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The Effect of Immigration along the Distribution of Wages

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Non-Technical Abstract

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The Effect of Immigration along the Distribution of Wages[1]

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Abstract: This paper analyses the effect immigration has on wages of native workers. Unlike most previous work, we estimate wage effects along the *distribution* of wages. We derive a flexible empirical strategy that does not rely on pre-allocating immigrants to particular skill groups. In our empirical analysis, we demonstrate that immigrants downgrade considerably upon arrival. As for the effects on native wages, we find that immigration depresses wages below the 20th percentile of the wage distribution, but leads to slight wage increases in the upper part of the wage distribution. The overall wage effect of immigration is slightly positive. The positive wage effects we find are, although modest, too large to be explained by an immigration surplus. We suggest alternative explanations, based on the idea that immigrants are paid less than the value of what they contribute to production, generating therefore a surplus, and we assess the magnitude of these effects.

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1. Introduction

This paper analyses the effect of immigration on the wages of native born workers. Our analysis is for the UK, which experienced an increase of its foreign born population equal to three percent of the native population over the period between 1997 and 2005. We focus on the effect of immigration on wages of native born workers along the native wage distribution. Importantly, the estimator we develop does not rely on pre-allocation of immigrants to skill categories. Our estimation strategy is motivated by two observations. First, we believe that the distributional effect of immigration on wages is a matter of considerable policy interest. Secondly, we believe that estimation of *relative* wage effects across skill groups is problematic, at least in the case of the UK, as immigrants considerably downgrade after arrival, and pre-allocation to skill groups may therefore lead to considerable misclassification error.

Our paper adds to the current literature on immigration in various ways. First, we propose a simple estimation method that allows assessing the effect immigration has on native workers at each point in the native wage distribution, without pre-assigning immigrants to particular skill groups. Secondly, we provide a clear theory-based interpretation to the estimated parameter, and show that it is exactly proportional to the density of immigrants along the native wage distribution. Our analysis gives a fresh interpretation to the latest work by Manacorda, Manning and Wadsworth (2006) for the UK, suggesting that the incomplete substitutability of immigrants and natives within age and education cells they find is much related to a substantial downgrading of immigrants on arrival.[2] Finally, we address the overall positive wage effect that we find, and we propose, and assess, alternative explanations for these.

We commence with a general theoretical discussion. First, we note that the common notion that immigration depresses *average* wages of native workers is

[2] See Ottaviano and Peri (2005, 2006) for a similar argument for the US, and Borjas, Grogger and Hanson (2008) for a critical re-assessment.

based on a simple one industry model, where capital is fixed.[3] We develop a model with not just two, but many skill types and capital as factors of production. We show that, whenever the immigrant skill composition differs from that of the native labour force, and if capital is elastic in supply, the effect on *average* wages of native workers should be zero or even slightly positive. This result is unsurprising as it is based on a simple surplus argument, but has, in our view, not received sufficient attention in the literature on the effects of immigration, where capital supply is usually assumed as being fixed, so that the surplus goes mainly to capital owners.

Although the overall wage effect of immigration may therefore be close to zero, the effects of immigration should be differently felt along the wage distribution, possibly depressing wages of workers who are in segments of the labour market where the density of immigrants is higher than that of native workers. This calls for an empirical approach that investigates the impact of immigration along the wage distribution. Earlier papers do distinguish between wage effects on skilled and unskilled workers (see e.g. Altonji and Card 1991, Borjas 2003, Card 2001, Dustmann et al. 2005, Friedberg 2001 and Jaeger 2007a), and/or analyse the effect of immigration on *relative* wages (see e.g. Card 2005, 2007, Card and Lewis 2007, Manacorda et al. 2006, Ottaviano and Peri 2006, Glitz 2006). These approaches require pre-allocation of immigrants to skill groups, based on their observable characteristics.[4] We demonstrate for the case of the UK that immigrants downgrade upon arrival, and that pre-allocation of immigrants according to their *measured* skills would place them at different locations across the native wage distribution than where we actually find them. This is particularly problematic when estimation is based on differences between time periods defined as years rather than decades, as only recent arrivals will affect estimates.

We suggest a strategy that circumvents this problem. Based on our theoretical framework, where we allow for many different skill types, we derive an estimable model where we allocate immigrants to skill groups according to

[3] See Ottaviano and Peri (2006) and Lewis (2005) for a similar critical assessment of this assumption.

[4] Card (2008) defines skill groups according to the quartile of the wage distribution where a worker would be predicted to be located. This is similar in spirit to our approach.

their observed position in the native wage distribution rather than pre-allocating them to skill groups according to their observed characteristics. We then estimate wage effects of immigration across the distribution of native wages. With our approach no *ex-ante* restriction is imposed on where immigrants compete with natives.

Our empirical investigation first demonstrates that immigrants to the UK over the period we consider are on average much better educated than natives. But while perfect substitutability of immigrants with natives within measured age-skill groups would imply that immigrants are located at the upper and middle part of the wage distribution, their *observed* location after arrival is at the lower end of this distribution. Our estimated wage effects along the wage distribution are strikingly in line with the location of immigrants: while immigration depresses wages below the 20^{th} percentile, it contributes to wage growth above the 20^{th} percentile.

We also find that the *average* effects of immigration on wages are positive. Although this is in principle possible within a model where capital supply is elastic, simulations of our model, based on the *actual* distribution of immigrants across the wage distribution, suggest that the *average* wage effects we find, although relatively modest, are too large to be explained by a surplus argument. In the last section of the paper, we discuss a number of possible mechanisms that may explain our estimates. The underlying idea of all explanations is that immigrants are paid less than the value of what they contribute to production, generating therefore a surplus. We then assess empirically the magnitude of this surplus for our data.

The structure of the paper is as follows. In the next section we explain our theoretical framework, and discuss our estimation strategy. In section 3 we present the datasets we use in the analysis and describe the main features of the immigrant population. Section 4 presents the results. Section 5 discusses mechanisms of surplus generation and presents some simulations and section 6 concludes.

2. Theoretical and Empirical Framework

We commence by setting out the overall theoretical and empirical framework on which our analysis is based. Our model is based on standard economic theory, where as a starting point an equilibrium is considered where all workers are fully employed. The most general model would not restrict the number of industries that may produce different products, and allow for any number of labour input types, as well as allowing for any number of capital inputs into production. We develop such a model in Appendix A.1.

Here we elaborate a simplified version of this model, where we allow only for one output and make the assumption that production follows a nested CES technology. We analyse the model under different assumptions about the elasticity of capital supply. We then develop the empirical implications of the model.

2.1 Theory

Following much of the literature on the effect of immigration on wages,[5] we assume that the number of output types (output being denoted y) is equal to one. However, we allow for a multitude of labour types, $i=1,\ldots,L$. Let the output be traded on world markets at a fixed price which we normalise to equal 1.

We adopt a nested CES production function whereby if labour supplied by the ith type is l_i and capital used is K then

$$y = \left[\beta H^{s} + (1-\beta)K^{s}\right]^{1/s} \qquad \text{(1-a)}$$

$$H = \left[\sum_i \alpha_i l_i^{\sigma}\right]^{1/\sigma} \qquad \text{(1-b)}$$

where H is a CES aggregate of purely labour inputs, α_i determines productivity of the ith type of labour and $\sigma \leq 1$ determines the elasticity of substitution between labour types, while β determines relative productivity of labour and capital and $s \leq 1$ determines the elasticity of substitution between capital

[5] See e.g. Altonji and Card (1991), Borjas (2003), Card and Lewis (2007), Manacorda, et al. (2006) and Ottaviano and Peri (2006). We therefore exclude possible alternative adjustments to immigration in a world with traded goods, through factor price equalisation, as discussed by e.g. Lewis (2004). We also exclude adjustment through technology, see Lewis (2005).

and labour. We assume without loss of generality, a numbering of labour types such that $\alpha_i > \alpha_j$ for $i>j$.

Firms can employ either native labour l_i^0 or immigrant labour l_i^1 of each type *i*. We assume that native and immigrant labour of the same type are both perfect substitutes and equally productive: $l_i = l_i^0 + l_i^1$.[6] For the markets for each labour type to clear[7], $l_i=n_i$ for all *i*, where n_i is the supply of labour of the *i*th type. The labour supply is made up of natives n_i^0 and immigrants n_i^1, $n_i = n_i^0 + n_i^1$, so that $n_i = N(\pi_i^0 + \pi_i^1 m)$ where $N = \sum_i n_i^0$ is total native labour supply, $\pi_i^0 = n_i^0 / N$ is the fraction of native labour of the *i*th type, $\pi_i^1 = n_i^1 / \sum_j n_j^1$ is the fraction of immigrant labour of the *i*th type and $m = \sum_j n_j^1 / N$ is the ratio of the immigrant to native labour force. First order conditions for cost-minimising input choice imply that the real wage of the *i*th type of labour, w_i, equals the marginal product of labour. Similarly, the price of capital, ρ, equals the marginal product of capital. Deriving the first order conditions and taking logs results in equilibrium input prices of all labour types:

$$\begin{aligned} \ln w_i &= \ln \frac{\partial y}{\partial l_i} \\ &= \ln \beta\alpha_i + (\sigma-1)\ln(\pi_i^0 + \pi_i^1 m) + (1-\sigma)\ln\left(\frac{H}{N}\right) \\ &\quad + \left(\frac{1}{s}-1\right)\ln\left[\beta + (1-\beta)\left(\frac{K}{H}\right)^s\right] \end{aligned} \qquad \text{(2-a)}$$

where $\ln\left(\frac{H}{N}\right) = \frac{1}{\sigma}\ln\left(\sum_j \alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma\right)$ and

[6] Note that we do not identify labour types with education-age cells; thus, we do not make the assumption criticised by Ottaviano and Peri (2006) and Manacorda et al. (2006) that immigrants and natives are perfect substitutes in a given education-age cell.

[7] We assume the existence of an equilibrium in which wages w_i are ordered across types similarly to productivity α_i. It is possible that if low skilled types were in sufficiently short supply the wages required to equate their supply and demand would exceed wages of the highly skilled. If the highly skilled are able to do low skilled jobs then clearly this would not be an equilibrium. Strictly, the appropriate equilibrium condition would require that for each skill type the demand for those with skills no lower than that type should be no less than the supply of those with skills no lower than that type. We assume away this complexity.

$$\ln \rho = \ln \frac{\partial y}{\partial K}$$
$$= \ln(1-\beta) + (s-1)\ln\left(\frac{K}{H}\right) + \left(\frac{1}{s}-1\right)\ln\left[\beta + (1-\beta)\left(\frac{K}{H}\right)^{s}\right] \quad \text{(2-b)}$$

Let us suppose an elasticity of supply of capital given by $\theta = \frac{\partial \ln K}{\partial \ln \rho}$.[8] Then the equilibrium change in native log wages as a reaction to changes in the immigrant-native ratio is shown in Appendix A.2 to be given by:

$$\left.\frac{d \ln w_i}{dm}\right|_{m=0} = (\sigma - 1)\left(\frac{\pi_i^1}{\pi_i^0} - \phi \sum \omega_j \frac{\pi_j^1}{\pi_j^0}\right) \quad (3)$$

where $\omega_i = \frac{\alpha_i (\pi_i^0)^{\sigma}}{\sum_j \alpha_j (\pi_j^0)^{\sigma}}$ is the contribution of the *i*th type to the labour aggregate H^{σ}, $\psi = \frac{\beta H^s}{\beta H^s + (1-\beta)K^s}$ is the contribution of labour to the overall CES aggregate y^s and $\phi = 1 + \left[\frac{(1-s)(1-\psi)}{1+\theta(1-s)\psi}\right]\frac{1}{\sigma - 1}$ is a parameter depending on capital mobility θ, capital-labour substitutability s and the labour share ψ. The pattern of the effects of immigration along the native wage distribution therefore depends upon the relative density of immigrants and natives $\frac{\pi_i^1}{\pi_i^0}$ along that distribution.

Consider firstly the case $\phi = 1$, which arises if capital is perfectly mobile ($\theta=\infty$), capital and labour are perfectly substitutable ($s=1$) or the capital share is zero ($\psi=1$). Since $\sum_i \omega_i = 1$, the expression in parenthesis in (3) is the difference at that point in the distribution between the relative density of immigrants and natives and a weighted average of these relative densities across the entire skill distribution. The wage of any skill type is decreased by immigration if and only if the intensity of immigration at that point in the distribution of types exceeds an

[8] All discussion below covers the full range for possible values for θ, and is therefore compatible with Ottaviano and Peri's (2006) observation to allow for mobility of capital.

appropriately weighted average of immigration intensity across the whole distribution. If the distribution of skill types in the immigrant inflow exactly matches that in the native labour force, $\pi_i^0 = \pi_i^1$ for all *i*, then the effect on wages is everywhere zero.

If capital is used, imperfectly mobile and imperfectly substitutable with labour then $\phi < 1$ and even immigration which matches the native labour force in composition will result in wage losses. However the pattern of wage effects along the distribution will still be driven in just the same way by the relative density of immigrants and natives $\frac{\pi_i^1}{\pi_i^0}$.

The first order effect of immigration on mean native wages $\sum_i w_i \pi_i^0$, also derived in Appendix A.2 is

$$\left.\frac{d\sum w_i \pi_i^0}{dm}\right|_{m=0} = (\sigma - 1)(1-\phi)\bar{w}^0 \sum \omega_i \frac{\pi_i^1}{\pi_i^0} \leq 0. \qquad (4)$$

where $\bar{w}^0$ is mean native wage before immigration. The first order effect is negative unless $\phi = 1$ or $\sigma = 1$. Native labour on average is harmed by immigration, though obviously some labour types may gain if the composition of immigrant and native labour differ.

However if capital is perfectly mobile so that $\phi = 1$ then the first order effect is zero. Capital inflows follow the inflow of labour to keep marginal product of capital constant, immigrant labour is paid the value of its marginal product and there is no change at the margin in payments to native labour. Turning for this case to second order effects, we obtain (as shown in Appendix A.2)

$$\sum \pi_i^0 \left.\frac{d^2 w_i}{dm^2}\right|_{m=0} = (1-\sigma)\bar{w}^0 \left[\sum \omega_i \left(\frac{\pi_i^1}{\pi_i^0} \right)^2 - \left(\sum \omega_i \frac{\pi_i^1}{\pi_i^0} \right)^2 \right] \geq 0$$

so that second order effects on the mean native wage are positive if the immigrant inflow differs at all from native labour in its mix of skill types. Note that the last term in parentheses is a weighted variance: it is larger the larger the disparity between the immigrant and native skill distribution and disappears only if $\pi_i^0 = \pi_i^1$ for all *i*. For small levels of immigration we should therefore expect to find mean native wages rising if capital is perfectly mobile. Indeed, there can be a positive surplus for labour if capital is fairly mobile and immigrant labour sufficiently different to native labour, as we show quantitatively in section 6. This is the conventional "immigration surplus" argument establishing that immigration is beneficial to native factors – immigrating labour is paid less than the value of what it adds to production and the surplus must be returned to native factors if profits are zero[9].

That does not, of course, mean that in this case wages increase throughout the native skill distribution. Wages fall at any point in the distribution at which $\frac{\pi_i^1}{\pi_i^0}$ exceeds the weighted average $\sum \omega_i \frac{\pi_i^1}{\pi_i^0}$. In particular it will be those who compete with immigrants who will suffer wage losses[10].

2.2 Empirical Specification

We turn now to empirical implementation of the CES model as outlined above. Take the factor return equations in (2-a)-(2-b), combine with a capital supply equation and let ρ_0 be the equilibrium return to capital at m=0.

Taking a first order Taylor expansion of (2-a) around m=0 using the earlier expression $\left.\frac{d \ln w_i}{dm}\right|_{m=0} = (\sigma - 1)\left(\frac{\pi_i^1}{\pi_i^0} - \phi \sum \omega_j \frac{\pi_j^1}{\pi_j^0}\right)$ we obtain an approximate expression for the wage of the *i*th type:

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[9] Appendix A.1 establishes that these qualitative observations apply in a much more general model with many outputs and many perfectly mobile capital inputs, assuming only constant returns to scale.

[10] For example, any native subgroup of identical composition to immigrants must lose as shown in Appendix: A.2

$$\left.\frac{d \sum w_i \pi_i^1}{dm}\right|_{m=0} = (\sigma - 1)\bar{w}^0 \left[\sum \omega_i \left(\frac{\pi_i^1}{\pi_i^0}\right)^2 - \phi \left(\sum \omega_i \frac{\pi_i^1}{\pi_i^0}\right)^2\right] \leq 0.$$

$$\ln w_i \approx \ln \beta\alpha_i + (\sigma-1)\ln \pi_i^0 + \frac{1-\sigma}{\sigma}\ln\left(\sum_j \alpha_j (\pi_j^0)^\sigma\right) + G(\rho_0) + (\sigma-1)\left(\frac{\pi_i^1}{\pi_i^0} - \phi\sum \omega_j \frac{\pi_j^1}{\pi_j^0}\right) m \quad (5)$$

where $G(\rho) = \ln\left(\frac{\rho}{1-\beta}\right) + \frac{s-1}{s}\ln\left[\frac{1}{\beta}\left(\frac{\rho}{1-\beta}\right)^{s/(1-s)} - \frac{1-\beta}{\beta}\right]$.

Our data come from different regions at different points in time and our empirical approach is based on using variation in immigrant inflows across different regions in the UK. We therefore observe a distribution of native and immigrant wages in different regions at different points in time. We choose to identify different skill types *i* with different locations in the observed distribution of native wages. In other words, if W_{prt} denotes the *p*th percentile of the native wage distribution in region *r* at time *t* then, in terms of the earlier theory, we identify this with w_i where *i* is the smallest value such that $\sum_{j\le i} \pi_j^0 \ge 100p$.

Accordingly, we adopt a model

$$\ln W_{prt} \approx a_{pr} + b_{pt} + c_p X_{rt} + \gamma_p m_{rt} + \varepsilon_{prt} \quad (6)$$

where at each point in the distribution *p* we include region and time effects, $a_{pr} + b_{pt}$. The former capture the role of technological parameters given the initial skill distribution and capital price in the region, whereas the latter capture the influence of changes in national capital prices on the chosen capital-labour ratio. Controls for changing age and skill composition of the native labour force are included in X_{rt}. The coefficient on the region-specific immigrant-native ratio is then the key parameter of interest: $\gamma_p = (\sigma-1)\left(\frac{\pi_i^1}{\pi_i^0} - \phi\sum \omega_j \frac{\pi_j^1}{\pi_j^0}\right)$. Constancy of this across regions reflects an assumption that immigrant skill composition relates

similarly to native skill composition in different regions and periods[11]. Finally ε_{prt} is a random error term.

3. Background, Data and Descriptives

3.1 Migration to the UK

In 2001, the last census year, 4.8m immigrants lived in the UK, which amounts to 8.47 percent of the total population. Over 3.5m of them were of working age (16-65), so that they counted for 9.75 percent of the working age population. Since then, Britain has experienced a further increase in its foreign born population, and the share of foreign born in the total working age population in 2005 was 11.5%. The share of foreign born population in the UK is thus similar to the corresponding share in the US, which was 11.9% in 2004[12]. Until the late 1990s almost one third of the foreign born population in the UK used to be from Western European countries, one fifth from the Indian Sub-continent, and less than 2 percent from Eastern Europe. Since the late 1990s migration from Eastern Europe has intensified, and Eastern Europeans constitute now over 5% of the total foreign born population, while Western Europeans are less than one fourth and immigrants from the Indian Sub-Continent are still about 20%.

3.2 The Data

The main dataset we use for our analysis is the UK Labour Force Survey (LFS) over the period from 1997 till 2005. The LFS, established in 1973, is a sample survey of households living at private addresses in Great Britain, conducted by the Office for National Statistics (ONS). We restrict our analysis to Great Britain, and omit Northern Ireland. Since 1992, the LFS has been a rotating

[11] It seems reasonable to assume that capital is perfectly mobile between regions (but not necessarily internationally). In that case the capital price would be the same in all regions and any influence of immigration on national capital price would be absorbed fully in the time effects. In such a case it would make sense to identify $a_{pr} = (\sigma - 1)\ln(\pi_i^0) + \frac{1-\sigma}{\sigma}\ln\left(\sum \alpha_j (\pi_j^0)^{\sigma}\right)$ and $b_{pt} = \ln \beta\alpha_i + G(\rho_0)$ and to have $\gamma_p = (\sigma - 1)\left(\frac{\pi_i^1}{\pi_i^0} - \sum \omega_j \frac{\pi_j^1}{\pi_j^0}\right)$.

[12] Source: US Census Bureau – Current Population Survey.

quarterly panel. Each sampled address is interviewed for 5 consecutive times at 3 monthly intervals. The sample size is about 55,000 responding households in Great Britain every quarter, representing about 0.2% of the population.

The LFS collects information on respondents' personal circumstances and their labour market status during a reference period of one to four weeks immediately prior to the interview. From the 1992 -1993 winter quarter onwards the LFS contains information on gross weekly wages and on number of hours worked. Initially this information was asked only in the final wave, but from the 1997 spring quarter onwards questions on wages were asked during the first and the fifth interview.

Spatial information is available at regional level, where region is determined according to usual residence. The LFS originally identifies 20 regions[13]. We unify Inner and Outer London into Greater London, and Strathclyde and the Rest of Scotland into Scotland, to create territorially homogeneous regions, and limit our analysis to Great Britain, dropping Northern Ireland. We have therefore 17 regions, and the usual average sample size for the period we consider is about 19,297[14].

We combine information from the LFS with information from various years of the UK Population Census. The Census is a decennial survey of all people and households. The most recent Census was in 2001. Although providing information on age, education, and employment status, the UK Census has no information on wages. Moreover comparability across Census years is not always possible, as variable classifications change quite often. This is for instance the case for occupation and education between the 1991 and 2001 Census. In our analysis below, we use information from the 1991 and 1981 Census to construct variables for immigrants' geographical distribution.

[13] Tyne & Wear, Rest of Northern Region, South Yorkshire, West Yorkshire, Rest of Yorkshire & Humberside, East Midlands, East Anglia, Inner London, Outer London, Rest of South East, South West, West Midlands (Metropolitan counties), Rest of West Midlands, Greater Manchester, Merseyside, Rest of North West, Wales, Strathclyde, Rest of Scotland, Northern Ireland.
[14] The average population size in a region is 2,163,121.

3.3 Descriptive Evidence

In 1971, the percentage of foreign born individuals on the total population in Great Britain was 5.9%, or 3 million individuals. Over the next decades this number increased to 6.3% (1981), 6.8% (1991) and 8.47% (2001). Between 1989 and 1997, the foreign born working age (16-65) population on the total working age population increased by only 0.7 percentage points. In contrast, between 1997 and 2005 the percentage of the foreign born in the working age population increased by almost 3 percentage points. This is the period we consider for our analysis, and we concentrate on the working age population only.

Table 1 reports some characteristics of the native born and foreign born population in Britain, where among the foreign born we distinguish between earlier and more recent immigrants. We define as "earlier immigrants" all foreign born who have been in the UK two years or more at the time of interview; we define as "recent immigrants" all immigrants who arrived in the UK over the last two years. This distinction is important as our empirical analysis is based on variation in the stock of immigrants between two subsequent years; this variation is driven by recent arrivals.

[Table 1 here]

In Table 1, we report average age and educational attainments for 1997 and 2005, the first and the last year of our observation period. Natives and earlier immigrants are very similar in their average age (around 40) while new immigrants are about 10 years younger. The percentage of females on the other hand is roughly similar, with a slight drop for more recent immigrants between 1997 and 2005.

The lower panel of the table reports educational attainment of the different groups. We base our measures on information about the age at which the individual left full time education[15], and we classify individuals in three groups:

[15] The LFS has two alternative measures for educational achievements, age at which individuals left full time education, and "highest qualification achieved". The problem with the latter measure

low (left full time education before the age of 17), intermediate (left full time education between 17 and 20), and high (left full time education after age 20). For natives and earlier immigrants, the table shows an improvement in educational attainment between 1997 and 2005. However, earlier immigrants are better educated than natives in both years, with a higher percentage in the highest category, and lower percentages in the lowest category. Nearly one in two of new arrivals is in the highest educational category, and slightly more than one in 10 in the lowest category. The educational attainment of new arrivals have roughly remained constant over the period considered.

Recent immigrants may not be able to make use of their educational background to its full potential, as they may lack complementary skills like language, or they may have to start searching for their best job match (see Eckstein and Weiss 2004). In Table 2 we display the occupational distribution of immigrants in 2004 and 2005, where we distinguish between 6 occupational categories using the National Statistics Socio-economic Classification (NS-SEC). We exclude employers and the self-employed because we do not have information on their wages. The last column shows the average wage by occupation in the years considered, expressed in 2005 prices[16].

[Table 2 here]

The occupational distribution of those who have been in the country for at least 2 years is similar to the native born, except for the higher immigrant concentration in the highest paid category, and the slightly higher concentration of natives in the two intermediate categories. However, recent immigrants, i.e. those who arrived within 2 years of the interview, although being better educated than the overall immigrant population (see table 1), tend to be in lower occupation categories, with the partial exception of higher managerial and professional occupations: 47% are in the lowest three occupational groups, compared with 27% of natives and of earlier immigrants. This suggests that new arrivals, unable to put their human capital into immediate use, start lower down the occupational

is that it is defined on the British education system and classifies all foreign classifications as "other qualification" (see the discussion in the appendix of Manacorda et al. (2006)).

[16] We discount wages using the 2005-based CPI.

distribution, and compete with native workers much further down the distribution. This finding mirrors results for Israel on considerable downgrading of new immigrants - see the work by Eckstein and Weiss (2004).

In table 3 we break down the occupational distribution by educational attainment, using the same grouping. The figures show that within each education group, recent immigrants are distributed more towards the lower end of the occupational distribution. For instance, while among highly skilled natives, only 5% work in the lowest two occupational categories, this is the case for 11% of earlier immigrants, but 26% of recent immigrants. The respective numbers for the intermediate education category are 19%, 29% and 63%. Again, this suggests considerable downgrading of recent immigrants within educational categories.

[Table 3 here]

In our empirical analysis, we will associate the changes in wages across different spatial units with the changes in the stock of immigrants. Our theoretical model above suggests that the immigrant population will exert pressure on wages of natives at those parts of the distribution where the relative density of immigrants is higher than that of the weighted relative density of natives.

Where we actually find immigrants in the native wage distribution can be straightforwardly estimated from the data: in each year, and for each immigrant, we can calculate the proportion of natives with a lower wage. In figure 1, we display the distribution[17] of immigrants along the wage distribution of native workers, where again we distinguish between immigrants who have been in the country for less than 2 years, and immigrants who have been in the country for less than 6 years.

[Figure 1 here]

[17] These are kernel density estimates. Given that the variable in question is bounded, by construction, between 0 and 1, conventional kernel estimation with fixed window width would give misleading estimates at the extremes. The kernel estimates are therefore calculated on the log of the odds of the position in the non-immigrant distribution and appropriately transformed.

The dashed line shows the density of recent immigrants along the wage distribution of natives. Contrary from what we should expect based on information on their educational background, the density of recent immigrants is higher than that of natives everywhere below the 25th percentile of the wage distribution. On the other hand, it is lower between the 25th percentile and the 90th percentile, and higher again afterwards. The dotted line shows the distribution for immigrants who have been in the country for less than 6 years. The overall pattern is still similar, but it is apparent that some "upgrading" has taken place, with less mass below the 25th percentile. Based on these figures, we should expect therefore that immigrants put a pressure on wages below the 25th percentile of the native wage distribution.

Where would we find immigrants along the native wage distribution if we had allocated them according to their observed age and education distribution? We illustrate that in Figure 2. Figure 2 is obtained by estimating a flexible log wage regression for natives, where we condition on five age categories and four educational categories, as well as interactions between the two[18]. We estimate that equation separately for males and females. If immigrants and natives are perfect substitutes within age and education categories, then immigrants should be located in the native wage distribution according to their predicted wages. We predict wages for all recent immigrants, where we add an error term to the prediction which is drawn from a normal distribution, with heteroscedastic variance according to age, education and gender. We then draw the density of immigrants across the native wage distribution.

[Figure 2 here]

The difference between figure 1 and 2 is striking. In figure 2, immigrants are strongly present at the very low end of the wage distribution; however, above the 7th percentile, their density is much lower than that of native workers. On the other hand, the density becomes increasingly larger above the 60th percentile.

[18] Our regressors include five age categories (16/25, 26/35, 36/45, 46/55, 56/65), four educational categories, based on age at which individuals left full time education (before 16, 16/18, 19/20, after 20), interaction between the two, a dummy for London residents, and quarter dummies. We fit separate models for men and women and for different years.

Based on this figure, we would expect immigrants to exert a pressure on wages at the bottom of the native wage distribution, and above the median. The figure shows clearly that it may be misleading to pre-allocate recent immigrants across the native skill distribution based on their observable characteristics.

4. Estimation

4.1 Implementation and Identification

In our empirical analysis, we estimate the effects of immigration along the distribution of wages. Our starting point is the empirical model that derives directly from our theoretical framework, as in (6). The parameter we estimate in that model is a combination of the elasticity of substitution between skill groups, and the relative density of immigrants at the particular part of the native wage distribution. As we explain above, the relative size of the parameter should directly correspond to the density of immigrants, as we have illustrated in Figure 1.

The way we implement that model is to regress differences over time in percentiles of log wages across different regions in the UK on changes in the fraction of immigrants to natives Δm_{rt}, time dummies β_t, and changes in the average age of immigrant and native workers in the region as well as the ratio of high (intermediate) to low educated native workers, Δc_{prt}:

$$\Delta \ln W_{prt} = \beta_t + \Delta c_{prt} + \gamma_p \Delta m_{rt} + \Delta \varepsilon_{prt} \qquad (7)$$

It is important to note that our approach does not depend in any way on pre-assignment of immigrants to particular skill cells. For estimation, we use variation across spatial units *r* and across time. This approach may potentially lead to an overly optimistic picture of immigration on native outcomes if natives leave labour markets that experienced in-migration. However, if this occurs, it is likely to be less relevant in our case, as the large regional definitions we use in our analysis make it more likely that any movements will be internalised (see Borjas

et al. 1997 for a similar argument). We nevertheless check this by using an extension of the methodology in Card (2001), adapted to our quantile approach, and find no evidence for native responses to immigration[19] (details are available on request). In addition, we condition on native skill group proportions, which should take account of changes in the native skill group over time. Of course, there are obvious concerns about whether such proportions ought themselves to be regarded as endogenous in such a setting and there are less obvious instruments to deal with the issue.

A further problem is the endogenous allocation of immigrants into particular regional labour markets. One solution is to use instrumental variables estimation. We follow the literature and use settlement pattern of previous immigrants as instruments. This instrument has been used in various studies in this literature, following Altonji and Card (1991), and is motivated by a number of studies (see for instance Bartel 1989, Jaeger 2007b, Munshi 2003) showing that settlement patterns of previous immigrants are a main determinant of immigrants' location choices.[20] When estimating equation (7) we use years 1997-2005, and we compute the ratio of immigrants to natives for each year in each of the 17 regions. Estimation in differences eliminates region specific permanent effects that are correlated with immigrant settlement patterns and economic conditions alike. We instrument the *change* in this ratio using two alternative but closely related instruments: the 1991 ratio of immigrants to natives for each of these regions, from the Census of Population, and four period lags of the ratio of immigrants to natives in each region from the LFS. Both instrumental variables are strongly correlated to the ratio of immigrants to natives. The first stage regression of the change in the immigrant-native ratio on the 1991 ratio and time dummies gives a coefficient of 0.068 with a t-statistic of 9.51[21] , while the partial R^2 of excluded instruments is 0.29, and the F-test for their significance is 90.47. A regression of the endogenous variable on the fourth lag of the immigrants-natives ratio and on time dummies gives a coefficient of 0.043, with a t-statistic of 12.22, while the

[19] Absence of counterbalancing native outflows is also detected by Card and DiNardo (2000), Card (2001) and Cortes (2006) among others. Borjas et al. (1997) on the other hand do find significant displacement effects of immigrants on resident natives.
[20] See among others Card (2001), Card and Lewis (2007), Cortes (2006), Cortes and Tessada (2008), Lewis (2005), Ottaviano and Peri (2006, 2007) and Saiz (2007) for a similar strategy.
[21] Standard errors are clustered by region.

partial R^2 of excluded instruments is 0.3 and the F-test for their significance is 149.27. The instruments are valid under the assumption that economic shocks are not too persistent. We report in table 4 the results of Arellano-Bond tests for first and second order serial correlation in the residuals of regressions for all the dependent variables we consider. Absence of second order serial correlation cannot be rejected for all variables except for the median wage and the 75th percentile.

[Table 4 here]

In addition we perform several robustness checks, using instruments that are based on settlement patterns further aback. We use further lags of the ratio of immigrants to natives (going back to the 14th lag) and the 1981 immigrant-native ratio. We also construct a series of instruments based on the predicted inflow of immigrants in each region, along the lines of Card (2001). We take account of the area of origin of immigrants and design a variable which predicts the total immigrant inflow in each region in every year, net of contemporary demand shocks. In order to do so we divide immigrants into 15 areas of origin[22] and calculate the number of immigrants from each area who entered the UK in every year. We then allocate every group of immigrants across regions according to the location of previous immigrants from the same area[23]. Results obtained with these alternative instrumental variables are very similar to those obtained with the instruments described above, which we report in the tables (see Table A1 for estimation results for average wages. Results along the distribution are available on request).

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[22] Irish Republic, Old Commonwealth, Eastern Africa (New Commonwealth, NC), Other Africa (NC), Caribbean (NC), Bangladesh, India, Pakistan, South East Asia (NC), Cyprus, Other New Commonwealth, European Community (1992 members), Other Europe, China, Rest of the World.

[23] If we define M_{ct} as the number of new immigrants from area *c* in year *t*, and $\lambda_{ci} = M_{ci} / M_c$ as the fraction of immigrants from area *c* in region *i* in a base period, then $\lambda_{ci} M_{ct}$ is the predicted number of new immigrants from area *c* in region *i* in year *t*. As base periods, we experiment with different years: 1981, 1985, and 1991, using data from the LFS and for 1991 from the Census. Finally, we sum over all origin groups to obtain a predicted total immigrant inflow into region *i* which is "cleansed" of local demand shocks : $\sum_c \lambda_{ci} M_{ct}$. Finally, we divide this predicted inflow by the number of natives in the region at time *t-2*, to normalize by region size.

4.2 Measurement

As we explained in section 3.2 the LFS is a nationally representative survey, and since the immigrant population accounted for less than 10% of the total population for most of the years we consider (and much less so in some regions), the number of observations for immigrants may be quite small. Therefore measures of regional immigrant concentration may suffer from measurement error due to small sample size. As we estimate our equations in first differences, this may amplify the impact of measurement error, resulting in a possibly severe downward bias. Instrumental variable estimation accounts for the measurement error problem as long as the measurement error in the instrumental variable is uncorrelated with the measurement error in the variable of interest. Aydemir and Borjas (2006) argue that, if the instrument of choice is some lagged measure of the immigrant share, and measurement error is correlated over time, the instruments may not be valid. In our case this is not a concern because we use a minimum of four lags as instrument, therefore avoiding any correlation in the measurement error of the endogenous variable and the instrument even in first differences. Alternatively we use as an instrument the immigrant concentration from the Census, whose measurement error is independent from that in the LFS.

We use four different measures for average wages to test the robustness of our results. First we use the simple average regional wage. Second, we compute a robust regional average by trimming in every region and year the wage distribution of natives at the region- and year- specific 1st and 99th percentile. This measure reduces the impact of outliers on our averages by considering only central observations in the wage distribution. Third, we calculate a wage index constructed as the weighted sum of the average wages in each education group, defined as above in terms of years of education (see discussion in section 3.3). The educational composition of the native population is kept constant by choosing as weights the share of each education group in the native population in a base year (which we choose to be 1998)[24]. By holding constant the skill composition

[24] The wage index is constructed for each region as follows. First we calculate $\overline{w}_{et}$, the average wage for education group e=1,2,3 in time t=1997,…,2005. Then we calculate the time-invariant

of the assessed population, this measure is isolated from compositional issues associated with changing native skills. The theoretical results of earlier sections show that wage changes could raise average wages in the native population (if capital is perfectly elastic) holding skill composition fixed and this measure comes closest to capturing that. Finally, we use a robust version of this index based on wages in the trimmed sample. The robust index is constructed using robust average wages for each education group, where the average wages by education group are computed on the same trimmed sample as explained above.

In table A2 in the Appendix we report means and standard deviations of all the variables we use, and in table A3 we show the year specific means and standard deviations of the change in the immigrant-native ratio.

5. Results

5.1 Effects along the wage distribution

We now turn to our analysis of immigration on wages of native workers. We commence by estimating the effect of immigration along the distribution of wages. In table 5, we report results for the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile of the wage distribution. Columns 1 and 2 present OLS results and columns 3, 4, and 5, 6 present IV results, using alternative instruments. Reported results are based on difference estimations. Columns 2, 4, and 6 control, in addition to time effects, for average natives' and immigrants' age, and the logarithm of the ratio of natives in each education group to natives with no qualifications. Estimation is based on yearly data for the years 1997-2005 and for 17 regions.

[Table 5 here]

The regression results show a sizeable negative impact of immigration on the lower wage quantiles. According to IV estimates in column 4, which use the

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weights $\pi_{e1998} = N_{e98} / N_{98}$, the proportion of natives in education group e in 1998. Finally, we define the index $I_t = \sum_{e=1,2,3} \pi_{e98} \overline{w}_{et}$

1991 settlement patterns of immigrants drawn from the Census as instrument and include all controls, the impact of an inflow of immigrants of the size of 1% of the native population would lead to a 0.6% decrease in the 5th wage percentile and a 0.4% decrease in the 10th wage percentile. On the other hand, it would lead to an almost 0.7% increase in the median wage and a 0.5% increase in the 90th percentile. Estimates using the fourth lag of the ratio of immigrants to natives (see columns 5 and 6) give the same picture, but with slightly smaller coefficients. Both IV estimates indicate a strong positive impact of immigration around the median wage, but a negative effect at the bottom of the wage distribution. According to these estimates, immigration seems to put downward pressure on the lower part of the wage distribution, but increases wages at the upper part of the distribution.

We note that the OLS estimates are smaller in absolute magnitude than the IV estimates. This is not what we should expect if immigrants allocate in regions which experienced positive economic shocks. However, as we point out above, instrumentation removes also measurement error, which leads to a bias towards zero in the estimated parameters.[25] Our results suggest that the measurement error bias is larger in magnitude than the selection bias.[26]

In terms of magnitude, our estimates in column 6 of table 5 suggest that each 1 percent increase in the immigrant/native working age population ratio led over the period studied to a 0.5 percent decrease in wages at the 1st decile, a 0.6 percent increase in wages at the median, and a 0.4 percent increase in wages at the 9th decile. The average increase in the immigrant/native working age population ratio over the period considered was about 0.35% per year, whereas the real hourly wage increased over the period by 18p (4.28%) per year at the 1st decile, by 25p (3.25%) per year at the median, and by 53p (3.18%) per year at the 9th decile (in 2005 terms). Therefore immigration held wages back by 0.7p per hour

[25] Aydemir and Borjas (2006) show that the measurement error induced attenuation bias becomes exponentially worse as the sample size used to calculate the immigrant concentration declines, and that adjusting for attenuation bias can easily double or triple the estimated wage impact of immigration.

[26] It is worthwhile to note that the standard errors of the IV estimator are smaller than the standard errors of the OLS estimator in differences. The reason is that standard errors are calculated on the assumption of lack of serial correlation in the residuals of the levels equation so that the differenced equation is assumed to have residuals with a specific pattern of first order serial correlation. OLS is not efficient given such serial correlation, even under exogeneity of the regressors, and IV may accordingly give lower standard errors.

at the 10th percentile, contributed about 1.5p per hour to wage growth at the median and slightly more than 2p per hour at the 90th percentile.

To obtain a more detailed picture, we have estimated the model at a finer grid of wage percentiles. In figure 3 we plot the estimated coefficients of regressions from the 5th to the 95th percentile, in intervals of 5 percentage points for the IV regressions, using the specification in column 6 of the table. The dotted lines are the 95% confidence interval. The graph shows the negative impact on low wage percentiles and the positive impact on percentiles further up the wage distribution.

[Figure 3 here]

The graph of wage effects illustrated in the figure is strikingly similar to the distribution of immigrants along the native wage distribution, as shown in Figure 1. The wage effects curve is like a mirror image of the observed distribution of recent immigrants over the native wage distribution. The consonance of these two independent pieces of evidence offers strong support for the pattern of effects as suggested by our theoretical model. Overall, these results suggest that immigration tends to stretch the wage distribution, particularly below the median. Our IV coefficients imply that an increase in the immigrant population by about 1 percent of the native population would increases the 50-10 differential by about 1 percentage point, but there is hardly any effect of immigration on the wage distribution above the median.

5.3 Immigration and Average Wages

In table 6 we present results on mean regressions from estimating equation (7), using the different measures for average wages which we discuss above. Results are consistent across all specifications, and show a positive impact of immigration on natives' average wages throughout.

[Table 6 here]

The coefficients on the wage index (in the third row), and on the robust wage index (in the fourth row) capture most closely the mean impact at fixed skill composition corresponding to our theoretical model (see section 4.3). These estimates indicate that an increase in the foreign born population of the size of 1% of the native population leads to an increase of between 0.2% and 0.3% in average wages. As the average yearly increase in the immigrant/native ratio over our sample period (1997-2005) was about 0.35%, and the average real wage growth just over 3 percent, immigration contributed about 3.5-4.5 percent to annual real wage growth. These estimates are similar in magnitude to those obtained in other studies finding positive wage effects of immigration, such as Friedberg (2001) and Ottaviano and Peri (2007).

6. Explaining positive mean wage effects

How can we explain the positive impact of immigration on mean native wages? One reason, as set out in recent work by Ottaviano and Peri (2006), may be imperfect substitutability of immigrants and natives within skill groups[27] so that native marginal product can be enhanced by expansion of the immigrant labour force. We explore here a variety of possible reasons which are not dissimilar in spirit. Common to each is the idea that immigrants are paid less than the value of what they contribute to production, generating therefore a surplus. Exactly who captures this surplus depends upon assumptions made about production decisions. Under conditions implying zero profits, such a surplus will result in enhanced payments to pre-existing factors of production. If factors other than labour, and in particular capital, are supplied sufficiently elastically, because for example of international mobility, then the surplus will accrue in increased average wages to native labour.

We first consider the possibility that a surplus arises if immigration takes the economy down its labour demand curve. We discuss this surplus in section 2.1. We show that such a surplus is *second order* and may create an increase in native wages at larger inflows, and if capital supply is elastic. Secondly, we

[27] See also D'Amuri, Ottaviano and Peri (2008) and Peri (2007) for a similar argument, and Borjas, Grogger and Hanson (2008) for a reappraisal of Ottaviano and Peri (2006).

explore arguments that rely on immigrant wages falling below marginal products and imply *first order* surplus effects. We consider two such possibilities. In the first of these, in the pre-migration situation, wages paid are different from the marginal product in local labour markets. This situation could occur if wages are sticky, for instance through institutions, natives are insufficiently mobile to re-establish an equilibrium, and immigrants tend to go to areas where the difference between wage and marginal product is largest. In the second possibility, immigrants work in jobs appropriate to lower skills and are paid below the value of their marginal product. We provide strong evidence for downgrading in section 3.3. This will also generate a surplus, which will be captured by native workers.

Below we will explore each of these reasons in detail. Based on our data and the parameters we have estimated, we then assess through simulation, whether immigration of the magnitude observed in our data could account for wage effects of the size found through such a means. We conclude that while it seems unlikely that any of these arguments alone explain the size of positive effects, it might be explained through a combination of the different explanations.

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6.1 Equilibrium immigration surplus

We know from theoretical considerations (see Section 2.1) that positive effects on native wages are compatible with a standard equilibrium model with differentiated labour and elastically supplied capital. Immigration generates a surplus which is paid to inelastically supplied native factors and which will accrue to labour if other factors are supplied elastically. Such an effect is second order however – the marginal impact is zero.

Can the positive mean wage effects of the magnitude found in our analysis be accounted for by equilibrium surplus arguments for the sort of magnitudes of immigration observe in our data? To investigate this, we simulate our model for the distribution of immigrants we observe in the data, and establish the overall effects on wages, for different sets of model parameters. To do this we first need to augment the equations of Section 2.1 with a capital supply equation. Assuming a constant elasticity of capital supply θ, the system of equations used for

simulation of the effects of immigration consists of equations (3-a), (3-c) and the capital supply equation $\ln K = \ln A + \theta \ln \rho$.

For simplicity we hold the labour share parameter β constant at 0.5. The native ability distribution is set at $\pi_i = 1$ for *i=1,…,100* so that simulated wages are percentiles of the distribution. The ability distribution, α_i, is then chosen to replicate the observed wage distribution at *m=0*. These parameters are kept constant across simulations. Parameters varied are the elasticity of supply of capital, θ, the elasticity of substitution between labour types, *1/(1-σ)*, and the elasticity of substitution between capital and labour, *1/(1-s)*.

We consider firstly an ability distribution for immigrants to match the estimated wage distribution of immigrants shown in Figure 1. On this basis we are able to simulate the effect on mean native wages for different extents of immigration, *m*, as shown in Table 7 (in the columns headed 'Observed'). All entries are percentage changes in mean native wage.

[Table 7 here]

As can be seen, and confirming the observations made above, perfectly elastic supply of capital ($\theta=\infty$) or perfect substitutability of capital and labour ($s=1$) leads always to an unambiguously non-negative mean native wage effect as the immigration surplus accrues exclusively to native labour. In none of these cases however is the size of this surplus large for immigrant ability distributions of the sort suggested by the distribution of immigrant wages observed. As we relax the assumption of elastic capital supply, mean native wage effects become negative as would be expected. Although immigrants are concentrated at the extremes of the native wage distribution they do not seem to be so to anything like the extent necessary to make large positive equilibrium mean wage effects plausible.

For comparison, we also consider a more extreme case where immigrants are taken to be concentrated entirely (and therein evenly spread) in the lower half of the distribution of native abilities. This alternative scenario (in the columns headed 'Extreme') does generate larger effects, showing that the argument for large equilibrium effects would be sustainable for more extreme configurations of

immigrant abilities. It may be, of course, that immigrants do differ from natives not so much in their distribution across percentiles of the native wage distribution but across labour types *within* percentiles and that the divergence between the native and immigrant ability distributions is therefore more extreme than Figure 1 suggests. This argument is similar to that made by Ottaviano and Peri (2006) regarding the imperfect substitutability of native and immigrant labour within observed skill cells. However, it remains difficult to argue that the conventional equilibrium immigration surplus accounts alone for mean wage effects of the magnitude estimated.

6.2 Labour market disequilibrium

The above illustration seeks to rationalise the extent to which positive mean wage effects can occur within an equilibrium framework. The native wage gains which might occur under the assumption of highly elastic capital supply are second order, which is inevitable if immigrant labour is paid the value of its marginal product at the margin. In this section we explore an alternative possible explanation based on an assumption of disequilibrium in the allocation of native labour across markets.

The argument is similar to Borjas (2001) who suggests that immigration may "grease the wheels" of the labour market. The idea is that sluggish responsiveness of the native labour allocation to economic signals, because of costs of internal migration between localities or sectors, may create scope for immigration to realise efficiency gains. If the marginal product of identical labour differs in different submarkets of the economy then there is scope for reallocation of labour across submarkets to lead to greater output. If mechanisms exist whereby inflows of relatively mobile immigrants are attracted towards those submarkets where labour is more productive (see Jaeger 2007b) then such inefficiencies can be eliminated. However, provided immigrants are paid the value of their marginal products (as Borjas assumes), the associated gains are captured by immigrants rather than flowing to native labour.

Now consider the possibility that wages deviate from the values of marginal products. This may happen for instance because labour market

agreements impose equality of wages across regions or occupations or because wages are rigid and local demand conditions lead to differences in the productivity of identical labour. It is quite plausible that this characterises many pre-migration situations.

More formally, suppose production is ***F(n,K).*** We can think in this context of labour types corresponding not only to different skills but to different locations and occupations. The difference at the margin between the contribution of immigration to the value of production and payments made to migrants, per native worker, is

$$\frac{1}{N}\sum_i\left(\frac{\partial F}{\partial n_i}-w_i\right)\frac{\partial n_i}{\partial m}=\sum_i\left(\frac{\partial F}{\partial n_i}-w_i\right)\pi_i^1 .$$

If we allow that the economy is out of equilibrium so that marginal products and wages can diverge then this expression can be positive. Indeed in this case it is possible that a simple proportional expansion of native labour could generate a surplus

$$\sum_i\left(\frac{\partial F}{\partial n_i}-w_i\right)\pi_i^0\equiv\delta\neq 0,$$

although if we assume constant returns to scale, capital stocks which adjust elastically to keep marginal product of capital equal to a constant rate of return and zero profits[28] then $\delta=0$.

Immigration creates a first order surplus greater than would a comparable expansion of the native labour force if

$$\sum_i\left(\frac{\partial F}{\partial n_i}-w_i\right)\pi_i^1-\delta=\sum_i\left(\frac{\partial F}{\partial n_i}-w_i\right)\left(\frac{\pi_i^1}{\pi_i^0}-1\right)\pi_i^0>0$$

[28] Given constant returns to scale, Euler's theorem guarantees $\sum_i\left(\frac{\partial F}{\partial n_i}-w_i\right)n_i^0=F(n,K)-K\frac{\partial F}{\partial K}-\sum_i w_i n_i^0$ which must be zero if capital is paid the value of its marginal product and profits are zero.

so that the covariance, across the native wage distribution, between disequilibrium wage gaps $\left(\frac{\partial F}{\partial n_i} - w_i\right)$ and intensity of immigration $\frac{\pi_i^1}{\pi_i^0}$ is positive. Hence, assuming $\delta = 0$, immigration would generate a surplus if there were skill shortages which attracted strong immigrant inflows. This could happen for example if there were labour market institutions fixing relative wages across different locations or occupations independently of differences in productivity and if no mechanism were to exist to direct native labour adequately towards areas or occupations of high productivity relative to wages.

We can use these observations to put a bound on the magnitude of wage gaps required before immigration in order for this to rationalise the magnitude of average wage effects observed. By the Cauchy-Schwarz inequality

$$\left[\sum_i \left(\frac{\partial F}{\partial n_i} - w_i\right)\left(\frac{\pi_i^1}{\pi_i^0} - 1\right)\pi_i^0\right]^2 \leq \sum_i \left(\frac{\partial F}{\partial n_i} - w_i\right)^2 \pi_i^0 \sum_i \left[\left(\frac{\pi_i^1}{\pi_i^0}\right)^2 - 1\right]\pi_i^0$$

and therefore

$$\sqrt{\sum_i \left(\frac{\partial F}{\partial n_i} - w_i\right)^2 \pi_i^0} \geq \frac{1}{\sqrt{\chi_{10}^2}}\left[\sum_i \left(\frac{\partial F}{\partial n_i} - w_i\right)\pi_i^1 - \delta\right]$$

where $\chi_{10}^2 \equiv \sum_i \left[\left(\frac{\pi_i^1}{\pi_i^0}\right)^2 - 1\right]\pi_i^0$ is the chi-square divergence between the distributions of immigrant and native labour. To the extent that we can estimate χ_{10}^2 we can therefore bound the standard deviation of prior wage gaps $\left(\frac{\partial F}{\partial n_i} - w_i\right)$ given an estimate of the average wage effect $\sum_i \left(\frac{\partial F}{\partial n_i} - w_i\right)\pi_i^1 - \delta$.

If we identify wage types with percentiles of the native wage distribution then Figure 1 provides estimates of $\frac{\pi_i^1}{\pi_i^0}$ from which an estimate of χ_{10}^2 can indeed be calculated[29]. Any such estimate will be somewhat sensitive to the bandwidth used in density estimation. If we concentrate on immigrants arriving in the previous two years then a sensible range of bandwidths suggests values for χ_{10}^2 around 0.3 which suggests, assuming $\delta = 0$, required wage gaps around 3 times the estimated average wage effect, which is quite large.

As noted above when discussing the conventional equilibrium surplus, this may be misleadingly high, however, if the inefficiency in allocation of native labour is not predominantly across labour types at different percentiles of the wage distribution but across labour types differing in unobserved ways at similar points in the wage distribution. The extreme scenario considered in section 6.1, for comparison, would give the larger value $\chi_{10}^2 = 1$ implying wage gaps of smaller magnitude, similar in size to the estimated wage effect.

6.3 Downgrading

A third possible explanation, and one requiring no divergence between wages and marginal products in the native population, is simply that wages paid to immigrants fail to recognise their marginal product, perhaps because of allocation to jobs inappropriate to their true skills. We observed in Section 3.3 that there is evidence of considerable downgrading among immigrants, particularly in earlier years of residence. If, because say of uncertainties or informational difficulties leading to problems in recognition of qualifications, recent immigrants find occupation in jobs in which they are more productive than native co-workers but are nonetheless paid at wage rates equal to natives then it is evident that this also will generate a first order surplus. Such an effect would be expected to be

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[29] For each immigrant *k* of the *K* in the data let $\hat{f}_k$ denote a consistent estimate of the density of immigrants at the corresponding point in the native wage distribution, ie π_i^1 / π_i^0 where immigrant *k* is of type *i*. Then $\frac{1}{K}\sum_k \hat{f}_k - 1$ is a consistent estimate of $\chi_{10}^2 \equiv \sum_i \left(\frac{\pi_i^1}{\pi_i^0} \right) \pi_i^1 - 1$.

temporary as the mismatch is alleviated over time as immigrants move to more suitable jobs.

Let us think of different labour types as corresponding to different occupations and suppose we allow that native and immigrant labour may no longer be equally productive so that $\frac{\partial F}{\partial n_i^0} \neq \frac{\partial F}{\partial n_i^1}$ because, for example, of employment of immigrant labour in inappropriately low-skilled jobs. Immigrants and natives are nonetheless paid equal wages in the same occupation determined by native productivity. Immigration now generates a surplus $\sum_i \left(\frac{\partial F}{\partial n_i^0} - w_i \right) \pi_i^0 = \sum_i \left(\frac{\partial F}{\partial n_i^0} - \frac{\partial F}{\partial n_i^1} \right) \pi_i^0 \neq 0$ which will, under assumptions of zero profits, be returned to native factors.

Wages paid to immigrants are observed. The difficulty in estimating the possible magnitude of any such effect is in estimating immigrants' true marginal products $\frac{\partial F}{\partial n_i^0}$. To the extent that underpayment may be related to downgrading, one possible approach would be to compare their wages with those earned by natives with similar levels of education and age, say $\tilde{w}_i$, as estimated by wage regressions in the native population, calculating the surplus as $\sum_i \left(\tilde{w}_i - w_i \right) \pi_i^0$. The precise size of potential surplus estimated by such an approach depends on the precise specification of the native wage regression[30]. Our estimates that allow for heteroscedasticity across individuals give a surplus per immigrant equal to about 0.137 of the mean native wage. This is an appreciable fraction, between a third and a half, of the positive effect we are seeking to explain.

[30] We run separate native log-wage regressions by gender and year, and include as regressors five age categories (16/25, 26/35, 36/45, 46/55, 56/65), four educational categories, based on age at which individuals left full time education (before 16, 16/18, 19/20, after 20), interactions between the two, a dummy for London residents, and quarter dummies. Based on these estimated coefficients, we predict for every immigrant the wage of an identical native individual and take the difference between this and the actual wage. We then add up all the differences and express this as a share of the total native wage bill. The obtained value is then rescaled by dividing by the ratio of immigrants to natives in the population.

7. Discussion and Conclusions

Upon arrival, immigrants may work in jobs or occupations that do not correspond to their observed skill distribution. We demonstrate that this "downgrading" is substantial for the case of the UK, and positions recent immigrants at different percentiles of the native wage distribution as to where we would expect them based on their observed skills. Based on a nested CES framework with a large number of skill groups and capital, we derive an estimator that determines the effect of immigration along the *distribution* of native wages. Our approach is flexible, in the way that it does not necessitate pre-allocation of immigrants to particular groups, and relies on estimating the impact of immigration for different percentiles of the native wage distribution.

In our setting, immigration may have differential effects along the native wage distribution, with some workers gaining, and others losing. In particular, immigration should lead to wage pressure at those parts of the native wage distribution where immigrants are relatively more "dense", and to gains where immigrants are less "dense". Where in the distribution of native wages immigration leads to wage pressure is in our view the interesting research question. In particular, the estimated effect is a combination of the relative density of immigrants at the particular point of the distribution of native wages, which determines the sign of the immigration effect at that part in the distribution, and structural model parameters.

The results we obtain are remarkably in line with what we should expect given the actual density of immigrants along the distribution of natives, and what our simple empirical model suggests. We find that immigration leads to a decrease in wages at those parts of the distribution where the relative density of immigrants is higher than the relative density of natives. On the other hand, it leads to a slight increase in native wages at parts of the distribution where the opposite is the case. On average over the distribution of natives, we find that immigration, over the period considered, leads to a slight increase in average wages.

We then investigate possible reasons for the positive average wage effects we obtain. We note that even in a simple one industry model, where the only

adjustment mechanism to changes in skill mix are wages, average wages need not to decrease if capital supply is sufficiently elastic. Moreover, with elastic capital supply and finite immigration, the immigration surplus will be distributed among native workers, so that the average wage effect may well be positive. Simulating the magnitude of the surplus reveals however that the wage effects we obtain are too large to be explained by this surplus.

We suggest two other reasons for a migration surplus. First, in the presence of wage stickiness, changes in demand conditions may create a situation where the wage received differs from the marginal product of labour within particular skill groups. If immigrants tend to allocate to labour markets where this difference is large, then this may lead to a surplus which may partly go to native labour. Secondly, if immigrants downgrade (as we demonstrate in our data), and work for wages which are below their marginal productivity, then this may again lead to a surplus, where native workers are the beneficiaries. Our simulations suggest that both explanations may contribute to the overall positive wage effect we observe.

Our analysis adds a number of important insights to the academic debate on the impact of immigration. First, we would like to argue that estimates of wage effects along the distribution of native wages are useful and important parameters, as it clearly reveals the impact immigration has on workers positioned across the distribution. These effects may be masked if concentrating on mean effects, or on effects between skill groups. Further, the approach we suggest has the added advantage that it does not require any pre-allocation of immigrants to skill groups. Finally, the parameters have a clear-cut interpretation as they translate the relative density of immigrants along the native distribution in effect on wages at that part of the distribution. As we show, the correspondence between these two independent parts of evidence is remarkable.

The average effects on wages that we find are positive. We do not believe that positive effects are surprising; they should perhaps be expected if we deviate from some assumptions that are often made in the literature. First, we note that in the simplest possible model, negative average wage effects are only to be expected if capital is a fixed factor – which may well be a too restrictive assumption, in particular given the openness of small economies like the UK, and

when accommodating the relatively small inflows of immigrants that are usually considered in studies that estimate immigration effects. Secondly, we suggest that perhaps labour markets are not in perfect equilibrium when immigration occurs. It seems not unreasonable to think that wage stickiness may lead to wages being different from marginal productivity of particular skill groups. Further, and compatible with the substantial downgrading we observe for new immigrant cohorts in our data, immigrants may well receive wages that are below their marginal productivity, at least in the first periods after their arrival. This alone could lead to quite substantial surpluses which may benefit native wages, as our simulations show.

References

Aydemir, Abdurrahman and George J. Borjas (2006), "Attenuation Bias in Measuring the Wage Impact of Immigration", Working Paper, Harvard University, July 2006.

Altonji, Joseph G. and David Card (1991), "The effects of immigration on the labor market outcomes of less-skilled natives", in: John M. Abowd and Richard B. Freeman, (eds.), *Immigration, trade and the labor market*, University of Chicago Press, 201–234

Bartel, Ann P. (1989), "Where Do the New United-States Immigrants Live", *Journal of Labor Economics*, 7 (4), 371-391

Borjas, George J. (2001), "Does Immigration Grease the Wheels of the Labor Market?", *Brookings Papers on Economic Activity*, 2001 (1), 69-119

Borjas, George J. (2003), "The Labor Demand Curve Is Downward Sloping: Reexamining The Impact Of Immigration On The Labor Market", *The Quarterly Journal of Economics*, 118(4), 1335-1374.

Borjas, G. J., Freeman, R.B. and L.F. Katz (1997), "How Much Do Immigration and Trade Affect Labor Market Outcomes?", *Brookings Papers on Economic Activity*, no. 1, 1-67.

Borjas, G. J., Grogger, J. and G.H. Hanson (2008), "Imperfect Substitution between Immigrants and Natives: A Reappraisal", NBER Working Paper No.13887, National Bureau of Economic Research.

Card, David (2001), "Immigrant Inflows, Native Outflows and the Local Labor Market Impacts of Immigration", *Journal of Labor Economics*, Vol. 19 (1), 22-64.

Card, David (2005), "Is the New Immigration Really so Bad?", *Economic Journal*, vol. 115(507), F300-F323.

Card, David (2007), "How Immigration Affects US Cities", CReAM Discussion Paper Series, No. 11/07.

Card, David (2008), "Local Labor Market Adaptation to Increased Immigration", mimeo, University of Berkeley.

Card, David and John DiNardo, J. (2000) "Do Immigrant Inflows Lead to Native Outflows?" *American Economic Review*, Vol. 90 (2), 360-367.

Card, David and Ethan Lewis (2007), "The Diffusion of Mexican Immigrants during the 1990s: Explanations and Impacts", in George J. Borjas (editor), *Mexican Immigration*, Chicago: University of Chicago Press (for NBER).

Cortes, Patricia (2006), "The Effect of Low-skilled Immigration on U.S. Prices: Evidence from CPI Data", Manuscript, University of Chicago, October 2006.

Cortes, Patricia and Jose Tessada (2007), "Cheap Maids and Nannies: How Low-skilled Immigration is changing the labor supply of High-skilled American Women", Manuscript, University of Chicago and MIT, August 2007.

D'Amuri, F., Ottaviano, G.I. and G. Peri (2008), "The Labor Market Impact of Immigration in Western Germany in the 1990's", NBER Working Paper No.13851, National Bureau of Economic Research.

Dustmann, C., Fabbri, F. and I. Preston (2005), "The Impact of Immigration on the British Labour Market", *Economic Journal*, vol. 115(507), F324-F341.

Eckstein, Zvi and Yoram Weiss (2004), “On the Wage Growth of Immigrants: Israel 1990-2000”, *Journal of the European Economic Association*, 2(4), 665–695.

Friedberg, Rachel M. (2001), “The Impact of Mass Migration on the Israeli Labor Market”, *The Quarterly Journal of Economics*, 116(4), 1373-1408.

Glitz, Albrecht (2006), “The Labour Market Impact of Immigration: Quasi-Experimental Evidence“, CReAM DP 12/06

Jaeger, David A. (2007a), “Skill Differences and the Effect of Immigrants on the Wages of Natives”, mimeo, College of William and Mary.

Jaeger, David A. (2007b), “Green Cards and the Location Choices of Immigrants in the United States, 1971-2000”, *Research in Labor Economics*, 27, 131-183.

Leamer, Edward E. and James Levinsohn (1995), "International Trade Theory: The Evidence", in Handbook of International Economics, Volume 3, edited by G. M. Grossman and K. Rogoff, North Holland Press, 1339-1394.

Lewis, Ethan (2004), “Local Open Economies within the US: How Do Industries Respond to Immigration”, Federal Reserve Bank of Philadelphia Working Paper No. 04-1.

Lewis, Ethan (2005), “Immigration, Skill Mix, and the Choice of Technique”, Federal Reserve Bank of Philadelphia Working Paper 05-08.

Manacorda, M., Manning, A. and J. Wadsworth (2006), “The Impact of Immigration on the Structure of Male Wages: Theory and Evidence from Britain”, CReAM Discussion Paper Series, No.08/06.

Munshi, Kaivan (2003), “Networks in the Modern Economy: Mexican Migrants in the US Labor Market”, *The Quarterly Journal of Economics*, 118(2), 549-599.

Ottaviano, Gianmarco I.P. and Giovanni Peri (2005), “Rethinking the Gains from Immigration: Theory and Evidence from the U.S”, NBER Working Paper No. 11672, National Bureau of Economic Research.

Ottaviano, Gianmarco I.P. and Giovanni Peri (2006), “Rethinking the Effects of Immigration on Wages”, NBER Working Paper No. 12497, National Bureau of Economic Research.

Ottaviano, Gianmarco I.P. and Giovanni Peri (2007), “The effects of Immigration on U.S. Wages and Rents: A General Equilibrium Approach”, CReAM Discussion Paper Series, No 13/07.

Peri, Giovanni (2007), “Immigrants' Complementarities and Native Wages: Evidence from California”, NBER Working Paper No.12956, National Bureau of Economic Research,

Saiz, Albert (2003) “Immigration and Housing Rents in American Cities”, *Journal of Urban Economics*, Vol.61 (2), 345–371.

Appendix A.1: General theory

We start with as general a setting as possible. Suppose the economy consists of many firms producing many outputs using many inputs. Specifically, suppose the i^{th} firm produces outputs $\boldsymbol{y_i}$ using capital inputs $\boldsymbol{k_i}$ and labour inputs $\boldsymbol{l_i}$, where each of these can be a vector of any length, according to technological restrictions specifying that the output plan $\boldsymbol{(y_i,k_i,l_i)}$ lies in some technology set. We assume technology obeys constant returns to scale, outputs are sold at fixed world prices $\boldsymbol{p}$ and capital inputs are elastically supplied at world capital prices $\boldsymbol{r}$. Wages are denoted $\boldsymbol{w}$.

Individual firms maximise profits taking prices as given so that economy-wide profit $\boldsymbol{p\cdot y-r\cdot k-w\cdot l}$ is maximised at the given prices where $\boldsymbol{y=\Sigma_i y_i}$, $\boldsymbol{k=\Sigma_i k_i}$ and $\boldsymbol{l=\Sigma_i l_i}$. Equilibrium profits of zero are assured by the assumption of constant returns to scale.

Wages are determined to equate aggregate demand for labour $\boldsymbol{l}$ to aggregate supply. Before immigration aggregate supply is $\boldsymbol{n^0}$ where $\boldsymbol{n^0}$ is native labour and after immigration it is $\boldsymbol{n=n^0+n^1}$ where $\boldsymbol{n^1}$ is immigrant labour.

Let $\boldsymbol{y^0}$ and $\boldsymbol{k^0}$ be the equilibrium outputs and capital inputs and $\boldsymbol{w^0}$ be the equilibrium wages before immigration and let $\boldsymbol{y}$ and $\boldsymbol{k}$ be the equilibrium outputs and capital inputs and $\boldsymbol{w}$ be the equilibrium wages after immigration.

By the assumption, given constant returns to scale, that profits are maximised at zero before and after immigration

$$\boldsymbol{0 = p\cdot y^0-r\cdot k^0-w^0\cdot n^0 \geq p\cdot y-r\cdot k-w^0\cdot n} \qquad \text{(A.2-1)}$$

and

$$\boldsymbol{0 = p\cdot y-r\cdot k-w\cdot n \geq p\cdot y^0-r\cdot k^0-w\cdot n^0.} \qquad \text{(A.2-2)}$$

Hence, by subtraction of the rightmost expression in (A.2-2) from the leftmost expression in (A.2-1)

$$\Delta w \cdot n^0 \geq 0 \qquad \text{(A.2-3)}$$

which is to say the average wage of natives cannot fall. If wages change at all, average native wages must rise. This is the immigration surplus. It arises because demand curves for labour cannot slope up and immigrants are therefore paid no more than the value of their addition to output. Given that profits are zero, the resulting surplus is returned to existing factors and, given perfectly elastic supply of capital, payments to existing labour must rise.[31]

Furthermore, by subtraction of the leftmost expression in (A.2-2) from the rightmost expression in (A.2-1)

$$\Delta w \cdot n \leq 0. \qquad \text{(A.2-4)}$$

Note here that if n is proportional to n^0, so that immigrant skill composition is the same as that in the existing population, then (A.2-3) and (A.2-4) can both be true only if $\Delta w=0$ so there are necessarily no changes to equilibrium wages (and consequently also no surplus).

This is not the only case in which wage changes are zero. If the number of output types produced is the same as the number of labour types before and after immigration then immigration should also lead to no change in equilibrium wages (see Leamer and Levinsohn 1995).

Further, by subtraction of (A.2-3) from (A.2-4) ,

$$\Delta w \cdot n^1 \leq 0 \qquad \text{(A.2-5)}$$

Hence, given $n^1>0$, if wages do change then equilibrium wages must fall for some types. The inequality in (A.2-5) shows the sense in which these falls must tend to be greater where immigration is most intense.

[31] If capital is less than perfectly elastically supplied then some of the surplus may go to capital and it can be said only that existing inputs as a whole gain.

Appendix A.2: CES Production

Wage determination

Production technology takes the nested CES form

$$y = \left[\beta H^s + (1-\beta) K^s \right]^{1/s}$$
$$H = N \left[\sum_i \alpha_i \left(\pi_i^0 + \pi_i^1 m \right)^\sigma \right]^{1/\sigma} \qquad \text{(A.1-1)}$$

Equilibrium values of wages w_i and return to capital ρ are given by the value of the respective marginal products

$$\ln w_i = \ln \beta \alpha_i + (\sigma - 1) \ln(\pi_i^0 + \pi_i^1 m) + (1-\sigma) \ln\left(\frac{H}{N}\right) + \left(\frac{1}{s} - 1\right) \ln\left[\beta + (1-\beta)\left(\frac{K}{H}\right)^s \right] \qquad \text{(A.1-2)}$$

$$\ln \rho = \ln(1-\beta) + (s-1) \ln\left(\frac{K}{H}\right) + \left(\frac{1}{s} - 1\right) \ln\left[\beta + (1-\beta)\left(\frac{K}{H}\right)^s \right] \qquad \text{(A.1-3)}$$

First order effect of immigration on the wage distribution

Differentiating these expressions gives

$$\frac{d \ln w_i}{dm} = (\sigma - 1) \frac{\pi_i^1}{\pi_i^0 + \pi_i^1 m} + (1-\sigma) \frac{d \ln H}{dm} + (1-s)(1-\psi) \left(\frac{d \ln K}{dm} - \frac{d \ln H}{dm} \right)$$
$$\frac{d \ln H}{dm} = \sum_i \frac{\alpha_i \pi_i^1 (\pi_i^0 + \pi_i^1 m)^{\sigma-1}}{\sum_j \alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma} = \sum_i \omega_i \frac{\pi_i^1}{\pi_i^0 + \pi_i^1 m}$$
$$\frac{d \ln \rho}{dm} = -(1-s)\psi \left(\frac{d \ln K}{dm} - \frac{d \ln H}{dm} \right)$$

where $\omega_i = \dfrac{\alpha_i (\pi_i^0)^\sigma}{\sum_j \alpha_j (\pi_j^0)^\sigma}$ is share of the *i*th type in the labour aggregate H^σ and

$\psi = \dfrac{\beta H^s}{\beta H^s + (1-\beta) K^s}$ is share of labour in the CES aggregate y^s.

Letting $\dfrac{d \ln K}{dm} = \theta \dfrac{d \ln \rho}{dm}$, where θ is the elasticity of supply of capital, we can substitute into the expression for $\dfrac{d \ln \rho}{dm}$ to get

$$\frac{d\ln\rho}{dm}=\frac{(1-s)\psi}{1+(1-s)\psi\theta}\frac{d\ln H}{dm}$$

and thus

$$\begin{aligned}\frac{d\ln w_i}{dm}&=(\sigma-1)\frac{\pi_i^1}{\pi_i^0+\pi_i^1 m}+(1-\sigma)\frac{d\ln H}{dm}+\frac{1}{\psi}(1-\psi)\frac{d\ln\rho}{dm}\\&=(\sigma-1)\left(\frac{\pi_i^1}{\pi_i^0+\pi_i^1 m}-\left[1-\frac{(1-s)(1-\psi)}{1+(1-s)\psi\theta}\frac{1}{(\sigma-1)}\right]\frac{d\ln H}{dm}\right)\\&=(\sigma-1)\left(\frac{\pi_i^1}{\pi_i^0+\pi_i^1 m}-\phi\sum_j\frac{\alpha_j(\pi_j^0+\pi_j^1 m)^\sigma}{\sum_k\alpha_k(\pi_k^0+\pi_k^1 m)^\sigma}\frac{\pi_j^1}{\pi_j^0+\pi_j^1 m}\right)\end{aligned}$$

where $\phi=1+\left[\frac{(1-s)(1-\psi)}{1+(1-s)\psi\theta}\right]\frac{1}{\sigma-1}\le 1.$ Notice that $\phi=1$ if there is perfectly elastic supply of capital ($\theta=\infty$), perfect substitutability of capital and labour ($s=1$) or capital share is zero ($\psi=1$).

If we set $m=0$ then we get

$$\left.\frac{d\ln w_i}{dm}\right|_{m=0}=(\sigma-1)\left(\frac{\pi_i^1}{\pi_i^0}-\phi\sum\omega_j\frac{\pi_j^1}{\pi_j^0}\right)\qquad\text{(A.1-3)}$$

First order effect of immigration on the mean native wage

From (A.1-2), at $m=0$, $w_i\pi_i^0=\omega_i\overline{w}^0$ where $\overline{w}^0$ denotes the mean wage at $m=0$. Hence the first order effect of immigration on mean wages in the preexisting population is

$$\left.\frac{d\sum w_i\pi_i^0}{dm}\right|_{m=0}=\sum_i\pi_i^0 w_i\left.\frac{d\ln w_i}{dm}\right|_{m=0}=(\sigma-1)(1-\phi)\overline{w}^0\sum\omega_i\frac{\pi_i^1}{\pi_i^0}\le 0.\qquad\text{(A.1-4)}$$

This is nonpositive since $\sigma\le 1$ and $\phi\le 1$ and equals zero iff $\phi=1$ or $\sigma=1$.

First order effect of immigration on the wage of competing labour

The first order effect on mean wages of a population composed similarly to immigrants is

$$\begin{aligned}\left.\frac{d\sum w_i\pi_i^1}{dm}\right|_{m=0}&=\sum_i\frac{\pi_i^1}{\pi_i^0}\pi_i^0 w_i\left.\frac{d\ln w_i}{dm}\right|_{m=0}\\&=(\sigma-1)\overline{w}^0\left[\sum\omega_i\left(\frac{\pi_i^1}{\pi_i^0}\right)^2-\phi\left(\sum\omega_i\frac{\pi_i^1}{\pi_i^0}\right)^2\right]\le 0.\end{aligned}\qquad\text{(A.1-5)}$$

In this case nonpositivity follows from the Cauchy-Schwarz inequality, given $\phi \leq 1$, since

$$\sum \omega_i \left(\frac{\pi_i^1}{\pi_i^0}\right)^2 - \phi\left(\sum \omega_i \frac{\pi_i^1}{\pi_i^0}\right)^2 \geq \sum \omega_i \left(\frac{\pi_i^1}{\pi_i^0}\right)^2 - \left(\sum \omega_i \frac{\pi_i^1}{\pi_i^0}\right)^2 \geq 0,$$

and the first order effect is zero iff either $\phi=1$ and $\pi_i^1 = \pi_i^0$ for all *i* or $\sigma=1$.

Second order effect of immigration on the mean native wage

In the special case that $\phi=1$ it is necessary to turn to second order terms in order to sign the effect of small amounts of immigration:

$$\sum \pi_i^0 \frac{d^2 w_i}{dm^2} = \sum w_i \pi_i^0 \left[\frac{d^2 \ln w_i}{dm^2} + \left(\frac{d \ln w_i}{dm}\right)^2\right]. \qquad \text{(A.1-6)}$$

Given $\phi=1$,

$$\frac{d \ln w_i}{dm} = (\sigma - 1)\left(\frac{\pi_i^1}{\pi_i^0 + \pi_i^1 m} - \sum_j \frac{\alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma}{\sum_k \alpha_k (\pi_k^0 + \pi_k^1 m)^\sigma} \frac{\pi_j^1}{\pi_j^0 + \pi_j^1 m}\right)$$

and therefore

$$\frac{d^2 \ln w_i}{dm^2} = (\sigma - 1)\left(\begin{array}{l} -\left(\frac{\pi_i^1}{\pi_i^0 + \pi_i^1 m}\right)^2 - (\sigma - 1)\sum_j \frac{\alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma}{\sum_k \alpha_k (\pi_k^0 + \pi_k^1 m)^\sigma}\left(\frac{\pi_j^1}{\pi_j^0 + \pi_j^1 m}\right)^2 \\ \qquad + \sigma\left(\sum_j \frac{\alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma}{\sum_k \alpha_k (\pi_k^0 + \pi_k^1 m)^\sigma} \frac{\pi_j^1}{\pi_j^0 + \pi_j^1 m}\right)^2 \end{array}\right)$$

$$\left(\frac{d \ln w_i}{dm}\right)^2 = (\sigma - 1)^2\left(\begin{array}{l} \left(\frac{\pi_i^1}{\pi_i^0 + \pi_i^1 m}\right)^2 - 2\left(\frac{\pi_i^1}{\pi_i^0 + \pi_i^1 m}\right)\sum_j \frac{\alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma}{\sum_k \alpha_k (\pi_k^0 + \pi_k^1 m)^\sigma} \frac{\pi_j^1}{\pi_j^0 + \pi_j^1 m} \\ \qquad + \left(\sum_j \frac{\alpha_j (\pi_j^0 + \pi_j^1 m)^\sigma}{\sum_k \alpha_k (\pi_k^0 + \pi_k^1 m)^\sigma} \frac{\pi_j^1}{\pi_j^0 + \pi_j^1 m}\right)^2 \end{array}\right)$$

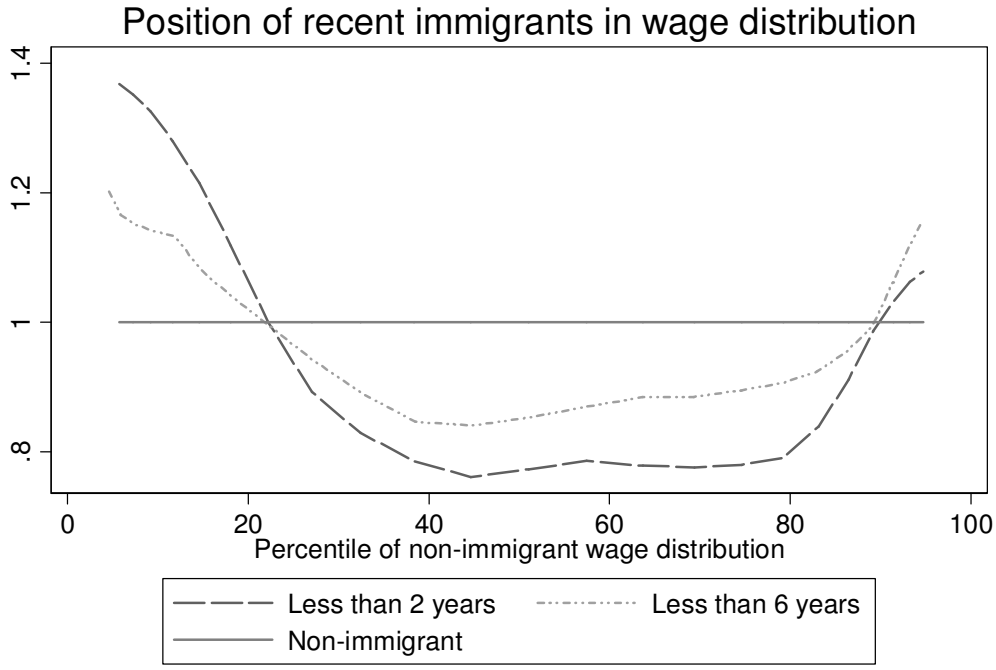
Substituting into (A.1-6), summing and simplifying for the case *m*=0, gives

$$\begin{aligned} \sum \pi_i^0 \left.\frac{d^2 w_i}{dm^2}\right|_{m=0} &= \sum w_i \pi_i^0 \left.\left[\frac{d^2 \ln w_i}{dm^2} + \left(\frac{d \ln w_i}{dm}\right)^2\right]\right|_{m=0} \\ &= (1-\sigma)\overline{w}^0 \left[\sum \omega_i \left(\frac{\pi_i^1}{\pi_i^0}\right)^2 - \left(\sum \omega_i \frac{\pi_i^1}{\pi_i^0}\right)^2\right] \geq 0 \end{aligned} \qquad \text{(A.1-7)}$$

which is positive provided the skill composition of immigrants differs from the pre-existing population, again by the Cauchy-Schwarz inequality. Furthermore the size of the second order effect on mean wages is evidently greater the greater the dissimilarity.

Figures

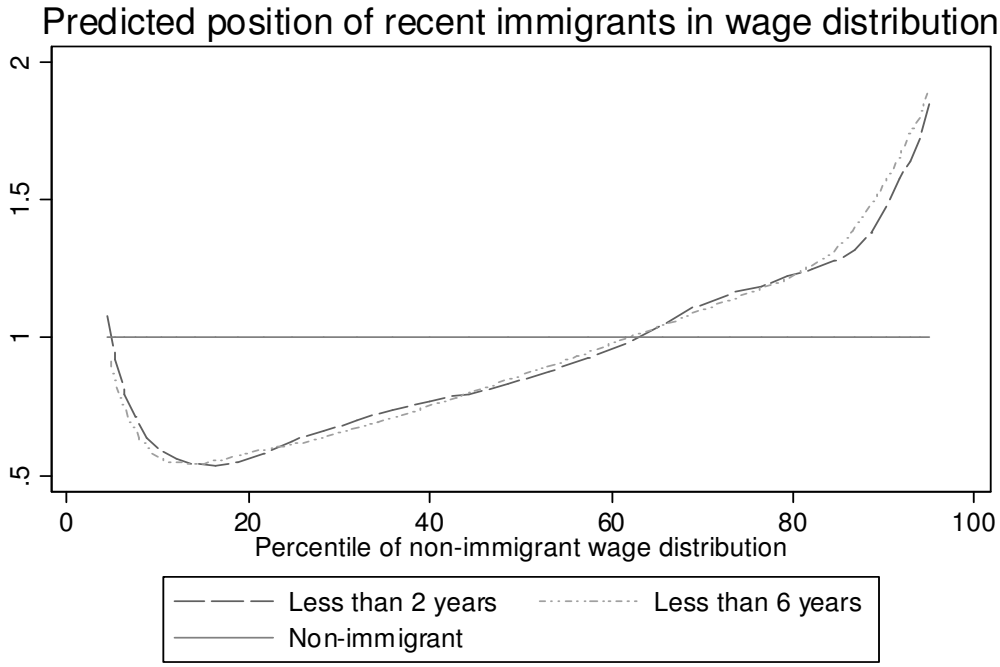
Figure 1



Source: LFS, various years

The figure shows kernel estimates of the density of immigrants who arrived within the last two (dashed line) or six (dotted line) years in the non-immigrant wage distribution. The horizontal line shows as a reference the non-immigrant wage distribution The kernel estimates are above the horizontal line at wages where immigrants are more concentrated than natives, and below the horizontal line at wages where immigrants are less concentrated than natives.

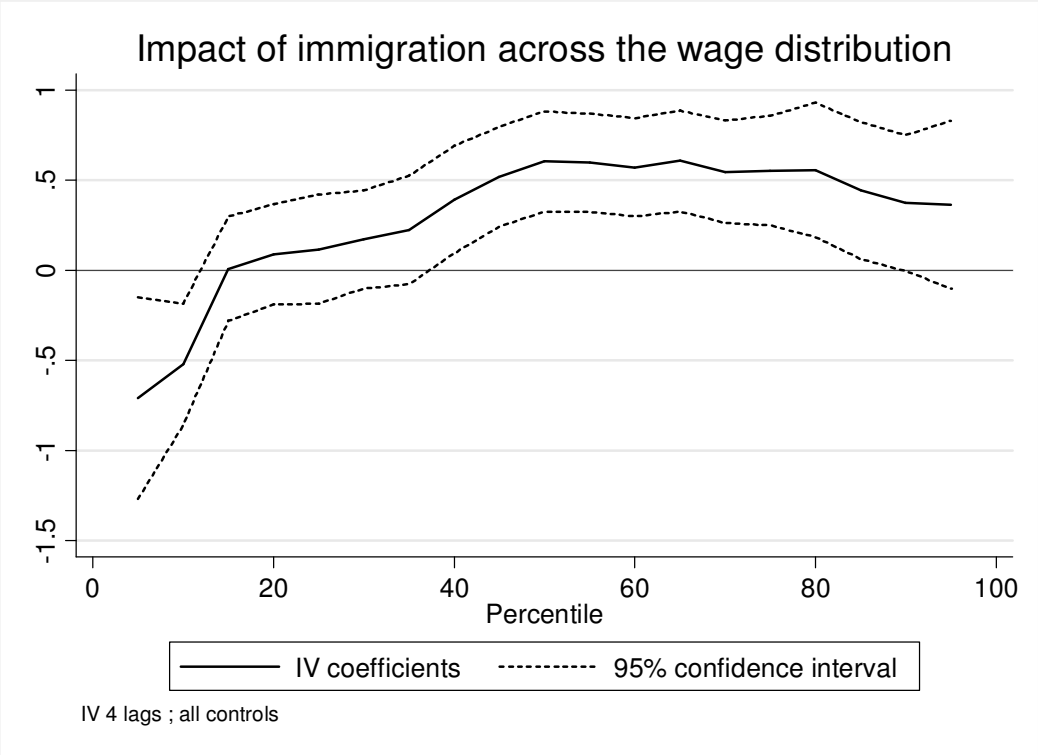
Figure 2



Source: LFS, various years

The figure shows kernel estimates of the predicted density of immigrants who arrived within the last two (dashed line) or six (dotted line) years in the non-immigrant wage distribution. The horizontal line shows as a reference the non-immigrant wage distribution The kernel estimates are above the horizontal line at wages where immigrants are more concentrated than natives, and below the horizontal line at wages where immigrants are less concentrated than natives. See text for details about wage prediction.

Figure 3



The figure reports the estimated IV regression coefficients and the 95% confidence interval from a difference regression of each wage percentile from the 5th to the 95th percentile in intervals of 5 percentage points on the ratio of immigrants to natives for years 1997/2005 and time dummies Instrumental variable is the fourth lag of the ratio of immigrants to natives

Tables

Table 1 – Average age, gender ratio, and education in 1997 and 2005

	Natives		***Foreign Born***			
			Earlier		***Recent***	
	1997	***2005***	***1997***	***2005***	***1997***	***2005***
Age	39.32	40.26	40.44	39.88	28.72	29.09
% Female	50.32	50.64	53.22	52.46	56.42	49.83
Education:						
% High	11.90	16.49	26.00	34.68	49.08	45.60
% Intermediate	23.64	26.76	33.57	34.31	39.91	41.22
% Low	64.46	56.75	40.43	31.01	11.01	13.18

Entries are the average age, the percentage of female, and the share of working age (16-65) natives and immigrants of both sexes in each education group in1997 and 2005.
High education: left full time education at age 21 or later
Intermediate education: left full time education between age 17 and 20 (included)
Low education: left full time education not after age 16, or never had full time education
Source: LFS 1997, 2005

Table 2 – Occupational distribution in 2004 and 2005

	Natives	***Foreign Born***		***Average wage***
		Earlier	***Recent***	
Higher managerial and professional	15.06	21.92	16.99	18.92
Lower managerial and professional	31.45	31.17	20.79	12.99
Intermediate occupations	14.02	10.97	8.79	8.60
Lower supervisory and technical	12.40	9.39	6.59	8.51
Semi-routine occupations	15.88	15.77	21.95	6.62
Routine occupations	11.19	10.78	24.89	6.74

Entries are the share of working age (16-65) natives and immigrants of both sexes in each occupation group in years 2004-2005 pooled.
Average wage is the average wage in the occupation in 2004-2005, expressed in 2005 terms.
Source: LFS 2004,2005

Table 3 - Occupation by level of education in 2004 and 2005

	High education			***Intermediate education***			***Low education***		
	Natives	***Foreign Born***		***Natives***	***Foreign Born***		***Natives***	***Foreign Born***	
		Earlier	***Recent***		***Earlier***	***Recent***		***Earlier***	***Recent***
Higher managerial and professional	36.87	39.63	29.71	15.2	12.59	4.62	7.04	5.75	3.62
Lower managerial and professional	46.84	36.29	29.81	37.41	33.38	13.52	22.7	19.47	6.19
Intermediate occupations	8.51	8.61	9.45	18.56	14.5	9.77	13.61	9.78	1.92
Lower supervisory and technical	2.75	4.43	4.86	9.31	10.08	8.65	17.64	16.74	8.6
Semi-routine occupations	3.83	7.32	14.37	13.4	18.49	29.47	21.47	26.07	29.79
Routine occupations	1.2	3.72	11.79	6.13	10.95	33.97	17.54	22.19	49.88

Entries are the share of working age (16-65) natives and immigrants of both sexes in each occupation group by level of education in 2004-2005 pooled.
Source: LFS 2004, 2005

Table 4 – Test for serial correlation in wage variables

Dependent Variable	*M1*	*M2*
Average Wage	-2.860 p=0.004	0.320 p=0.750
Robust Average Wage	-2.840 p=0.004	-1.190 p=0.233
Wage Index	-2.490 p=0.013	-0.050 p=0.960
Robust Wage Index	-2.590 p=0.010	-1.100 p=0.273
5^{th} Percentile	-3.830 p=0.000	-0.900 p=0.369
10^{th} Percentile	-3.940 p=0.000	0.090 p=0.926
25^{th} Percentile	-3.950 p=0.000	0.440 p=0.661
50^{th} Percentile	-2.370 p=0.018	-2.870 p=0.004
75^{th} Percentile	-1.200 p=0.230	-4.040 p=0.000
90^{th} Percentile	-2.830 p=0.005	-1.500 p=0.132
95^{th} Percentile	-3.410 p=0.001	-0.570 p=0.566

The table reports Arellano-Bond tests for first (M1) and second (M_2) order serial correlation based on residuals from the first differenced equation with all control variables, estimated using the 4^{th} lag of immigrant/native ratio as IV. The test is asymptotically distributed as a normal.

Table 5 – Effect of immigration on wage distribution– impact on different wage percentiles

Dependent Variable	OLS First Differences		IV [1991 Immigration Share] First Differences		IV [4 period lag] First Differences	
	(1)	(2)	(3)	(4)	(5)	(6)
5th Percentile	-0.153	-0.162	-0.688	-0.590	-0.709	-0.604
	(0.373)	(0.374)	(0.271)	(0.272)	(0.283)	(0.281)
10th Percentile	-0.032	-0.076	-0.445	-0.443	-0.523	-0.512
	(0.223)	(0.227)	(0.162)	(0.166)	(0.170)	(0.172)
25th Percentile	0.156	0.091	0.148	0.229	0.117	0.207
	(0.203)	(0.198)	(0.146)	(0.144)	(0.153)	(0.149)
50th Percentile	0.280	0.258	0.616	0.658	0.603	0.655
	(0.185)	(0.183)	(0.135)	(0.134)	(0.141)	(0.139)
75th Percentile	0.386	0.397	0.576	0.640	0.553	0.628
	(0.203)	(0.196)	(0.147)	(0.143)	(0.153)	(0.148)
90th Percentile	0.307	0.323	0.450	0.495	0.374	0.430
	(0.253)	(0.246)	(0.183)	(0.178)	(0.191)	(0.184)
95th Percentile	0.295	0.290	0.427	0.439	0.364	0.384
	(0.312)	(0.315)	(0.225)	(0.228)	(0.235)	(0.236)
Coefficient for IV in first stage regression			0.068	0.068	0.043	0.043
			(0.007)	(0.007)	(0.003)	(0.004)
R^2 for first stage regression			0.352	0.382	0.350	0.377
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes	No	Yes
Observations	136	136	136	136	136	136

Entries are the estimated regression coefficients of the ratio of immigrants to natives in regressions of different natives' wage percentiles on the ratio of immigrants to natives for years 1997-2005.
"Other Controls" include average natives' and immigrants' age, and the logarithm of the ratio of natives in each education group to natives with no qualifications.
Standard errors are reported in parenthesis.

Table 6 – Effect of immigration on average wages

Dependent Variable	OLS First Differences		IV [1991 Immigration Share] First Differences		IV [4 period lag] First Differences	
	(1)	(2)	(3)	(4)	(5)	(6)
Average	0.309	0.292	0.373	0.433	0.319	0.393
	(0.181)	(0.172)	(0.131)	(0.125)	(0.136)	(0.129)
Robust average	0.317	0.304	0.473	0.531	0.422	0.489
	(0.156)	(0.150)	(0.113)	(0.110)	(0.117)	(0.113)
Wage index	0.248	0.260	0.229	0.301	0.199	0.274
	(0.162)	(0.159)	(0.117)	(0.115)	(0.122)	(0.119)
Robust index	0.258	0.275	0.334	0.399	0.302	0.365
	(0.134)	(0.132)	(0.097)	(0.096)	(0.101)	(0.099)
Coefficient for IV in first stage regression			0.068	0.068	0.043	0.043
			(0.007)	(0.007)	(0.003)	(0.004)
R^2 for first stage regression			0.352	0.382	0.350	0.377
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes	No	Yes
Observations	136	136	136	136	136	136

Entries are the estimated regression coefficients of the ratio of immigrants to natives in regressions of different measures of natives' average wages on the ratio of immigrants to natives for years 1997-2005. Robust average wages are computed by trimming the wage distribution at the (region- and year-specific) top and bottom percentile .The wage index is the weighted log sum of the average wage of each education group, using time invariant weights. Its robust version uses the trimmed distribution to compute education-specific averages.
"Other Controls" include average natives' and immigrants' age, and the logarithm of the ratio of natives in each education group to natives with no qualifications.
Standard errors are reported in parenthesis.

Table 7 - Simulated mean wage effects

Elasticity of supply of capital θ	Elasticity of substitution between labour types $1/(1-\sigma)$	Elasticity of substitution between capital and labour $1/(1-s)$	Ability distribution of immigrants			
			Observed		Extreme	
			m=0.01	*m=0.1*	*m=0.01*	*m=0.1*
∞	∞	∞,2,1	0.000	0.000	0.000	0.000
	2	∞,2,1	0.000	0.002	0.002	0.201
	1	∞,2,1	0.000	0.005	0.005	0.397
1	∞	∞	0.000	0.000	0.000	0.000
		2	-0.239	-2.240	-0.188	-1.788
		1	-0.321	-3.044	-0.252	-2.422
	2	∞	0.000	0.002	0.002	0.201
		2	-0.239	-2.237	-0.185	-1.539
		1	-0.321	-3.041	-0.248	-2.156
	1	∞	0.000	0.005	0.005	0.396
		2	-0.239	-2.234	-0.182	-1.297
		1	-0.321	-3.038	-0.245	-1.896
0	∞	∞	0.000	0.000	0.000	0.000
		2	-0.299	-2.775	-0.234	-2.219
		1	-0.480	-4.496	-0.377	-3.589
	2	∞	0.000	0.002	0.002	0.201
		2	-0.299	-2.772	-0.231	-1.959
		1	-0.480	-4.492	-0.373	-3.292
	1	∞	0.000	0.005	0.005	0.396
		2	-0.299	-2.768	-0.228	-1.706
		1	-0.480	-4.489	-0.370	-3.002

*Entries are the simulated percentage changes in mean native wage following an inflow of immigrants of magnitude m*native population under different assumptions on the elasticity of capital supply, the elasticity of substitution between labour types and between capital and labour, and the ability distribution of migrants. "Observed" distribution is the distribution estimated in figure 1; "Extreme" distribution assumes all immigrants are evenly spread in the lower half of the distribution of native abilities.*

Table A1 - Effect of immigration on log average natives' wages, different instruments

Instrumental variable	*Average wage* (1)	*Robust Average* (2)
4th lag of immigrant-native ratio	0.319	0.422
	(0.136)	(0.117)
10th lag of immigrant-native ratio	0.330	0.446
	(0.134)	(0.116)
1991 immigrant-native ratio (Census 1991)	0.373	0.473
	(0.131)	(0.113)
1981 immigrant-native ratio (Census 1981)	0.372	0.478
	(0.135)	(0.116)
change 91-81	0.375	0.456
	(0.128)	(0.110)
Predicted inflow by ethnic group (Census 91)	0.222	0.365
	(0.159)	(0.137)
Predicted inflow by ethnic group (LFS 91)	0.237	0.388
	(0.163)	(0.140)
Predicted inflow by ethnic group (LFS 85)	0.184	0.343
	(0.182)	(0.156)
Predicted inflow by ethnic group (LFS 81)	0.205	0.359
	(0.169)	(0.145)

Entries are the estimated IV regression coefficients of the ratio of immigrants to natives in regressions of log average regional wages and robust log average regional wages on the ratio of immigrants to natives for years 1997-2005. The instrumental variable used is described in the first column.
Robust average wages are computed by trimming the wage distribution at the (region- and year-specific) top and bottom percentile.
Standard errors are reported in parenthesis.

Table A2 – Descriptive statistics

Variable	*Mean*	*Std. Dev.*
Log-wages, all natives		
Average hourly pay	2.199	*0.133*
Robust average hourly pay	2.173	*0.132*
Wage index	3.315	*0.143*
Robust wage index	3.315	*0.143*
Average hourly pay, men	2.314	*0.131*
Average hourly pay, women	2.061	*0.142*
Robust average hourly pay, men	2.280	*0.128*
Robust average hourly pay, women	2.047	*0.142*
Log-wages, natives by education group		
Average hourly pay, high	2.637	*0.103*
Average hourly pay, intermediate	2.247	*0.116*
Average hourly pay, low	2.062	*0.105*
Robust average hourly pay, high	2.573	*0.103*
Robust average hourly pay, intermediate	2.221	*0.117*
Robust average hourly pay, low	2.054	*0.106*
Log-wages, earlier immigrants		
Average hourly pay	2.257	*0.146*
Robust average hourly pay	2.202	*0.147*
Natives' log- wage percentiles		
5^{th}	1.266	*0.148*
10^{th}	1.433	*0.129*
25^{th}	1.678	*0.131*
50^{th}	2.022	*0.132*
75^{th}	2.413	*0.134*
90^{th}	2.763	*0.139*
95^{th}	2.970	*0.152*
Immigrant-native ratio	0.088	*0.110*
Annual change in immigrant-native ratio	0.004	*0.008*
Average natives' age	39.881	*0.890*
Average immigrants' age	38.895	*1.961*
ln high educ./low educ.	-1.639	*0.388*
ln intermed. educ./low educ.	-1.032	*0.283*

Entries are the mean value and the standard deviation of the variables used in the analysis, across all regions and years 1997-2005.
Wages are expressed in 2005 pounds, using the 2005 CPI index.
Source: LFS 1997, 2005

Table A3 – Descriptive statistics on immigrants' inflow

Years	*Mean*	*Std.Dev*	*Min*	*Max*
1997-1998	0.23%	0.78%	-1.28%	2.59%
1998-1999	-0.02%	0.56%	-1.25%	0.83%
1999-2000	0.22%	1.14%	-0.69%	4.46%
2000-2001	0.41%	0.63%	-0.48%	2.05%
2001-2002	0.43%	0.86%	-0.53%	3.01%
2002-2003	0.29%	0.45%	-0.42%	1.55%
2003-2004	0.50%	0.82%	-0.80%	2.95%
2004-2005	0.77%	0.59%	-0.43%	1.77%
Average 1997/2005	0.35%			
1997-2005	2.83%	3.50%	-0.27%	15.83%

Entries are the annual mean, standard deviation, minimum, and maximum across all regions of the change in immigrant-native ratio for years 1997-2005.

The last row reports the mean, standard deviation, minimum, and maximum across all regions of the 1997/2005 change in immigrants-natives ratio.

Source: LFS, 1997-2005