in the wages of university educated immigrants on the order of 0.8 percentage points per year over the 30 year period. They conclude that due to imperfect substitution of natives and immigrants, the main impact of increased immigration in the UK is on the wages of immigrants who are already there.

In light of Ottaviano and Peri's higher estimate of the substitutability between immigrants and natives, which is consistent with the estimate by Card (2009), Manacorda et al. recomputed their estimates of the effect of immigration on wages using a value of the elasticity of substitution of 21 instead of 7. Using this new value, they still find that the effect of increased immigration was largely concentrated among immigrants.

Wages of university educated immigrants were reduced by 0.36 percentage points per year while wages of university educated natives were reduced by less than a quarter of this. As before, there was no effect on workers with only a secondary school education whether they are natives or immigrants.

Dustmann, Frattini and Preston (2013) analyse the effect of immigration on native workers. Rather than measure the effects on wages of different types of labour like the papers discussed above, they focus on the effect of immigration on the wages of native workers along the native wage distribution. Their approach avoids pre-allocating immigrants to skill categories thus avoiding the misclassification problem caused by skill downgrading of immigrants as discussed above. Their analysis is based on a simple model where output, y, is produced using multiple labour types according to the following nested CES production function where labour supplied by the ith type is l_i and capital used is K:

$$y = [\beta H^s + (1-\beta)K^s]^{\frac{1}{s}} \tag{6}$$

$$H = \left[\sum_i \alpha_i l_i^{\sigma}\right]^{\frac{1}{\sigma}} \tag{7}$$

α_i represents the productivity of the ith type of labour and $\sigma \leq 1$ is the elasticity of substitution between labour types. β determines the relative productivity of labour and capital and $s \leq 1$ determines the elasticity of substitution between capital and labour.

Native and immigrant labour of the same type are perfect substitutes and equally productive. Note that since labour types are not defined according to age or education levels, this does not mean that natives and labour in a given education-age group are perfect substitutes. Dustmann et al. show that if capital is supplied perfectly elastically and capital and labour are perfect substitutes, then the effects of immigration on the native wage distribution depend on the relative density of immigrants and natives along that distribution. The wage of a skill type at a point in the distribution where the relative density of immigrants is above an appropriately weighted average of the relative density across the whole distribution will be decreased by immigration. Similarly skill types located at a point in the distribution where immigration density is below an appropriately weighted average will experience a wage increase. As long as capital is at least fairly mobile and immigrant labour is sufficiently different to native labour, it is possible that mean native wages will rise as a consequence of immigration. However those workers who are competing with immigrants will experience a wage fall.

The equation estimated is:

$$\Delta lnW_{prt} = \beta_t + \Delta c_{prt} + \gamma_p \Delta m_{rt} + \Delta \epsilon_{prt} \tag{8}$$

where W_{prt} denotes the pth percentile of the native wage distribution in region r at time t. β_t is a vector of time dummies, and Δc_{prt} measures changes in the average age of immigrant and native workers in the region as well as the ratio of high to low educated workers. Δm_{rt} measures the change in the ratio of immigrants to natives in region r and the parameter γ_p is a combination of the elasticity of substitution between different skill groups and the relative density of immigrants at that part of the native wage distribution. ϵ_{prt} is an error term. The authors divide Great Britain in to 17 regions and after testing using methodology as in Card (2001), claim that the resulting size of regions is large enough that endogenous migration of natives is likely to be contained within these regions. The above equation is estimated using OLS and twice using instrumental variables. The first IV estimation instruments the change in the ratio of immigrants to natives using the 1991 ratio from the Census of Population, the second instruments this ratio using four period lags from the Labour Force Survey.

Both IV estimates and the OLS estimate suggest that immigration has had a negative effect on wages at or below the 10th percentile and a positive effect on wages further up the distribution. Estimates using as an instruments the 4 period lag of the immigrant to native ratio indicate that an inflow of immigrants equal to 1 percent of the native population would lead to a 0.67 percent decrease in native wages at the 5th percentile, a 0.66 percent increase in the median native wage, a 0.41 percent increase in native wages at the 90th percentile and a 0.47 percent increase in mean native wages. Estimates using the immigrant concentration from the 1991 Census are similar but smaller in magnitude: -0.34 percent, 0.44 percent, 0.34 percent and 0.26 percent. The authors claim that these results, although modest, are too large to be explained by an immigration surplus.

The idea that immigrants and natives are not perfect substitutes within skill groups, as proposed by Ottaviano and Peri and Manacorda et al., could explain the positive effect of immigration on mean native wages. Imperfect substitutability between immigrants and natives implies that an increase in the immigrant labour force increases native marginal productivity and therefore wages. Other potential explanations depend on immigrants being paid less than the value that they contribute to production, generating a surplus that gets paid to native labour if capital is supplied elastically. Borjas (2001) suggests that cost of internal migration, both geographic and sectoral, prevent native labour from reallocating fully in response to economic signals. In this case immigration may realise efficiency gains.

4 Productivity externalities

The papers discussed in the previous section do not take into account the possibility that high-skilled migration is an engine for endogenous technological change. Grossmann and Stadelmann (2013) argue that international migration of high-skilled workers leads to productivity effects that raise the wage rate of high-skilled workers in host countries and lower the wage rate of high-skilled workers in source countries. Grossmann and Stadelmann use data on international bilateral migration flows to examine the effect of an increase in high-skilled migration rates on GDP per capita, total factor productivity (TFP) and wages of high-skilled workers between pairs of source and destination countries. They theorise that for a given TFP, diminishing marginal productivity means that high-skilled migration lowers the wages of skilled workers in the destination country and raises the wages of high-skilled workers in the source country. However, the effect on TFP (positive in the destination country, negative in the source country) has the opposite effect. The overall effect on the wages of high skilled workers is therefore ambiguous in theory.

Their model considers two economies, home and foreign. There is a homogenous consumption good and output Y is produced competitively according to the production function

$$Y = AF(H, L) \equiv ALf(k) \tag{9}$$

F is a constant returns to scale function, H and L denote high and low-skilled labour input, A is total factor productivity, $k \equiv \frac{H}{L}$ denotes the skill intensity of production and f is an increasing, concave function. Higher concentrations of skilled labour, $h = \frac{H}{L+H}$, exert a positive externality on TFP

$$A = a(h) \tag{10}$$

where is an increasing function. This human capital externality could be due to learning spillover effects across workers, increased innovation activity or better institutional quality associated with a high average skill level of the population.

Labour is paid its marginal product so that wages are as follows

$$w_H = a(h)f'k \tag{11}$$

$$w_L = a(h)\left[f(k) - kf'\right] \tag{12}$$

Let w_H and w_L be the wages earned workers in the home country and w_H^* and w_L^* be the wages earned by workers in the foreign country. The cost of migration is modelled by a factor which discounts consumption. Utility u_i is given by

$$u_i = \begin{cases} c_i & \text{if } i \text{ stays at home,} \\ \frac{c_i}{\theta_i} & \text{if } i \text{ emigrates.} \end{cases} \tag{13}$$

$\theta_i = \theta_H > 1$ if i is skilled and $\theta_i = \theta_L > 1$ if i is unskilled.

An individual of skill type $j \in= H, L$ chooses to migrate if $\frac{w_j^*}{\theta_j} \geq w_j$. Thus in equilibrium

$$\frac{w_j^*}{\theta_j} = w_j \tag{14}$$

The numbers of skilled and unskilled workers are endogenous. Education comes at time cost e_i such that an unskilled individual supplies 1 unit of time to the labour market and a skilled individual supplies $(1 - e_i)$ units. Thus utility of individual i born in the home country is given by

$$u_i = \begin{cases} (1 - e_i)w_H & \text{if } i \text{ is skilled and stays at home,} \\ w_L & \text{if } i \text{ is unskilled and stays at home,} \\ (1 - e_i)\frac{w_H^*}{\theta_H} & \text{if } i \text{ is skilled and emigrates,} \\ w_L \frac{w_L^*}{\theta_L} & \text{if } i \text{ is unskilled and emigrates.} \end{cases} \tag{15}$$

A non-migrating individual i chooses to become skilled if $(1 - e_i)w_H > w_L$. All individuals with e_i below an endogenous threshold level, $\overline{e}$, become skilled.

$$\overline{e}(k) = 1 - \frac{w_L}{w_H} = 1 - \frac{f(k) - kf'(k)}{f'(k)} \tag{16}$$

Since $f'' < 0$, $\overline{e}$ is decreasing in the skill intensity, k. A higher skill intensity means that the wage rate of unskilled workers is higher relative to that of skilled workers, which reduces the number of individuals who choose to become skilled.

The authors show that if the effect of a change in the skill intensity due to migration on the education decision is small, then an increase in the migration rate of skilled labour results in a positive effect on TFP of the destination country relative to the source country. Migration of unskilled labour only affects TFP indirectly via its effect on education incentives (lowering incentives in the source country and and raising incentives in the destination country). An increase in the migration rate of unskilled labour has a positive but small effect on on relative TPF. The effect of an increase in unskilled migration on the wage of skilled workers in the destination country relative to the source country is unambiguously positive. An increase in the migration rate of skilled workers may raise the wages of skilled workers in the destination country relative to the source country, if the effect on TFP is large enough.

For each country pair (i, j) the authors estimate the following equation where y_i is the outcome variable of interest in country i. This can be GDP per capita, TFP, or a measure of the wage of high skilled workers. Since data on wage incom eby education category is not widely available, the authors use the 80th and 90th percentile as a proxy measure for the wages of high-skilled workers.

$$log\left(\frac{y_j}{y_i}\right) = \beta_0 + \beta_1 SMig_{ij} + \beta_2 UMig_{ij} + x'_{ij}\beta_x + u_{ij} \tag{17}$$

$SMig_{ij}$ is high-skilled emigration rate from country i to county j defined as the stock of skilled emigrants from country i living in country j divided by the stock of residents in country i. $UMig_{ij}$ is the low-skilled emigration rate defined analogously. x'_{ij} is a vector of controls potentially affecting income differences between countries i and j such as relative school enrolment rates, relative urban population shares, relative investment rates and source country fixed effects. u_{ij} is an error term. If the external effect of high skilled migration on TPF is large enough to dominate the effect of decreasing marginal productivity, then we would expect $\beta_1 > 0$.

The relationship of interest is the effect of high skilled migration on relative GDP, relative TFP and relative high skilled wages, yet such migration is endogenous and likely depends on relative wages there is a potential reverse causality problem that needs to be addressed. The authors focus on the year 2000 with respect to the dependent variable measures and measure controls other than skilled migration in the year 1990 to reduce endogeneity bias. In OLS regressions the high-skilled emigration rate in 2000 is replaced by the rate in 1990. Instrumental variable regressions use the total emigration rate from country i to country j in 1990 as an instrument for the high skilled emigration rate from country i to country j in 2000. Additionally the total emigration rate in 1960 is used as an alternative instrument for $SMig_{ij}$.

Their results indicate that increased high skilled migration has a small but positive and statistically significant effect on GDP per capita, TFP and wages of high skilled workers in destination countries relative to source countries. The estimates for the effect of increased low skilled migration on relative GDP per capita and TFP are not statistically significant but estimates for the effect of on relative wages at the 80th and 90th percentile are positive, as predicted by the theoretical model, and statistically significant. If there are indeed positive effects on TFP, as suggested by this paper, Manacorda et al. (2012) may be too pessimistic about the long-run effect of immigration on wages since according to Dustmann et al. (2013), immigrants to the UK are on average much better educated than natives.

The idea that increasing numbers of high-skilled workers spurs technological progress is similar to the theory of directed technical change proposed by Acemoglu (1998, 2002, 2003, 2007). Technological change does not necessarily affect all sectors or all factors of the economy in the same way and may be biased towards some sectors or factors. Acemoglu (2007) shows that if technologies are factor augmenting, an increase in the supply of a factor induces technological change relatively biased towards that factor i.e.

an increase in the number of high-skilled workers in an economy incentivises development of technology that is complimentary to high-skilled labour. If the technological bias is sufficiently strong, an increase in the number of high-skilled relative to low-skilled workers in an economy raises the relative wage of high-skilled workers. This is in contrast to Grossmann and Stadelmann who construct a model where an increase in the relative supply of high-skilled workers results in a fall in their wages relative to the wages of low-skilled workers but do not test this empirically. Their work is focused on the effects of immigration on the destination country relative to the source country. An interesting extension to their work would be to look at effects of relative wages of high and low-skilled workers within a country.

5 Conclusion

Much of the literature on the effect of immigration on wages focuses on cross-city comparisons which in most cases do not account for the endogenous allocation of immigrants or movement of natives. Card (2001) addresses the issue of endogenous movement of natives and offers a methodology for testing the extent to which natives relocate due to immigration inflows.

Borjas (2003), Ottaviano and Peri (2012), and Manacorda et al. (2012) use a different approach: they first estimate various elasticities of substitution and use these to simulate the effect of observed migration flows on wages. Ottaviano and Peri and Manacorda et al. conclude that immigration to the US and the UK respectively has had little effect on the wages of natives and a substantial negative effect on the wages of previous immigrants. Borjas, in contrast, finds that immigration lowers the wages of competing workers. These differences come from the fact that Ottaviano and Peri and Manacorda et al. allow for imperfect substitution between immigrants and natives, as supported by Card (2009), and also assume that capital is perfectly elastically supplied rather than fixed, an assumption that seems reasonable in the long run. Generally the assumptions made by Ottaviano and Peri and Manacorda et al. seem more reasonable and thus their results more reliable.

In summary, it seems that for the US and the UK, recent immigration flows have had little effect on the wages of natives. A branch of the literature on which there is still little empirical work is on endogenous technological change driven by immigration flows.

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Is the demand curve for high-skilled labour upward sloping?

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Abstract

This paper analyses the evidence for an upward sloping demand curve for high-skilled labour. By calibrating a simple multi-sector model of the economy using high and low-skilled labour as inputs, I find for reasonable values of the parameters this model supports a demand curve for high skilled labour that is downward sloping in the short-run but upward sloping in the long-run.

1 Introduction

This paper addresses the conflicting evidence for an upward sloping demand curve for high-skilled labour. Textbook models predict that as a factor of production becomes more abundant, its price falls. However, since the late 1970s, the number of workers with a college degree has been rising rapidly, yet the college premium has also been rising over the same period.

Models of directed technical change developed in Acemoglu (1998, 2002, 2003a, 2003b, 2007) propose a possible mechanism to explain this phenomenon. Many models of endogenous technological change focus on a single type of technology which increases aggregate productivity. In practice, technological change is often not neutral: it affects some factors of production more than others. Acemoglu (2007) shows that if technologies are factor augmenting, an increase in the supply of a factor induces technological change relatively biased towards that factor. Under certain conditions, this induced bias is strong enough that the marginal product or price of a factor increases in its supply. To my knowledge, no empirical investigation of whether or not this theorem holds in the data exists. Caselli (1999) presents a similar model in which skill-biased technological revolutions induce capital reallocation from the low to high-skill sectors, increasing the relative wage of workers in the high-skill sector. The paper relates changes in industry capital intensity to the skill composition of the labour force.

A related branch of the literature concerns the effects on wages of high skilled immigration. The evidence for a positive effect of high-skilled immigration on the skill premium is mixed. Grossmann and Stadelmann (2012) argue that international migration of high-skilled workers triggers productivity effects such that the wage rate of skilled workers may rise in host countries and fall in source countries. On the other hand, Borjas (2003) finds that immigration lowers the wage of competing skill groups with the own factor price elasticity for high skilled workers to be between -0.317 and -0.348 depending on the workers' level of experience.

In this paper I will present a model based on Epifani and Gancia (2008) who develop a model in which increased trade between similar countries can increase the skill premium. Their result is conditional on stronger returns to scale in the skill-intensive sector compared to the unskill-intensive sector, so increasing the scale of production results in skill-biased wage effects. While this paper does not consider explicitly the effects of trade on the skill premium, an increase in the number of a particular type of worker in the economy leads to an increase in the scale of operations in the corresponding sector and affects relative wages via the same channel. Thoenig and Verdier (2003) and Neary (2002) propose models whereby trade between similar countries leads to skill-biased technological change. The mechanism underlying both models is that increased competition spurs "defensive innovation" whereby firms implement skill-intensive technologies in order to deter entry.

I develop a simple multi-sector model of the economy using high and low-skilled labour as inputs in a static and a dynamic setting. The economy is modelled using a Dixit-Stiglitz (1977) approach, where there are two final good sectors; a low-skilled and a high-skilled labour sector. Final goods are produced by using varieties of intermediate goods, which are supplied under monopolistic competition. This paper then analyses the effect of a change in the number of high-skilled workers on relative prices and wages. The static model is an equilibrium model, where the number of intermediate varieties is defined by zero profit conditions. The dynamic approach allows for a gradual convergence back towards the steady state in response to a change in the number of high-skilled workers. Then I calibrate this model using European Labour Force Survey data and data on the skill premium for a sample of 18 countries. The results from the calibration of both the static and the dynamic model support the hypothesis that increasing the number of skilled workers in an economy can increase the relative wage of high skilled workers. Calibration of the dynamic model produces results that are consistent with a demand curve for skilled labour that is downward sloping in the short-run but upward sloping in the long-run as in Acemoglu (2007).

I am first going to present the static model in the following section 2, before presenting a dynamic model in section 3, which accounts for gradual adjustments to the steady state. I then attempt to calibrate the model to the data using different measures for fit of the data in section 4, before providing a brief conclusion in section 5.

2 A Static Model

This model is based on Epifani and Gancia (2008) who show that the increasing the size of an economy can increase the skill premium. They emphasise trade induced scale effects. This paper focuses on the effects of changes in the size as well as the composition of the labour force, e.g. due to immigration. Consider an economy in which two final goods are produced. The utility of a representative consumer is given by:

$$U = \left[(Y_l)^{\frac{\epsilon-1}{\epsilon}} + (Y_h)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \tag{1}$$

where Y_i represents consumption of final good i and $\epsilon > 1$ is the elasticity of substitution between the two final goods.

2.1 Consumers

Taking the standard approach in this Dixit-Stiglitz (1977) setting by maximising utility with respect to the consumer's budget constraint, we get the following relative demand after simplifying the first order conditions of a standard Lagrangian:

$$\left(\frac{P_h}{P_l} \right)^{-\epsilon} = \frac{Y_h}{Y_l} \tag{2}$$

where P_i is the price of final good i.

2.2 Firms

Good i is produced by perfectly competitive firms by assembling n_i own-industry differentiated intermediate goods:

$$Y_i = \left[\int_0^{n_i} y_i(v)^{\frac{\sigma_i - 1}{\sigma_i}} dv \right]^{\frac{\sigma_i}{\sigma_i - 1}} \tag{3}$$

where $y_i(v)$ is the amount of intermediate variety type v used in production of final good i, Y_i is the amount of final good i and $\sigma_i > 1$ is the elasticity of substitution between any two types of intermediate good in production of final good i. Intermediate varieties v are supplied monopolistically and one can think of each variety v as a firm.

The price of final good i implied by (3) is:

$$P_i = \left[\int_0^{n_i} p_i(v)^{1-\sigma_i} dv \right]^{\frac{1}{1-\sigma_i}} \tag{4}$$

Assume that sector h uses only skilled labour and sector l uses only unskilled labour. The total number of skilled and unskilled workers in the economy are H and L respectively. The production of each intermediate in sector i involves a fixed requirement, F_i, and a constant marginal requirement, c_i, of labour. The total cost function of a single variety produced in sector i is:

$$TC_i = (F_i + c_i y_i)\, w_i \tag{5}$$

where w_h and w_l are the wage rates of skilled and unskilled labour respectively. F_i and c_i are the same for every firm in sector i and therefore all firms in sector i hire the same amount of labour.

Profit maximisation under monopolistic competition implies that price is given by a constant mark-up over marginal cost:

$$p_i(v) = p_i = \frac{\sigma_i}{\sigma_i - 1} c_i w_i \tag{6}$$

The ratio of prices of intermediate goods h and l can be expressed as an increasing function of the skill premium, ω:

$$\frac{p_h}{p_l} = \frac{\sigma_h}{\sigma_h - 1} \frac{\sigma_l - 1}{\sigma_l} \frac{c_h}{c_l} \omega \tag{7}$$

where $\omega = \frac{w_h}{w_l}$

Free entry means that profits must be zero in equilibrium:

$$\pi_i(v) = \pi_i = \left(\frac{1}{\sigma_i - 1} c_i y_i - F_i \right) w_i = 0 \tag{8}$$

which implies that:

$$y_i = (\sigma_i - 1) \frac{F_i}{c_i} \tag{9}$$

Using equations (6) and (9) we can simplify (3) and (4):

$$Y_i = n_i^{\frac{\sigma_i}{\sigma_i - 1}} (\sigma_i - 1) \frac{F_i}{c_i} \tag{10}$$

$$P_i = n_i^{\frac{1}{1-\sigma_i}} p_i = n_i^{\frac{1}{1-\sigma_i}} \frac{\sigma_i}{\sigma_i - 1} c_i w_i \tag{11}$$

The effect of an increase in varieties in sector i is equivalent to a model with technical change biased in favour of labour working in sector i as in Acemoglu (2007). This equivalency becomes obvious when considering equation (5). One could think of $n_i^{\frac{\sigma_i}{\sigma_i - 1}} \frac{1}{c_i}$ as productivity in such models.

2.3 Equilibrium

Total demand for high (low) skilled labour must equal the stock of high (low) skilled labour in the economy in equilibrium, yielding the following labour market clearing conditions:

$$\int_0^{n_h} (c_h y_h(v) + F_h)\, dv = H, \tag{12}$$

$$\int_0^{n_l} (c_l y_l(v) + F_l)\, dv = L. \tag{13}$$

Since firms are symmetric and all firms in sector i produce the same output we get expressions for the number of firms in each sector:

$$n_h = \frac{H}{c_h y_h + F_h} \tag{14}$$

$$n_l = \frac{L}{c_l y_l + F_l} \tag{15}$$

If we assume constant returns to scale in both intermediate and final good production in sector l, i.e. $F_l = 0$ and $\sigma_l = \infty$, and normalise $c_l = 1$, then profits in intermediate sector l are always zero, independent of the number of intermediate goods and n_l can take any value.

Equations (11) and (15) can be simplified as follows:

$$P_l = p_l = w_l \tag{16}$$

$$n_l = \frac{L}{y_l} \tag{17}$$

which can be used to derive an expression for final good output in sector l.

$$Y_l = n_l y_l = L \tag{18}$$

Epifani and Gancia (2008) survey the literature and find that most studies find no significant departure from constant returns to scale in low-skill-intensive industries. There is more disagreement about the degree of returns to scale in skill intensive industries.

Since profits in both, final good production and intermediate good production, are zero, total expenditure in the economy equals the total wages paid to labour:

$$Y = P_l Y_l + P_h Y_h = w_l L + w_h H. \tag{19}$$

The zero profit condition implies that total wages in sector h equals total revenue of intermediate firms in sector h, which equals total expenditure on final good Y_h,

$$w_h H = n_h p_h y_h = P_h Y_h = \frac{P_l^{\epsilon-1}}{P_l^{\epsilon-1} + P_h^{\epsilon-1}} Y, \tag{20}$$

where the final step in this equation comes from substituting the relative demand given by (2) into (13).

Applying the same steps for sector l, we get

$$w_l L = n_l p_l y_l = P_l Y_l = \frac{P_h^{\epsilon-1}}{P_l^{\epsilon-1} + P_h^{\epsilon-1}} Y. \tag{21}$$

The aggregate price level in this economy is defined as:

$$P = \left[P_l^{1-\epsilon} + P_h^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} = \left[w_l^{1-\epsilon} + \left(\frac{H}{\sigma_h F_h}\right)^{\frac{\epsilon-1}{\sigma_h-1}} \left(\frac{\sigma_h}{\sigma_h - 1} c_h w_h\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{22}$$

Combining equations (14), (15), (17) and (19) we get:

$$\frac{w_h H}{w_l L} = \frac{P_h Y_h}{P_l Y_l} = \left(\frac{P_h}{P_l}\right)^{1-\epsilon} = \left(\left(\frac{H}{\sigma_h F_h}\right)^{\frac{1}{\sigma_h-1}} \frac{\sigma_h - 1}{\sigma_h} \frac{w_l}{c_h w_h}\right)^{\epsilon-1}. \tag{23}$$

Defining $\omega = \frac{w_h}{w_l}$ as the relative wage, this can be simplified to

$$\omega = L^{\frac{1}{\epsilon}} H^{\frac{\epsilon-\sigma_h}{\epsilon(\sigma_h-1)}} A_h, \tag{24}$$

where

$$A_h = \left(\left(\frac{1}{\sigma_h F_h}\right)^{\frac{1}{\sigma_h-1}} \frac{\sigma_h - 1}{\sigma_h} \frac{1}{c_h}\right)^{\frac{\epsilon-1}{\epsilon}} \tag{25}$$

is a constant. As can be seen in equation (22), the wage ratio is increasing in H if $\epsilon > \sigma_h > 1$.

For the skill premium to be increasing in the number of high skilled workers in the economy it is required that $\epsilon > \sigma_h > 1$, i.e. the elasticity of substitution between the skill-intensive final good and the less skill-intensive final good is greater than the elasticity of substitution between different intermediate goods in production of final good H, which is greater than 1. Epifani and Gancia (2008) start with the assumption that $\sigma_l > \sigma_h > \epsilon$, however $\sigma_h > \epsilon$ is not necessary for their result that an increase in market size increases the skill premium. The model presented in this paper supports their result since $\sigma_l > \sigma_h$, which is the necessary condition. Epifani and Gancia (2008) do not attempt to calibrate σ_h but assume that it is smaller than σ_l presumably because this generates the result that increasing the proportion of workers who are skilled decreases the skill premium which is what standard economic theory would predict.

Production of final good H is increasing and the price of final good H is decreasing in the number of intermediate varieties used if σ_h is greater than 1. The degree of returns to scale in production of final good H is $\frac{\sigma_h}{\sigma_h - 1}$. The increase in the number of intermediate varieties in sector H following an increase in the number of high-skilled workers reduces the price of final good H. This increases demand for intermediate goods in sector H and increases the wages of high skilled workers. The effect on the price of final good H is greater if σ_h is close to (but bigger than) 1. If epsilon is greater than σ_h, the positive effect on wages of high killed workers due to the increase in demand for intermediate goods in sector h is greater than the negative effect due to the increased supply of high skilled workers.

2.4 Prices and Wages

Normalising the aggregate price level in (20), $P = 1$, we get an expression for the real wage:

$$P = \left[w_l^{1-\epsilon} + \left(\frac{H}{\sigma_h F_h} \right)^{\frac{\epsilon-1}{\sigma_h-1}} \left(\frac{\sigma_h}{\sigma_h - 1} c_h w_h \right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} = 1, \tag{26}$$

which, using $\omega = \frac{w_h}{w_l}$ as the relative wage, we can write as

$$w_l \left[1 + \left(\frac{H}{\sigma_h F_h} \right)^{\frac{\epsilon-1}{\sigma_h-1}} \left(\frac{\sigma_h}{\sigma_h - 1} c_h \omega \right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} = 1. \tag{27}$$

Solving for the real wage in the low skilled sector yields:

$$w_l = \left[1 + \left(\frac{H}{\sigma_h F_h} \right)^{\frac{\epsilon-1}{\sigma_h-1}} \left(\frac{\sigma_h}{\sigma_h - 1} c_h \omega \right)^{1-\epsilon} \right]^{\frac{1}{\epsilon-1}}. \tag{28}$$

Substituting in the relative wage, determined by (22), and simplifying, we can say that the real wage in the low skill sector is given by:

$$w_l = \left[1 + \left(\frac{L}{H} \right)^{\frac{1-\epsilon}{\epsilon}} \left(\frac{H}{\sigma_h F_h} \right)^{\frac{\epsilon-1}{\epsilon(\sigma_h-1)}} \left(\frac{\sigma_h - 1}{\sigma_h} \frac{1}{c_h} \right)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{1}{\epsilon-1}} \tag{29}$$

The real wage of a worker in sector h is

$$w_h = \omega w_l, \tag{30}$$

and hence given by:

$$w_h = \left[\left(\frac{L}{H}\right)^{\frac{\epsilon-1}{\epsilon}} \left(\left(\frac{H}{\sigma_h F_h} \right)^{\frac{1}{\sigma_h-1}} \frac{\sigma_h-1}{\sigma_h} \frac{1}{c_h} \right)^{\frac{(\epsilon-1)^2}{\epsilon}} + \left(\left(\frac{H}{\sigma_h F_h} \right)^{\frac{1}{\sigma_h-1}} \frac{\sigma_h-1}{\sigma_h} \frac{1}{c_h} \right)^{\epsilon-1} \right]^{\frac{1}{\epsilon-1}}. \tag{31}$$

The real wage of workers in sector h is increasing in the number of high skilled workers, H, and therefore in high skilled labour supply in the economy, if $\epsilon > \sigma_h > 1$.

The effect of the number of high skilled workers on the relative price can be summarised in:

$$\frac{P_h}{P_l} = \left(\frac{H}{\sigma_h F_h}\right)^{\frac{1}{1-\sigma_h}} \frac{\sigma_h}{\sigma_h - 1} c_h \omega \tag{32}$$

$$\frac{\partial \frac{P_h}{P_l}}{\partial H} = -\frac{\sigma_h}{\epsilon(\sigma_h - 1)} \frac{1}{H} \frac{P_h}{P_l} < 0. \tag{33}$$

The relative price is therefore unambiguously decreasing in H.

3 A Dynamic Model

In the static model presented so far, we assumed that we are always in equilibrium. Intuitively in a dynamic setting the model would imply that adjustments to the steady state are instant. Whenever profits are non-zero, the number of varieties adjusts instantly. In the following dynamic model, we will allow for the adjustment to be gradual.

In the long run, zero profits in the intermediate sector mean $n_h = \frac{H}{\sigma_h F_h}$ and wages are as described in the previous section. It is reasonable to assume that the number of varieties, which can be thought of as a proxy for the level of technology, changes slowly. This is consistent with the models of Acemoglu (1998, 2002, 2003, 2007). Following an increase in H, new varieties appear but adjustment to the new steady state is not instantaneous. Let the steady state value of n_h at time t be $n^*_{h,t} = \frac{H_t}{\sigma_h F_h}$.

Suppose there are $n_{h,t}$ varieties active in the market at time t. Define $\Delta n_{h,t} \equiv n_{h,t} - n_{h,t-1}$. There is a congestion externality whereby entry by new varieties reduces the output of all varieties by $\frac{1}{c_h} C\left(\Delta n_{h,t}\right)$. This congestion externality can be thought of as (non-labour) resources being used in the creation of new varieties e.g. in research and development, reducing the resources available for existing varieties to use in production. We assume the congestion externality to take the following form:

$$C\left(\Delta n_{h,t}\right) = \begin{cases} \gamma \frac{\Delta n_{h,t}}{n_{h,t}} & \text{if } \Delta n_{h,t} \geq 0 \\ 0 & \text{if } \Delta n_{h,t} < 0. \end{cases} \tag{34}$$

Using the production technology for intermediate goods introduced in (4) and noticing that intermediary firms within a sector are identical and hence have identical labour input, we can write profits of a variety in intermediate sector H at time t as:

$$\pi_{h,t} = p_{h,t} \left[\frac{1}{c_h}\left(\frac{H_t}{n_{h,t}} - F_h\right) - \frac{1}{c_h} C\left(\Delta n_{h,t}\right)\right] - w_{h,t} \frac{H_t}{n_{h,t}} \tag{35}$$

Using our definition of $n^*_{h,t}$ and equation (8), defining the intermediary good price, we can write profits at time t as:

$$\pi_{h,t} = \frac{\sigma_h}{\sigma_h - 1} w_{h,t} \left[F_h \left(\frac{n^*_{h,t}}{n_{h,t}} - 1\right) - C\left(\Delta n_{h,t}\right)\right]. \tag{36}$$

Each period new varieties will enter until there are no more profits from entry, i.e. until

$$F_h\left(\frac{n^*_{h,t}}{n_{h,t}}-1\right)-\gamma\frac{\Delta n_{h,t}}{n_{h,t}}=0 \tag{37}$$

is satisfied. We can therefore write the change in the number of varieties as:

$$\Leftrightarrow \Delta n_{h,t}=\begin{cases}\frac{F_h}{\gamma+F_h}\left(n^*_{h,t}-n_{h,t-1}\right) & \text{if } n^*_{h,t}\geq n_{h,t-1}\\ n^*_{h,t}-n_{h,t-1} & \text{if } n^*_{h,t}<n_{h,t-1}.\end{cases} \tag{38}$$

3.1 Wages

In a given period t firms enter until profits net of congestion externality are zero. Profits in intermediate sector H (and in final sector H) net of the congestion externality are hence always zero and total revenue equals total wages in sector H. Using this we can write

$$\frac{w_{h,t}H_t}{w_{l,t}L_t}=\left(\frac{P_h}{P_l}\right)^{1-\epsilon}=\left(n_{h,t}^{\frac{1}{\sigma_h-1}}\frac{\sigma_h-1}{\sigma_h}\frac{1}{c_h}\frac{w_{l,t}}{w_{h,t}}\right)^{\epsilon-1}, \tag{39}$$

which leaves us with an expression for the relative wage in period t:

$$\omega_t=\frac{w_{h,t}}{w_{l,t}}=\left(\frac{L_t}{H_t}\right)^{\frac{1}{\epsilon}}\left(n_{h,t}^{\frac{1}{\sigma_h-1}}\frac{\sigma_h-1}{\sigma_h}\frac{1}{c_h}\right)^{\frac{\epsilon-1}{\epsilon}}. \tag{40}$$

Taking simple derivatives, we can show how the relative wage depends on the number of high skilled, low skilled workers and the number of varieties in the economy:

$$\frac{\partial\omega_t}{\partial H_t}=-\frac{1}{\epsilon}\frac{\omega_t}{H_t}<0, \tag{41}$$

$$\frac{\partial\omega_t}{\partial L_t}=\frac{1}{\epsilon}\frac{\omega_t}{L_t}>0, \tag{42}$$

$$\frac{\partial\omega_t}{\partial n_{h,t}}=\frac{\epsilon-1}{\epsilon(\sigma_h-1)}\frac{\omega_t}{n_{h,t}}>0. \tag{43}$$

We know from the static model that in the long run the positive effect of an increase in the number of varieties must dominate over the negative effect from having more high skilled workers. If this model was in continuous time, following an increase in the number of high-skilled workers in the economy, we would expect the skill premium to fall initially followed by a gradual rise until the new steady state is reached where the skill premium is higher than before the increase in high-skilled workers.

In the discrete model the change in the skill premium following an increase in the number of high skilled workers between two consecutive periods is given by:

$$\Delta\omega_t \equiv \omega_t - \omega_{t-1} \tag{44}$$
$$= \left(\frac{L_t}{H_t}\right)^{\frac{1}{\epsilon}} \left(\frac{\sigma_h - 1}{\sigma_h}\frac{1}{c_h}\right)^{\frac{\epsilon-1}{\epsilon}} \left[\left(\frac{F_h}{\gamma+F_h} n^*_{h,t} - \frac{\gamma}{\gamma+F_h} n_{h,t-1}\right)^{\frac{\epsilon-1}{\epsilon(\sigma_h-1)}} - \left(\frac{H_t}{H_{t-1}}\right)^{\frac{1}{\epsilon}} n_{h,t-1}^{\frac{\epsilon-1}{\epsilon(\sigma_h-1)}}\right]$$

This equation is derived by combining the expression for the relative wage (38) in period $t-1$ and t with the first case of the definition of $\Delta n_{h,t}$ in (36). The first case is the relevant one, because we assume that there has been an increase in H. The adjustment to the new steady state following a decrease as shown in (36) would be instant.

The relative wage is therefore increasing, $\Delta\omega_t > 0$, if:

$$\frac{F_h}{\gamma + F_h}\left(\frac{n^*_{h,t} - n_{h,t-1}}{n_{h,t-1}}\right) > \left(\frac{H_t}{H_{t-1}}\right)^{\frac{\sigma_h - 1}{\epsilon - 1}} - 1. \tag{45}$$

$\Delta\omega_t$ may be positive or negative depending on the magnitude of the change in the number of high skilled workers, the number of varieties in the previous period, and the speed of adjustment, $\frac{F_h}{\gamma+F_h}$. The different directions of the short and long run effects of an increase in the number of high skilled workers on the skill premium may account for the lack of consensus from the immigration literature on whether or not high skilled migration raises the skill premium.

3.2 Prices

Since in the dynamic setting $\frac{H}{\sigma_h F_h} = n_{h,t}$, we can write the relative price in t as:

$$\frac{P_{h,t}}{P_{l,t}} = n_{h,t}^{\frac{1}{1-\sigma_h}} \frac{\sigma_h}{\sigma_h - 1} c_h \omega_t. \tag{46}$$

Using the relative wage derived earlier and defined by (38), this can be written as:

$$\frac{P_{h,t}}{P_{l,t}} = \left(n_{h,t}^{\frac{1}{1-\sigma_h}} \frac{L_t}{H_t} \frac{\sigma_h}{\sigma_h - 1} c_h\right)^{\frac{1}{\epsilon}}. \tag{47}$$

Taking simple derivatives, we can identify the changes in the relative price cause by changes in the number of high skilled workers, low skilled workers and varieties as:

$$\frac{\partial P_{h,t}/P_{l,t}}{\partial H_t} = -\frac{1}{\epsilon}\frac{P_{h,t}/P_{l,t}}{H_t} < 0 \tag{48}$$
$$\frac{\partial P_{h,t}/P_{l,t}}{\partial L_t} = \frac{1}{\epsilon}\frac{P_{h,t}/P_{l,t}}{H_t} > 0 \tag{49}$$
$$\frac{\partial P_{h,t}/P_{l,t}}{\partial n_{h,t}} = \frac{1}{\epsilon(1-\sigma_h)}\frac{P_{h,t}/P_{l,t}}{n_{h,t}} < 0. \tag{50}$$

Following an increase in the number of high skilled workers (H), keeping the number of varieties (n) constant, the relative price of final good H falls. As new intermediate goods enter, the relative price of final good H falls further until the new steady state is reached.

4 Calibration

Epifani and Gancia use data from the OECD STAN database to find a relationship between relative expenditure on skill-intensive goods (compared to expenditure on low-skill-intensive goods) and the relative price of skill-intensive goods and estimate an elasticity of substitution of 1.44. This is consistent with the empirical evidence on the degree of substitution between high and low skilled labour, which is also represented by epsilon in this model. Their literature review concludes that most estimates for the elasticity of substitution between more and less educated labour lie in the range from 1 to 2 and therefore take $\epsilon = 1.5$ as a reasonable benchmark. I let $\epsilon = 1.5$ and $\frac{\sigma_l}{\sigma_l - 1} = 1$ as in Epifani and Gancia, and allow the substitution elasticity of intermediate varieties in the production of final good H, σ_h, to vary when calibrating equation 22.

4.1 Data

Table 1 shows the number of high skilled workers in the labour force, the number of low skilled workers in the labour force and the skill premium in years 1 and N. Year 1 is the earliest year for which data on the labour force breakdown by skill level and data on the skill premium are available for a given country. Year N is the latest year for which data on the labour force breakdown by skill level and data on the skill premium are available for a given country. The numbers of high and low skilled workers in the labour force are calculated from the EU Labour Force Survey database. Those aged 65 or more and children less than 15 years old are excluded from the sample.

The labour force includes anyone who worked for one hour or more for pay or profit during the reference week (including family workers but excluding conscripts on compulsory military or community service); anyone who was not working but had a job or business from which he/she was absent during the reference week (including family workers but excluding conscripts on compulsory military or community service); anyone who is seeking employment; anyone who did not work during the reference week but who has found a job that they have not yet started.

Workers are classified as high skilled if they have successfully completed tertiary education (those with an education level of 5b, 5a or 6 according to ISCED 1997 levels). All other workers are classified as low skilled. For some years in some countries, it was not compulsory to answer the question about educational attainment. In these cases I have assumed that the response rate does not depend on the education level and allocated the non-responders to high or low skilled groups according to the ratio of responders in each group for that particular country in that year. This assumption may not seem very plausible; however, in most cases the non-response rate is very small and hence this assumption should not affect results noticeably. The non-response rate is generally less than 3 percent, the exceptions being Germany in 2003 and 2004 where it is around 4 percent, Ireland in 2006 where it is 3.5 percent and the UK between 2000 and 2003 where it is between 8 and 9 percent.

Data on the skill premium comes from the OECD report "Education at a Glance 2013". It measures the ratio of the wage of 25-64 year olds (male and female) with tertiary education to the wage of those with upper secondary education.

Table 1:

Country		year 1	High skilled labour force	Low skilled labour force	Skill premium	year N	High skilled labour force	Low skilled labour force	Skill premium	Change in skill premium
Belgium	be	2000	1407	3031	1.28	2005	1638	3066	1.33	0.05
Switzerland	ch	2000	908	3008	1.52	2006	1181	2987	1.56	0.04
Czech Republic	cz	2004	654	4429	1.82	2006	719	4450	1.83	0.01
Germany	de	2002	9282	31496	1.43	2006	9987	32540	1.64	0.21
Denmark	dk	2001	761	2074	1.24	2006	948	1952	1.26	0.01
Spain	es	2001	5118	13374	1.29	2005	6580	14461	1.37	0.09
Finland	fi	2000	839	1863	1.53	2006	895	1864	1.49	-0.05
France	fr	2002	6900	19669	1.50	2006	7891	20018	1.49	-0.01
Hungary	hu	2001	662	3423	1.94	2006	856	3378	2.19	0.25
Ireland	ie	2000	418	1301	1.53	2006	697	1382	1.57	0.04
Italy	it	2000	2730	21756	1.38	2006	3664	20782	1.55	0.17
Luxembourg	lu	2002	41	153	1.45	2006	55	151	1.53	0.08
Netherlands	nl	2002	2059	6314	1.48	2006	2490	6045	1.54	0.06
Norway	no	2000	726	1579	1.29	2006	801	1604	1.29	-0.01
Poland	pl	2001	2174	15303	1.66	2006	3423	13395	1.73	0.08
Portugal	pt	2004	710	4457	1.78	2006	753	4513	1.77	-0.01
Sweden	se	2001	1112	3374	1.31	2006	1396	3383	1.26	-0.05
UK	uk	2000	8171	20486	1.60	2006	9280	20960	1.60	-0.01

* Figures for labour force are in thousands

4.2 The Static Model

I first consider the static model presented in section two of this paper. Taking $\epsilon = 1.5$ as in Epifani and Gancia, I look at different plausible values of σ_h to see with which value the model's predictions for the change in skill premium between years 1 and N best matches the data. The results are presented in tables 2-4, where different criteria are used with regards to what constitutes a good fit.

Table 2 shows the correlation between the model's predictions and the data on the change in skill premium between years 1 and N for different values of σ_h. Table 3 shows the square root of the expected squared distance from the 45 degree line if the model's predictions for each country were plotted on a graph against the data. Table 4 shows the square root of the expected squared distance from the 45 degree line weighted by labour force size.

Table 2:

σ_h	correlation
1.1	0.2380
1.15	0.2650
1.16	0.2677
1.17	0.2698
1.18	0.2713
1.19	0.2724
1.2	0.2729
1.21	0.2730
1.22	0.2725
1.23	0.2716
1.24	0.2701
1.25	0.2680
1.3	0.2460
1.4	0.0957
1.5	-0.1266

Table 3:

σ_h	Square root of expected sum of squared distances from 45° line
1.1	1.64788
1.2	0.38868
1.3	0.14291
1.35	0.10056
1.36	0.09636
1.37	0.09338
1.38	0.09151
1.39	0.09062
1.4	0.09059
1.41	0.09126
1.42	0.09252
1.43	0.09425
1.44	0.09634
1.45	0.09871
1.5	0.11266

Table 4:

σ_h	Square root of expected sum of squared distances from 45° line weighted by labour force size
1.1	1.35497
1.2	0.31397
1.3	0.12064
1.35	0.10056
1.36	0.10014
1.37	0.10055
1.38	0.10162
1.39	0.10323
1.4	0.10525
1.45	0.11864
1.5	0.13325

The tables indicate that setting $\sigma_h = 1.21$ maximises the correlation between the model's predictions and the data, while the expected deviation from the 45 degree line is minimised when $\sigma_h = 1.4$ or $\sigma_h = 1.36$ if countries are weighted by labour force size. Hence depending on the measure for the fit, I calibrate σ_h to be in the range of $1.21 - 1.40$. The following graphs, figure 1 and 2, show the model's predictions for the change in skill premium against the data when $\sigma_h = 1.21$. i.e. when maximising correlation between the model's prediction and the data, and when $\sigma_h = 1.4$, i.e. when minimising the square root of expected squared distance from the 45 degree line:

Figure 1: Static model with $\sigma_h = 1.21$

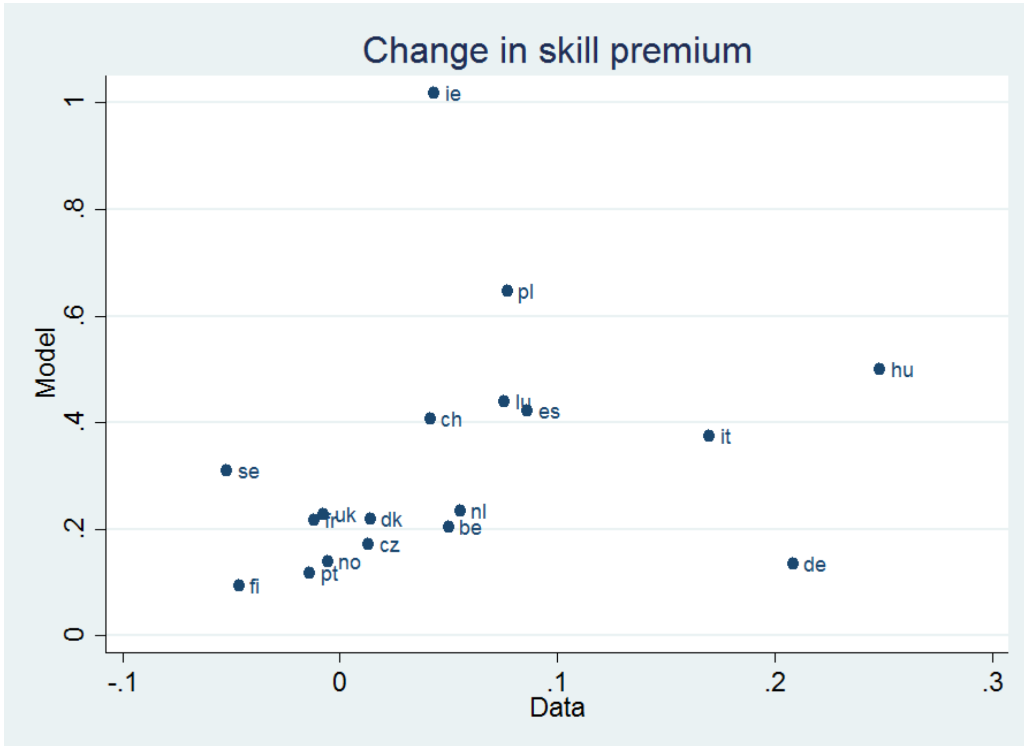
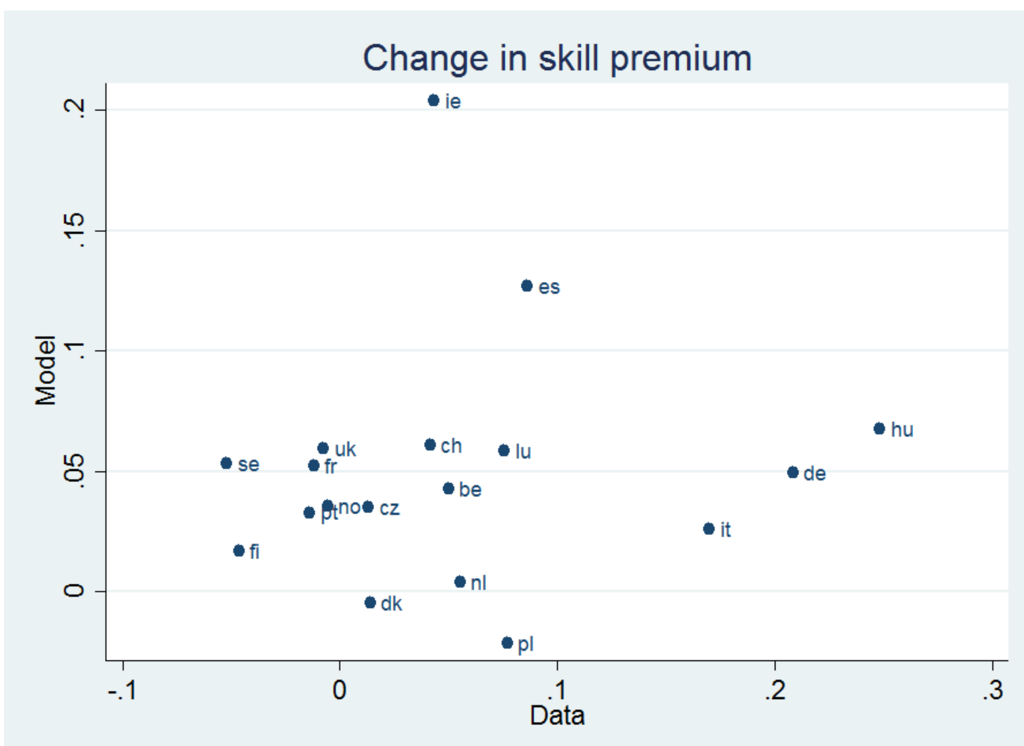


Figure 2: Static model with $\sigma_h = 1.4$



4.3 The Dynamic Model

Now I consider the dynamic model, in which the number of varieties adjusts gradually when out of steady state, using the same three different criteria for a good model fit. I assume that all countries are in steady state in year 1. Taking $\epsilon = 1.5$ as before, there are now two parameters to calibrate: σ_h and the speed of adjustment parameter, $k = \frac{F_h}{\gamma + F_h}$.

Table 5 shows the correlation between the model's predictions and the data on the change in skill premium between years 1 and N for different values of σ_h and k. Table 6 shows the square root of the expected squared distance from the 45 degree line if the model's predictions for each country were plotted on a graph against the data. Table 7 shows the square root of the expected squared distance from the 45 degree line weighted by labour force size.

Table 5:

correlation

	k = 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
σh = 1.05	0.206811	0.228517	0.216714	0.20436	0.193416	0.184503	0.175546	0.16671	0.158766	0.151601
1.1	0.126047	0.284525	0.300334	0.294451	0.283483	0.273951	0.264477	0.254948	0.246089	0.238039
1.15	-0.01649	0.275	0.327955	0.327196	0.315374	0.304766	0.294396	0.283924	0.274037	0.265014
1.2	-0.13189	0.194775	0.328536	0.341203	0.329801	0.3182	0.306641	0.294758	0.283369	0.272922
1.25	-0.1986	0.043077	0.278061	0.333104	0.329505	0.319048	0.306874	0.293479	0.280266	0.268016
1.3	-0.23553	-0.08821	0.141856	0.27232	0.298855	0.297967	0.288394	0.274637	0.259984	0.24601
1.35	-0.25726	-0.16443	-0.01274	0.133226	0.204898	0.229471	0.230754	0.220924	0.207442	0.193488
1.4	-0.27103	-0.20699	-0.11322	-0.01371	0.058074	0.100343	0.115184	0.113724	0.105818	0.095734
1.45	-0.28032	-0.23255	-0.17046	-0.10962	-0.06464	-0.0327	-0.01894	-0.01771	-0.02155	-0.02736

Table 6:

square root of expected squared distance from 45 deg line

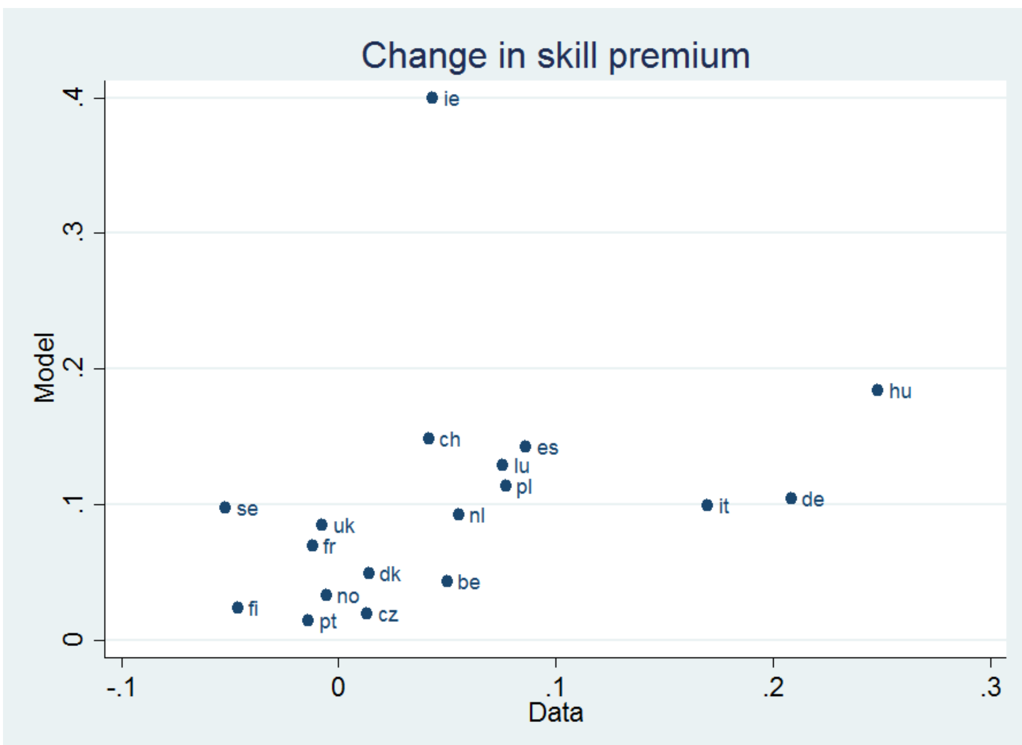
	k = 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
σh = 1.05	0.643032	1.808278	3.18521	4.574977	5.854915	6.967045	7.886221	8.650816	9.313578	9.896135
1.1	0.182539	0.411924	0.69779	0.946016	1.147718	1.306047	1.424037	1.513381	1.586707	1.647884
1.15	0.162124	0.157595	0.283685	0.401234	0.495128	0.567101	0.619351	0.657953	0.689242	0.715007
1.2	0.185752	0.102746	0.133894	0.198814	0.255197	0.29896	0.330697	0.354089	0.373067	0.38868
1.25	0.205784	0.120124	0.089069	0.108829	0.140761	0.16868	0.189729	0.205588	0.218652	0.229502
1.3	0.220517	0.145418	0.099947	0.085028	0.091429	0.104344	0.116436	0.12653	0.135336	0.142915
1.35	0.231481	0.166408	0.12259	0.097367	0.087048	0.085656	0.088184	0.092048	0.096344	0.100563
1.4	0.239876	0.182923	0.143272	0.117467	0.102281	0.094127	0.090458	0.089383	0.089626	0.090585
1.45	0.246484	0.196009	0.160405	0.136224	0.120568	0.110641	0.104772	0.101521	0.099667	0.098714

Table 7:

square root of expected squared distance from 45 deg line weighted by labour force size										
	k = 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
σh = 1.05	0.45689	1.390396	2.440425	3.497418	4.481368	5.349956	6.087832	6.699574	7.202521	7.612943
1.1	0.084261	0.307307	0.54728	0.750089	0.915034	1.047534	1.152885	1.235945	1.302179	1.354968
1.15	0.126906	0.10186	0.20877	0.306778	0.385252	0.44694	0.495316	0.533075	0.56308	0.586955
1.2	0.169706	0.088541	0.094619	0.143753	0.190181	0.227614	0.257268	0.280537	0.299121	0.313973
1.25	0.19626	0.123211	0.085463	0.086531	0.106569	0.127689	0.146112	0.161249	0.173668	0.18377
1.3	0.213938	0.15199	0.11144	0.0916	0.088431	0.092872	0.100099	0.107616	0.114568	0.120643
1.35	0.22649	0.173377	0.136603	0.113926	0.102473	0.097304	0.095985	0.096751	0.09848	0.100562
1.4	0.235848	0.189546	0.156853	0.135322	0.122391	0.114345	0.109602	0.107027	0.105744	0.10525
1.45	0.243088	0.202116	0.172946	0.153218	0.140631	0.132113	0.126425	0.122708	0.120245	0.118636

In general the calibration results do not differ much for the different criteria. The model performs reasonably well in all three measures of fit if $\sigma_h = 1.25$ and $k = 0.4$. The following graph shows the model's predictions for the change in skill premium against the data when $\sigma_h = 1.25$ and $k = 0.4$.

Figure 3: Dynamic model with $\sigma_h = 1.25$ and $k = 0.4$



The dynamic version of the model is a significantly better fit for the data than the static version. This can be seen immediately when comparing figure 3 to figures 1 and 2 representing the static model. The better the fit the closer all points would be to a line on which the model's predictions match the data exactly. However, we can easily see how the data points are much closer to such a line in the dynamic setting. Ireland remains a noticeable outlier, although much less so in the dynamic model. Other countries such as Poland, which are not matched well by the model in the static setting, are much better matched in the dynamic setting.

This implies that the number of intermediate varieties, or the level of technology, does not adjust instantaneously. The estimated value of $k = 0.4$ between the number of firms and the steady state number of firms shrinks by 40 percent each period. This provides a possible explanation for the lack of consensus in the literature on estimates of the degree of returns to scale in skill-intensive sectors. Suppose there is a one off increase in the number of high-skilled workers in an economy. Output in the skill-intensive sector will increase immediately in response to the increase in skilled labour, and will continue to increase over time as the level of skill biased technology increases. If one was to estimate the degree of returns to scale in the skill-intensive industry over a short time horizon, assuming that technology adjusts instantly, the estimate would be too low.

So far in this paper I have assumed that an increase in the number of high skilled workers is followed by investment in skill-biased technology. It is possible that the causality is in the reverse direction: an exogenous shock which increases the level of skill-biased technology could be followed by an increase in high-skilled workers as more people acquire skills and high-skilled immigration increases in response to the higher skill premium. The fact that the dynamic model is a better fit for the data is evidence in favour of the former hypothesis. If the high skilled labour force adjusts in response to changes in technology, and adjustments are not instantaneous because skill acquisition takes time and it is reasonable to expect that individuals plan to emigrate some time in advance of actually doing so, then the dynamic model ought to be a worse fit for the data.

For countries with recent large increases in the number of high-skilled workers, the skill premium is likely to be further from (and lower than) its steady state value. For a given σ_h, the static model predicts a higher value for the skill premium than the dynamic model for these countries. If the number of high skilled workers in an economy adjusts (not instantaneously) in response to changes in the skill premium, then the static model would predict too low value for the skill premium for countries with recent large increases in the number of high-skilled workers because the observed number of high-skilled workers is lower than the steady state value associated with a given value of the skill premium. The dynamic model, which would predict even lower values for the skill premium for these countries, would be a worse fit for the data.

The most conservative estimate of σ_h provided by the calibrations in this and the previous section are somewhat larger than those cited by Epifani and Gancia (2008). Antweiler and Treffler (2002) estimate that average scale elasticity in skill-intensive sectors is around 1.2, corresponding to a σ_h of around 6. Morrison Paul and Siegel (1999) estimate returns to scale in US manufacturing industries and a value of σ_h of 3.5 is consistent with their results. However, both of these papers rely on relatively old datasets. Antweiler and Treffler (2002) use data between 1972 and 1992, and Morrison and Siegel (1999) between 1979 and 89. It is possible that technological change has increased the average scale elasticity in skill-intensive industries over the last 20 to 30 years. As far as I am aware there is currently no literature concerning this hypothesis. Additionally, capital reallocation between sectors following changes in the labour force, as in Caselli (1999), would magnify the wage effect. It is likely that calibration of a model that includes capital, like that presented by Epfani and Gancia (2008), would produce more conservative, i.e. higher, estimates of σ_h.

5 Conclusion

The estimates for σ_h from both the static and the dynamic model using various criteria to measure the fit of the model to the data are between 1.21 and 1.4, all of which are consistent with an upward sloping long-run relative demand curve for high-skilled labour as in Acemoglu (1998, 2002, 2003, 2007).

The effect of an increase in the number of high skilled workers is an increase in the wages of both high and low-skilled workers, but the wage of high-skilled workers increases more, increasing the skill premium. This implies that there is some human capital externality generated by an increase in the number of skilled workers in an economy which increases the relative productivity of high-skilled workers. In this paper I have modelled this as a an increase in the number of varieties in intermediate sector h, but it could be due to skill-biased technical change or learning spillovers between high-skilled workers. Furthermore, we have seen that the effects of an increase in the number of high skilled workers on the skill premium can potentially differ in their directions when comparing the effects in the short and long run. This could account for the lack of consensus in the literature.

An area for further research could be to use this model, or a variation of it, to estimate the effect that recent immigration flows have had on wage inequality.

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