Understanding the Labor Market Impact of Immigration

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JOB MARKET PAPER

November 14, 2008

Abstract

I use variation within 2-digit industries across regions using Austrian panel data from 1986 to 2004 to identify the causal effect of immigration on native wages and employment. Using an instrumental variable strategy I find large displacement effects, and modest wage reductions, in the service industry and large employment increases, and modest wage gains, in manufacturing. The literature has focused on the elasticity of substitution between types of labor, which I find to be high in services and lower in manufacturing. I find that equally important are differences across industries in the elasticity of demand for the final product, which I estimate as being high in manufacturing and low in services. The structural estimates suggest that a 10% increase in immigrants in Austria will result in a 0.24% fall in average wages and a shift of 0.6% of the native labor force from services to manufacturing. Next I elaborate on my basic model to account for two further novel observations: immigration affects (1) net native employment through changes in both hire and separation rates and (2) the wages of new hires far more positively than those of incumbent workers. The innovation in my second model is that the elasticities of derived demand account for workers being able to choose what factor input to supply. My estimates suggest that the model is broadly consistent with the data. The implications are that (1) even within an industry there are large changes in relative wages due to immigration, and (2) natives respond by changing the tasks they carry out. The estimates suggest that a 10% increase in the number of immigrants, causes on average a 1.7% change in relative wages across tasks, resulting in a 2.8% shift in native relative supply of these tasks.

*I am especially grateful to Jonathan Guryan, Steve Levitt, John List and Robert Topel for advice. I would also like to thank David Autor, Gary Becker, Marianne Bertrand, Kerwin Charles, Patricia Cortes, Marco Fiaccadori, Stefania Garetto, Ali Hortacsu, Fabian Lange, Casey Mulligan, Kevin M. Murphy, Emily Oster, Jesse Shapiro, Michael Wagner-Pinter and workshop participants at the University of Chicago, the University of Illinois at Chicago and the Federal Reserve Bank of Chicago for helpful comments and suggestions. I especially thank Synthesis Forschung for providing the data used in this paper. All errors are my own. Email address: mwagner@uchicago.edu.

1 Introduction

Over the past two decades there have been renewed large and primarily low-skilled immigration flows to most developed countries. On average among OECD countries the fraction of population that is foreign born reached nearly 11% in 2005 and continues to increase. Such large flows are likely to have significant social and economic consequences for the native-born population. One of the most controversial issues in the debate over immigration, both politically and in the economics literature, is whether and to what degree immigrant workers displace native workers and adversely affect their wages. While most of the literature on the causal effect of immigration has used US data, in this paper I use a panel dataset for Austria. The data yields new empirical evidence on the impact of immigration on the wages and employment of native workers. I then provide a theoretical framework for thinking about these facts and estimate two models (of increasing complexity) to help us understand the results in terms of the basic parameters of the labor demand function and the elasticity of labor supply (allowing for the possibility of endogenous task choice).

The data I use is administrative panel data on all Austrian employees in the period 1972 to 2004. I identify the impact of immigration by using variation at the level of a 2-digit industry in one of Austria's nine regions in the years 1986 to 2004. To control for the endogeneity of immigration flows I use the historic distribution of immigrants to instrument for the current distribution of immigration flows across industry-regions (as originally proposed by Card, 2001). I also include region-specific time trends to account for possible long-term region-specific trends in demand. I make a number of novel findings about the heterogeneous impact of immigration. I find that immigration in the period 1986 to 2004 displaced native workers in service industries (around 0.7 native workers are displaced by the arrival of one immigrant) and resulted in a modest fall in wages. In contrast, in manufacturing immigration increased demand for native workers resulting in higher native employment and modestly higher wages. The estimate suggests that for every immigrant one additional native worker is hired, which is a very large response, but as it turns out, can be explained by a very high elasticity of product demand for manufacturing goods produced in an industry-region. On average the effect of immigration on demand for native workers is slightly negative since the service sector employs more workers than manufacturing. Immigration also has a large negative impact on the wages of immigrants. The fact that I have panel data allows me to further explore this issue. Two-thirds of the net increase in native employment in manufacturing is due to an increase in the hire rate of new workers, and one-third due to a fall in the separation rate. In services both the hire rate of native workers decreases and the separation rate increases, accounting for 60% and 40% of the net decrease in native employment. Finally, in both industries the effect of immigration on wages is more positive for new hires than it is for incumbent native workers.

To understand the labor market effects of immigration the literature, as exemplified by Card (2001) and Borjas (2003), has primarily focused on the degree of substitutability between immigrant and native labor. If immigrants and natives are substitutes then, for a given level of output, an increase in the number of immigrants employed will result in a fall in the wages of native workers. If they are complements in production then, for a given level of output, an inflow of immigrants will raise native wages. However, largely ignored by the literature has been the fact that output will increase as a consequence of immigration, which in turn effects native wages. This scale effect arises as immigration (which can be thought of as an outward shift in the supply of immigrant labor) lowers the cost of production and, since he elasticity of product demand is negative, output increases. As a consequence, for a given relative wage, the demand for native workers increases. The total effect of immigration on the demand for native labor depends on both substitution and scale effect. If the scale effect is larger than the substitution effect immigration results in an increase in the demand for native labor, while the opposite is true if the scale effect is smaller than the substitution effect In this paper I separately estimate each of these effects.

Estimating the degree of substitutability between native and immigrant labor is difficult and much of the controversy in the literature has focused on this issue. The first approach in the literature was to use cross-city variation in immigrant flows to estimate the local impact of low-skilled immigration.[1] Where immigrants choose to locate is, of course, not random but rather is likely to be correlated with shocks to the demand for labor (native and immigrant). However, it turns out that immigrants also tend to locate in industries and regions where previous waves of immigrants work and live. Card (2001) formalizes this idea by using the historical distribution of immigrants across local labor markets as an instrument for the current distribution.

Borjas, Freeman and Katz (1996) are critical of the local labor market approach arguing that it fails to take account of offsetting capital and native labor mobility across local labor markets, which will tend to attenuate the wage effects of immigration.[2] Instead Borjas (2003) estimates the effects of immigration at the national level, where native labor supply can be thought of as inelastic in the short-run, by using variation in immigrant flows across education-experience cells (in essence his "local labor market" is defined by worker characteristics rather than geographic location). Unfortunately the current approaches are not compatible: using cross-city variation allows a researcher to deal with

[1] See Card (1990), Altonji and Card (1991) and LaLonde and Topel (1991) for early examples of this approach.

[2] Card and DiNardo (2000), Card (2001, 2005) and Card and Lewis (2007) find that there is near to no offsetting native labor mobility in response to immigration shocks. Borjas (2006) and Cortes (2008) find large, but not perfectly, offsetting displacement effects.

the endogeneity of immigrant flows, while using variation at the national level deals with the endogeneity of native labor flows, and so ameliorating one source of bias exacerbates the other source of bias.

In this paper I try to simultaneously address both the endogeneity of immigrant and native labor flows. I model production as a CES-aggregate of native and immigrant labor and capital. I assume that a native worker's discrete choice problem takes the form of a two-level nested logit, where workers can choose an industry and region (i.e. an industry-region) within which to work. I derive the elasticities of derived demand for this model as a function of the elasticity of substitution between native and immigrant labor, the elasticity of demand for the final products produced in each industry, the labor and capital shares, and the elasticity of labor supply. Instead of thinking of native labor (and capital) flows as a source of bias I need to control for, I explicitly take account of these in my modelling and subsequent estimation procedure. I do not model the location decisions of immigrants. Instead I instrument for the distribution of the inflow of immigrants using the pattern of employment of immigrants in the 1970s (as proposed by Card, 2001). I also include regional time trends to account for long-term region-specific demand shocks that may bias the IV estimates.

I estimate the model and find that the increase in wages and employment in manufacturing due to immigration can be explained by a short-run elasticity of substitution between native and immigrant labor of around 3.7 and an elasticity of product demand of 22. The elasticity of product demand seems very large, however, given that an industry-region in Austria can be thought of as a very small open economy we would expect a very high elasticity of demand, in that light the results do not seem unreasonable. In services the reverse is true and the substitution effect dominates the scale effect. I estimate an elasticity of substitution of 13 and a short-run elasticity of product demand of

0.4 in services. On average across all industries I estimate the elasticity of substitution to be around 9 and an elasticity of product demand for labor of 5. These estimates imply that in the short-run, if there were a 10% increase in immigrants to all of Austria (from 15% to 16.5% of the workforce) this would result in a drop in average native wages of at least 0.24% (and probably at most 1%). It would also lead to quite a substantial shift of native workers from service industries to manufacturing, equivalent to around 0.6% of the private sector workforce.

Next I address the differential effect of immigration on hire and separation rates and associated wage changes that I observe in the data. I do so by extending the model to allow for endogenous task choice by native workers. The distinguishing feature of the two tasks is that in one task immigrant and native workers are perfect substitutes (I call this task "manual"), in the other task they are imperfect substitutes (I call this task "interactive").[3] The idea that natives may respond to immigration by changing the type of tasks they are engaged in is based on work by Autor, Levy and Murnane (2003), though these authors are thinking about the impact of technology rather than immigration shocks. Cortes (2006) and Peri and Sparber (2007) apply this idea to the effects of immigration. Using US data they find evidence in favor of native task specialization in response to immigration. I derive explicit expressions for the elasticities of derived demand in a model with task specialization. These derived demand elasticities include an additional term to account for the fact that workers can now choose to respond to immigration by changing task within the same industry-region. The overall effect this has is to attenuate the effect of immigration on both average wages and employment in an industry-region. The intuition for this result is that workers can now respond to immigration by switching tasks within a region and no longer just by moving between industry-regions.

[3] I adopt this terminology from Peri and Sparber (2007).

I am able to estimate this model without data on the actual tasks that workers do. The key assumptions I have to make are that all immigrants engage in manual labor (although this assumption can be relaxed), and that immigrants and natives are perfect substitutes when engaged in manual tasks. Given these assumptions I can infer the effect of immigration on manual task wages from the effect of immigration on immigrant wages; and the effect of immigration on interactive task wages from the effect on wages for new hires (since all additional new hires will be carrying out interactive tasks). I can also indirectly infer the elasticities of labor supply, within and across industry-regions, by the differential response to immigration of wages of incumbents and new hires, as well as the total change in native employment due to immigration. This estimation procedure is clearly only feasible due to the availability of panel data, and the results necessarily more speculative.

I find that a 10% increase in immigrants in an industry-region causes the relative wage of interactive to manual tasks to increase by 2.9% in manufacturing and 1.1% in services. Native workers respond by providing less manual and more interactive tasks in that industry-region, with the relative quantity of interactive tasks increasing by 5.5% in manufacturing and 1.4% in services. In manufacturing shifts the adjustment in relative labor supply is through changes in flows in and out of the industry. In services, in contrast, around one-third of the shift from manual to interactive tasks is due to workers switching task within the same industry-region. The elasticity of labor supply to tasks is around 1.9 in both services and manufacturing. The intuition for why it is so much lower than in the previous model is that adjustment now takes place through three channels (changes in hires, separations and internal switches between tasks), which means that there may be large changes in employment even though average wage do not change as much.

Similarly, the implied elasticity of demand for the final product for manufacturing is much lower in this model than in the basic model. The reason it is so high in the basic model is because a fall in wages for a comparatively small fraction of the workforce, namely immigrants, has to explain a large change in output. The model of endogenous task choice, however, suggests that wages for all manual workers fall, not just for immigrants. The average share of manual workers is much higher than that of immigrants, around one-third as opposed to less than 10%, and consequently the observed increase in output is consistent with a lower elasticity of demand.

The rest of the paper is organized as follows. I describe the data, provide descriptive statistics and basic information on the Austrian labor market in Section 2. I discuss my instrument in Section 3 and provide OLS and IV estimates of the impact of immigration on native wages and labor flows. In Section 4 I describe and estimate a model for understanding these wage and employment effects in terms of the elasticity of labor supply, scale and substitution effects. In Section 5 outline and estimate an extension of the basic model, allowing for endogenous tasks choice. Estimates of the parameters of this more complex model are provided. Section 6 concludes.

2 Data

2.1 Dataset

The analysis in this paper uses a dataset containing social security records for all individuals employed in Austria between the years 1972 and 2005, with the exception that I observe tenured public sector employees only starting in 1988 (or in some cases 1995). The observations are specific to a match between an employee and employer in a certain year (so continuous employment relations are truncated into separate observations ending on December 31 and starting on January 1 of a year). Observations contain information on income and days worked, as well as the type of employment. Also recorded for individuals are their gender, nationality, date of birth, and location of residence. For the employer I observe their 4-digit industrial classification and location. I also observe spells of unemployment, maternity (or paternity) leave and, only for women, live births. There is some top-coding of income, which in no year affects more than 9% of employees; income is not observed for tenured public sector employees. There is also some bottom-coding of incomes, which in no year affects more than 8% of employees. Until 1997 only an individual's latest nationality and location of residence is observed. Education records are obtained from data provided by the Austrian Employment Service (AMS) and only exist for individuals who are unemployed at some point during their career. Apprenticeships during the period 1972 to 2005 are observed directly in the data. I impute education for everyone else.[4] I distinguish between low skilled (those with at most compulsory schooling), medium skilled (those having completed apprenticeships or vocational training) and high skilled (completed *Matura* or tertiary education). Notice that these definitions are very different than the ones employed in the US. Since I have longitudinal information on workers I can construct actual experience and actual tenure variables. Work experience prior to 1972 is imputed using the information on education and average employment rates for men and women in prior years. Observed income is nominal (in euros) and per day worked. For around 16% of observations I have no information on the industry they work in (this is a problem primarily for the self-employed) and consequently I exclude them from the analysis. The unit of observation for most of the empirical work in this

[4]For 35 percent of native and 29 percent of foreign observations education needs to be imputed. I impute education for individuals using a multinomial logit. The explanatory variables are gender, cohort, as well as income, 2-digit industry, region and type of employment at various stages of a worker's career, and, where available, a proxy for years of schooling. The within sample fraction of correctly imputed education levels for natives is 59 percent, and 53 percent for foreign workers. For natives the fraction that has to be imputed is 40, 23 and 56 percent for low, medium and high skilled education groups respectively. The corresponding within sample fraction correctly imputed is 68, 44 and 63 percent respectively.

paper is a 2-digit industry in one of Austria's nine regions. I use the NACE economic activities classification scheme of the European Union. The exception is construction (itself a 2-digit industry), in which I use the 3-digit classification. I also combine agriculture with forestry and fishing to create a single industry.

2.2 Background

2.2.1 Immigration

During the 1970s until 1988 the percentage of employees in Austria who are foreign nationals is stable at around 4.5%. Then from 1988 onwards the number of foreign workers more than doubles in four years. From around 4.9% of those employed (180,000 individuals) in 1988 to around 10.5% (421,000 individuals) in 1992; after which it continues rising to around 15% (see Figure 1).[5] Up until 1989 most foreigners in Austria were from Yugoslavia, with a sizeable fraction from Turkey and an increasing number from developed countries. Following 1989 there was an increase in foreigners from all countries, but in particular Eastern Europe (see Figures 2 and 3).

Immigrants are on average less educated than the Austrian workforce (see Figure 4). The fraction low skilled among foreign workers is 73% on average over the period 1986 to 2004, as compared to 33% for native workers. Among Austrians the fraction medium skilled was around 53%, compared with 19% for foreigners. The fraction high skilled was 13% and 7% amongst native and foreign workers respectively. Educational attainment of immigrants varies considerably depending on their country of origin.

[5] Note that individual's nationality and not country of birth is recorded. Also nationality is available in the data only since 1997 on account of the way the Social Security Administration makes the data available. So it is not possible to directly observe an individual's nationality prior to 1997. This is a problem since throughout the 1980s and 1990s annually around 2-3% of foreigners living in Austria became Austrian citizens, according to data from the Austrian Forum for Migration Studies. Commonly foreigners can acquire the Austrian citizenship after having lived in Austria for 10 years, or 5 years if married to an Austrian citizen.

The fraction of foreigners has increased rapidly in all industries, though to differing degrees and from different starting levels. Currently nearly one-third of workers in agriculture and accommodation and food services are foreign, and nearly 20% of those employed in construction. The increase in the fraction foreign was particularly pronounced in retail trade, where the fraction quadrupled, and in agriculture; the expansion was slowest in business services, which employs a lot of foreigners from developed countries. One-quarter of workers employed in Vienna and Vorarlberg are foreign, though other regions, such as Burgenland, Styria and Corinthia, experienced more rapid increases over this period.

2.2.2 Labor Market

From 1972 onwards the Austrian labor market was characterized by a steady growth in employment. Male labor market participation rates declined in the 1970s from 85% and have since stabilized at around 80%. Meanwhile, female labor market participation steadily increased, from under 50% in the early 1970s to over 65% now. Austria has had low unemployment rates over the last 40 years; using ILO definitions unemployment was under 2% in the 1970s, 3-4% in the 1980s and somewhat over 4% since then. Log wages are close to normally distributed in Austria with a standard deviation of around 0.6. Wage growth has been decelerating throughout this period. Austria's wage inequality is close to the EU-15 average, with the 90th to 10th percentile earnings ratio equal to 3.03.[6]

The OECD Employment Outlook (2004) ranks Austria in the middle of OECD countries in terms of employment protection, with substantially higher protection than in the US, Canada or the UK, and less protection than Germany, France, Spain or Sweden. Notice periods for continuous employment relationships, i.e. not short or fixed term contracts, for white collar workers (*Angestellte*) start at 6 weeks and increase with unin-

[6] In comparison the 90th to 10th percentile income ratio is 3.15 for Germany, 3.16 for the UK, 3.36 for France and 2.03 for Sweden. Statistics are from Employment in Europe (2005)

terrupted tenure at a firm. For blue collar workers notice periods are agreed at an industry level as part of the collective bargaining process. They vary from 1 day in construction, to up to 5 months for high skilled blue collar workers (*Facharbeiter*) in parts of manufacturing.[7] Severance pay, starting at two months salary, for all workers is only available after 3 years of uninterrupted tenure at a firm and not available if the separation is due to a voluntary quit by the worker.[8]

Austria has a complex collective bargaining system covering 95% of employees in 2002. Currently around 450 separate wage agreements (*Kollektivverträge*) are reached by employer and employees representatives at the national level every year. These agreements typically specify minimum wages and minimum wage increases for employees by industry, occupation, skill level, and seniority. Agreements can be binding or merely recommended best-practice, and provide the framework within which actual wages are set. Detailed information on collective bargained minimum wages is only available for part of the economy, broadly corresponding to the manufacturing sector and for firms with ten or more employees. In the 1980s actual wages were on average around 30% above the minimum mandated by collective bargaining, and only around 10% of employees were actually paid that minimum. Since then there has been a narrowing of this gap, and currently it is around 20%. In a number of industries there are also agreed minimum wage growth rates of actual wages; these are somewhat smaller than the increases in the minimum wage and set above the rate of inflation, but below the rate of nominal growth.[9]

[7] The definition of a white collar worker is defined by law (Angestelltengesetz) and includes all salespersons and office workers (including secretaries and receptionists). Everyone else is a blue collar worker unless otherwise agreed, either by collective bargaining or at a firm or on an individual basis.

[8] Severance pay legislation was revised substantially for all employment relationships beginning after January 1, 2003. I describe the earlier system.

[9] Pollan (2001, 2005)

3 Wage and Employment Effects of Immigration

The identification strategies in this paper rely on inter-regional variation in the inflow (over time) of immigrants into an industry. Below I discuss in detail the instrument I will use to deal with the potential endogeneity of the distribution of immigrants. I also check for the existence of pre-existing trends and conduct a falsification exercise. I then proceed to provide OLS and linear IV estimates of the impact of immigration on native worker displacement and wages.

3.1 Instrument

The inflow of immigrants may be correlated with unobserved shocks to the demand for labor in a region. If immigrants are more likely to go to regions that are experiencing positive shocks to the demand for native and immigrant labor, then the OLS estimate of the effect of immigration on native employment and wages is upward biased. It is equally possible that immigrant inflows are affected by the availability of jobs in an industry. A plausible way in which the supply-side may matter is that declining industries may make a special effort to attract immigrant labor. For example, since many immigrants require a work permit to legally work in Austria (post-1995 EU citizens could work in Austria without a work permit) one way that declining industries may respond is by exerting political pressure that more work permits be issued for immigrants working in their industry. In that instance there is a negative correlation between the inflow of immigrants and shocks to the wages and employment of native labor and the OLS estimates would be downward biased.[10] The possibility of biased OLS estimates makes it important to instrument for the inflow of immigrants to an industry-region.

[10] This is what Friedberg (2001) finds when examing the distribution of Russian arrivals in Israel after the end of the Cold War.

I instrument for the distribution of the inflow of immigrants using the pattern of foreign employment in the 1970s. The underlying idea is that one of the primary determinants of an immigrants' destination choice is a social network that helps them settle in a foreign country, as well as helping them find a job (see Card (2001), Card and Lewis (2007) and Cortes (2008) for how this instrument works for the US). I use a long baseline period, 1972 to 1979, so as to minimize the effect of short-term employment fluctuations and measurement error, which given that the number of foreigners in some industry-region cells is small could lead to a weak first stage. The social networks justification for the use of this instrument suggests that I distinguish between foreigners by nationality. Sample size considerations lead me to put foreigners in Austria into six categories: former Yugoslavia, Turkey, Eastern Europe, developed countries, Germany and Switzerland (since nationals of those two countries are likely to speak German), and immigrants from the rest of the world.

Formally, the instruments for the inflow of immigrants to a certain 2-digit industry s and region r at time t are given by

$$\Delta foreigners_{rst}(IV) = \sum_{nationality} \frac{nationality_{rs,72-9}}{nationality_{s,72-9}} * \Delta nationality_{st} \tag{1}$$

I also construct a version of the instrument where the denominator is the number of immigrants to a 1-digit industry (as opposed to 2-digit industry). The correlation coefficient between the actual and instrumented inflow of immigrant labor to an industry-region averaged over the period 1986 to 2004 is 0.5 (see Table 1 and Figure 5).

3.2 Pre-Existing Trends and Falsification

For the instrument to be valid it has to be uncorrelated with other unobserved factors that may affect native (and immigrant) labor market outcomes during the period 1986 to 2004. All the main specifications in this paper are in growth rates and control for 2-digit industry by year effects, so much of the identification comes from the within 2-digit industry across regions variation in immigration flows. Hence, the biggest threat to the validity of the instrument is that there are long-term region specific trends in the growth rate of native employment or native wages that are correlated with the fraction of immigrants in that region (within each industry). Fortunately, the data lends itself to subjecting the instrument to a falsification exercise. During the period 1980 to 1985 there is near to no net immigration to Austria (see Figure 1) or any particular 1-digit industry. Hence, it is possible to test whether during this period the historical distribution of immigrants (and hence the instrument) is correlated with native labor market outcomes in this pre-period. Unfortunately the results suggests that the instrument is correlated with region-specific trends in native employment and, to a lesser degree, native wages, see Table 2. This correlation is negative in all 1-digit industries, foreigners seem to be disproportionately employed in regions where an industry is in decline. This means that the instrumental variable estimates of the impact of immigration on native wages and employment may be downward biased on account of long-term demand trends. To deal with the potential bias arising from long-term region-specific trends I include region fixed effects in all subsequent specifications.

3.3 Reduced Form Results

3.3.1 Immigration, Wages and Employment

This section describes the results of a regression of immigration flows ($\Delta \ln I$) into an industry-region (rs) in a given year (t) on to native employment growth ($\Delta \ln N$) or wage growth ($\Delta \ln w_n$). All specifications include 2-digit industry by year fixed effects and region fixed effects. Identification of the effect of immigration is from the within 2-digit industry variation in immigration flows across regions, pooled over years and conditional on region-specific long-term trends. No other covariates are included.

$$\Delta \ln N_{rst} = \beta_1 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{1,rst} \quad (2)$$

$$\Delta \ln w_{n,rst} = \beta_2 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{2,rst} \quad (3)$$

My main specifications are regressions of log changes on log changes since these best correspond to the theory in subsequent sections. In all specifications observations are weighted by employment in each industry-region cell. I exclude the public sector and non-for-profit industries from the analysis, reducing the sample size by 19%. I also exclude those industries that do not employ at least 20 foreigners in the period 1972 to 1979, accounting for 8% of native observations. Finally, since identification is (in large part) across industry I only include industries that on average employ at least 20 workers per year in at least six of the nine regions. This restriction reduces the sample size by 13%.

Throughout this paper I am thinking of changes in (instrumented) immigration flows as shocks to the supply of immigrant labor, and hence as shocks to the demand for other types of (native) labor. This approach differs somewhat from the dominant approaches in the literature, as exemplified by Card (2001) and Borjas (2003), which view immigration as shocks to factor proportions, as measured by education or experience. The main reason for doing so is practical, my data on worker education and foreign worker experience is limited, and so it does not seem sensible to rely on an approach that emphasizes changes in factor proportions. However, I do not want to over-emphasize this difference in methodology since ultimately I will be able to answer the same questions previous papers have.

I present the results, pooled by 1-digit industry, in Table 3. The first important issue to address is whether thinking of immigration as a shock to the demand for native labor is warranted by the data. In the data (OLS estimates) immigration is positively correlated with native employment growth, suggesting that there are common reasons why immigrants and natives move to a certain industry-region. However, the correlation with wages is not uniformly positive, suggesting that the data is generated by a combination of shocks to both demand and supply (hence wage and employment changes are uncorrelated). To disentangle the causal effect of immigration from this data I instrument immigration flows with the instrument described above, see equation (1). Thus I treat immigration as a demand shock to native labor, which if true means that native wages and employment should be positively correlated (assuming that the elasticity of native labor supply is positive). Indeed the estimates of the causal effect of immigration on native wages and employment (IV estimates) are of the same sign in most 1-digit industry (except for business services and agriculture).

The estimates also reveal that the effect of immigration is highly heterogeneous across industries. Notably, the estimates suggest that immigration is a positive demand shock for native labor in manufacturing, the point estimates of the elasticity of native employment and wages with respect to immigration at the industry-region level are 0.12 and 0.01 respectively (though the wage effect is not statistically significant). Similarly, immigration seems to have a positive effect on employment and wages in construction. However, immigration can be thought of as a negative demand shock for native labor in the service industries (defined as trade services, food and accommodation and business services), with an elasticity of -0.1 for employment and -0.02 for wages (though the wage effect is not statistically significant). In aggregate (across all industries) there is a small negative effect of immigration on native wages and employment. Since on average the fraction of immigrants in total employment is around 11% in manufacturing and 12% in services, the estimated elasticities translate into large changes in native employment. An exogenous inflow of one immigrant results in the employment of nearly one additional native worker in manufacturing. In contrast, in services an additional immigrant displaces 0.7 native workers.

The differences between the OLS and IV estimates provides evidence on the factors that determine the location decisions of immigrants. Notice that the bias in the OLS estimates is not uniform across industries. In services the OLS estimates are consistently more positive than IV estimates, which means that demand shocks are an important determinant of immigrant location decisions $E[I_{rst}\varepsilon_{rst}] > 0$. In manufacturing the OLS estimates are barely biased, $E[I_{rst}\varepsilon_{rst}] \simeq 0$, and demand and supply shocks seem to offset each other when it comes to determining immigrant location decisions. To check whether long-run region specific trends in demand are important I also run the same regressions without region-specific fixed effects. The point estimates are not substantially affected by the exclusion of region fixed effects. However, the standard errors of the estimates do fall, so perhaps the inclusion of these fixed effects is excessively cautious (see Table 5). I also run the regressions of the effect of immigration on native employment in levels (as opposed to percentages). The effects are of a similar magnitude, though not statistically significant, as when estimated in log changes (see Table 5).

The elasticity of labor supply (β_1/β_2) implied by the estimates is very high and varies across industries. On average the elasticity of labor supply is substantially larger in manufacturing (around 12) than in services (around 4). Of course this elasticity of labor supply will depend both on the level of aggregation at which the impact of immigration is measured (in my case a 2-digit industry in a region) and the length of time over which the impact is measured (in my case a single year). A consequence of the high elasticity of labor supply is that the sign of the demand shock (positive or negative) to native labor due to immigration is more easily discernible in the data on employment than in wages. Further, if the effect of immigration and the elasticity of labor supply are both heterogenous it is difficult to interpret estimates at an aggregate level. That may, for example, explain why the effects of immigration on wages and employment in business services, which is a highly heterogeneous industry, go in the opposite direction.

The other key assumption I am making, in addition to immigration being a shock to the demand for native labor, is that immigration can be thought of as a shock to the supply of immigrant labor. If that is true then the wages of immigrants should fall in response to an inflow of new immigrants (note that in practice this does not have to be true, LaLonde and Topel, 1991, find that new immigrants affect cohorts of previous immigrants differentially). Table 4 summarizes the results of the impact of immigration on wages of immigrants, where I estimate

$$\Delta \ln w_{i,rst} = \beta_3 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{3,rst} \tag{4}$$

Reassuringly in all 1-digit industries both the OLS and IV estimates are negative. The IV estimates suggest an elasticity of immigrant wages to immigration flows of -0.60 in manufacturing and -0.25 in the service industry. As would be expected the IV estimates are typically more negative than the OLS estimates (the exceptions again being business services and agriculture), which suggests that immigrants change industry-region in response to wage changes.

Recall that the education categories I use do not correspond to those used in the US since Austria's education system is very different. Moreover, there are a number of reasons, including measurement error, why workers across education groups are more similar than we might wish. Nevertheless, it is surprising that the effect of immigration on the wages and employment of low-skilled natives is near identical to that of higher-skilled natives (see Table 6). It seems as though in Austria educational attainment, at least the way I am able to measure it, is not a very salient feature for understanding wage differentials (see Blau and Kahn, 1996, and Leuven, Oosterbeek and van Ophem, 2004 for further discussion of this issue for countries other than the US). For this reason I will not differentiate between natives by education in the remainder of this paper, though all the models in the subsequent sections are easily extended to allow for differential effects by education.

3.3.2 Immigration, Hire and Separation Rates

The availability of panel data allows me to further explore the effects of immigration on employment and wages, by thinking about the impact of immigration on the hire and separation rates and associated wage changes. By definition the net changes in native employment $\Delta \ln N_{rst}$ in an industry-region is the difference between new hires H_{rst} and separations S_{rst}:

$$\Delta \ln N_{rst} \approx \frac{N_{rst} - N_{rs(t-1)}}{\left(N_{rst} + N_{rs(t-1)}\right)/2} = \frac{H_{rst}}{\left(N_{rst} + N_{rs(t-1)}\right)/2} - \frac{S_{rst}}{\left(N_{rst} + N_{rs(t-1)}\right)/2}$$

On average annually around 30% of all workers are new hires to an industry-region. Turnover is somewhat lower in manufacturing, with new hires accounting for 25% of employees in an industry-region. In services the number of new hires in total employment varies between 28% in retail and wholesale trade, 32% in food and accommodation and 36% in business services. In all industries around two-thirds of all new hires are hired from within the same region, and one-third previously worked in a different region.

I study the effect of immigration on the hire and separation rate using the following specifications

$$\frac{H_{rst}}{\left(N_{rst}+N_{rs(t-1)}\right)/2} = \beta_4 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{4,rst} \tag{5}$$

$$\frac{S_{rst}}{\left(N_{rst}+N_{rs(t-1)}\right)/2} = \beta_5 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{5,rst} \tag{6}$$

I also look at the associated changes in wages by looking at the effect of immigration on the wages of native new hires $w_{n|H}$ and native incumbent workers $w_{n|H'}$ (i.e. a currently employed worker who is not a new hire)

$$\Delta \ln w_{n|H,rst} = \beta_6 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{6,rst} \tag{7}$$

$$\Delta \ln w_{n|H',rst} = \beta_7 \Delta \ln I_{rst} + \delta_{st} + \delta_r + \varepsilon_{7,rst} \tag{8}$$

The results are summarized in Tables 7. In manufacturing the hire rate of new workers increases and the separation rate falls due to immigration. The elasticity of the hire rate with respect to immigration is 0.09, while the elasticity of the separation rate is -0.04. The elasticity of wages for those new hires with respect to immigration is 0.06. However, the wages of incumbent workers, those who stay in the industry-region despite the inflow of immigrants, are on average unaffected by immigration. In services, in contrast, the hire rate falls and the separation rates increase, with an elasticity of -0.06 and 0.04 respectively. Wages for new hires perhaps rise very slightly, while wages for incumbent workers in the service sector fall, with an elasticity of -0.02 with respect to immigration. What all industries have in common is that immigration has a more positive impact on the wage of new hires than it does on the wages of incumbent workers.

4 Substitution and Scale Effects

In this section I try to understand the heterogeneous impact of immigration in terms of scale and substitution effects and the elasticity of labor supply. Estimating these structural parameters also allows me address two key issues: the short-run aggregate impact of immigration to Austria on native wages (and not just the effect of immigration to an individual industry-region), and the effect on industrial composition of employment in Austria.

4.1 Setup

4.1.1 Firms

Consider an economy with S competitive industries in R regions producing final goods Y, sold at prices p and produced using a two-level nested-CES aggregation of native labor N, immigrant labor I and capital K.

$$\begin{aligned} Y_{rs} &= F^{Y}\left(Q_{rs}, K_{rs}\right) \\ &= F^{Y}\left(F^{Q}\left(N_{rs}, I_{rs}\right), K_{rs}\right) \end{aligned} \tag{9}$$

with σ_{in} as the elasticity of substitution between native and immigrant labor and σ_{qk} as the elasticity of substitution between labor and capital. Note that as $\sigma_{in} \rightarrow \infty$ native and immigrant labor become perfect substitutes. I assume constant returns to scale at the level of each nest. Note that since each nest only contains two inputs I have implicitly assumed that all elasticities of substitution are non-negative (since factor demands are homogenous of degree zero in factor prices). Intuitively, if the wage of immigrant labor falls all else equal more immigrant labor will be employed (the own-price elasticity of factor demand is always negative), and since output is assumed constant less native labor will have to be employed. The inverse demand function for the output of an sectors is given by

$$p_s = c_s Y_s^{-\psi_s} \tag{10}$$

4.1.2 Native Workers

Native workers of a certain type have a choice of industry and region within which to work, where for every worker it is possible to choose any combination of industry $s \in S$ and region $r \in R$. I assume that the utility of worker j in industry s and region r can be expressed as

$$U_{jrs} = \ln \alpha_j + \ln \alpha_{rs} + \ln w_{jrs} + \varepsilon_{js} + \varepsilon_{jr} + \varepsilon_{jrs}$$

In what follows I suppress the j subscript wherever possible. I further assume that $var(\varepsilon_s) = 0$. Thus

$$U_{rs} = \ln \alpha + \ln \alpha_{rs} + \ln w_{rs} + \varepsilon_r + \varepsilon_{rs} \tag{11}$$

where I assume that ε_r and ε_{rs} are independent for all industries and regions in workers' choice sets, ε_{rs} is independent and identically Gumbel (Extreme Value Type I) distributed with a scale parameter μ^s, and ε_s is distributed so that $\max_r U_{rs}$ is Gumbel distributed with a scale parameter μ^r (where these scale parameters are inversely related to the variance of the error term).[11] Thus the workers' discrete choice problem takes the form of a two-level nested logit, where workers can be thought of as first choosing a region and then an industry to work in. This formulation of the representative worker's choice problem results in an elasticity of labor supply to an industry-region, ϕ_n, with respect to a change in the wage given by:

$$\frac{d\ln N_{rs}}{d\ln w_{rs}} = \phi_n = \mu^s\left(1 - P\left(s|r\right)\right) + \mu^r P\left(s|r\right)\left(1 - P\left(r\right)\right) \tag{12}$$

where $P\left(s|r\right)$ is the probability that a worker in region r chooses industry s and $P\left(r\right)$ is the unconditional probability of a worker choosing to work in region r. The elasticity of labor supply contains two terms: the first pertaining to the response of workers in other industries within the same region, and the second to the response of workers from other regions to a change in the wage. The magnitude of each of these terms (and hence of the elasticity of labor supply) is inversely proportional to the variance of the error terms. Intuitively, a lower variance means that there are proportionally more workers over a given interval who respond to a marginal change in the wage. The nested logit assumption imposes the restriction that all the cross-elasticities within the same nest, i.e. within the same region across different industries, are the same. It does, however, allow the cross-elasticity across nests to differ from that within a nest. The order of the nesting implies that the elasticity of labor supply is higher across industries (with error term ε_r) than across regions (with error term $\varepsilon_r + \varepsilon_{rs}$).

[11] My formulation of the workers' discrete choice problem follows Ben-Akiva and Lerman (1985).

4.2 Effects of Immigration

The model delivers a number of important results. The effect of immigration on the wage w_n and employment N of native workers in an industry-region is given by

$$\frac{d\ln w_n}{d\ln I} = \frac{s_i(\eta-\sigma_{in})}{\sigma_{in}\eta+\phi_n(s_i\eta+s_n\sigma_{in})} \tag{13}$$

$$\frac{d\ln N}{d\ln I} = \phi_n\frac{d\ln w_n}{d\ln I} \tag{14}$$

where ϕ_n is the elasticity of native labor supply, η is the elasticity of demand for labor and s_i is the share of immigrant labor in total labor output. See Appendix A.1 for a derivation of the expressions for the labor supply elasticities and the inverse derived demand elasticities and Hicks (1963) and Allen (1938) for more general proofs of these results. The effect of immigration on wages and, since labor supply is upward sloping $\phi_n > 0$, on employment of natives is positive when $\eta > \sigma_{in}$. The inflow of immigrants is an increase in the labor supply of immigrant labor (for a given wage), reducing the cost of immigrant labor and hence resulting in two countervailing effects: (1) the substitution effect, where for a given level of output firms will substitute immigrant for native labor; and (2) the scale effect, for a given input ratio, the fall in the cost of native labor results in increased demand for native low-skilled labor. Note that the more substitutable immigrant and native labor are, the more likely it is that the wage effect is negative. The expression for the scale effect, assuming that the supply of capital is perfectly elastic, is

$$-\frac{d\ln Q}{d\ln w_q} = \eta = s_q\psi + s_k\sigma_{qk} \tag{15}$$

The scale effect is always positive and is increasing in the elasticity of demand for the final product ψ (weighted by the share of labor in total output s_q) and the elasticity of substitution between labor and capital σ_{qk} (weighted by the share of capital in total output s_k).

The degree to which the demand shock to native labor caused by immigration, whether positive or negative, expresses itself in a change in wages or employment depends on the elasticity of labor supply. The larger the elasticity of labor supply the more the wage effect of immigration is attenuated $\frac{d}{d\phi_n}\left(\frac{d\ln w_n}{d\ln I}\right) < 0$ and the employment effect is amplified $\frac{d}{d\phi_n}\left(\frac{d\ln N}{d\ln I}\right) > 0$.

The effect of immigration on immigrant wages is always negative

$$\frac{d\ln w_i}{d\ln I} = -\frac{\phi_n + s_n\eta + s_i\sigma_{in}}{\sigma_{in}\eta + \phi_n\left(s_i\eta + s_n\sigma_{in}\right)} < 0 \tag{16}$$

and the effect on total labor output is always positive

$$\frac{d\ln Q}{d\ln I} = \frac{s_i\eta\left(\sigma_{in} + \phi_n\right)}{\sigma_{in}\eta + \phi_n\left(s_i\eta + s_n\sigma_{in}\right)} > 0 \tag{17}$$

4.3 Estimation

The shares s_n and s_i are observed directly in the data. I use data from Eurostat to obtain measures of the shares of labor and capital in total output s_q and s_k. Further, I restrict all the elasticities of native labor supply to be the same across industry-regions. That leaves four unknown parameters $\phi_n, \psi, \sigma_{in}$ and σ_{qk}. There are three linearly independent estimating equations I choose to use $\frac{d\ln w_n}{d\ln I}$, $\frac{d\ln N}{d\ln I}$ and $\frac{d\ln w_i}{d\ln I}$. Finally, in the absence of good data on labor shares in total output I simply assume that $\sigma_{qk} = 1$ (Cobb-Douglas), which also implies that s_q and s_k are constant over time, thus the system is identified.

Since s_i and s_n vary across industry-regions and over time it would be most efficient to estimate this system of five equations and five unknowns using some form of GMM.

However, it is also possible to derive the structural parameters directly from the linear IV estimates of the previous section, since the inclusion of industry by region fixed effects means that the estimates of the previous section are (at least theoretically) unbiased. The advantage of this approach is that it is clear what variation identifies which parameter. I feel that this advantage outweighs any potential loss in efficiency.

I estimate the structural parameters as follows. The labor supply elasticity is simply the effect of immigration on native employment divide by the effect on native wages, see regressions (2) and (3).

$$\phi_n = \frac{d\ln N}{d\ln I} / \frac{d\ln w_n}{d\ln I} = \beta_1/\beta_2$$

The elasticity of substitution between native and immigrant σ_{in} labor is

$$\sigma_{in} = \frac{d\ln(I/N)}{d\ln(w_n/w_i)} = \frac{1-\beta_1}{\beta_2-\beta_3}$$

(from regressions (2), (3) and (4)). Finally, I use the expression for $\frac{d\ln Q}{d\ln I}$ and equation (15) to find the elasticity of product demand.

The strategy described relies on the assumption that the elasticity of labor supply is identical across industry-regions and over time. Maintaining that assumption and using the average $P(s|r)$ and $P(r)$ as observed in the data, it is possible to identify the scale parameters of the native workers' discrete choice problem (μ^s and μ^r). To identify these I use the expression for the ratio of new hires to an industry-region that originate in the same region $H(s'|r)$ and from other regions $H(r')$ (using equations (33) and (34) in Appendix A)

$$\frac{H(s'|r)}{H(r')} = \frac{\mu^s(1-P(s|r))}{\mu^r(1-P(r))} - (1-P(s|r)) \tag{18}$$

4.4 Results and Implications

The parameter estimates for manufacturing, the service sector and across all industries are summarized in Table 9. I find that in manufacturing the elasticity of substitution between native and immigrant labor is around 3.7. The very large estimated elasticity of product demand (around 22, equivalent to elasticity of demand for labor of 16) in manufacturing results in a large scale effect, which more than offsets the substitution effect. Hence, immigration results in an increase in the demand for native labor in manufacturing. Recall that the estimates are for individual industry-regions and so the very large scale effect suggests that the demand for output of such industry-regions is highly competitive. Indeed, if such industry-regions were perfectly competitive then product demand would be infinitely elastic. In contrast, in services I find that immigrant and native labor is very substitutable, the estimated elasticity of substitution is around 13. At the same time I estimate the elasticity of product demand to be only 0.4 (equivalent to an elasticity of demand for labor of 0.6) in services and so the scale effect does not offset the substitution effect. On average across all industries I estimate the elasticity of substitution to be around 9 and the elasticity of demand for final outputs of 5 (an elasticity of demand for labor of 3.8).

The estimated elasticities are short-run elasticities at the level of an individual industry-region. Consequently, the best counterfactual to consider is one where a large increase in immigrants occurs in a very short time period, such as in the period 1982 to 1992, where the number of immigrants basically doubled. The estimates suggest, assuming an immigrant share at the current 15%, that in the short-run a 10% increase in immigrants would result in a 0.24% decrease in average native wages. Despite Austria being a very open economy it seems unlikely that the elasticity of product demand is as large at the level of the entire country as it is for an individual industry-region. If the short-run aggregate elasticity of product demand were only 1.9 then the estimated cumulative effect of immigration on native real wages would be -0.63%. However, it would lead to quite a substantial shift of native workers from service industries to manufacturing, equivalent to around 0.6% of the private sector workforce.

5 Endogenous Task Choice

In this section I extend the model of the previous section to allow native workers to endogenously choose the type of task they are engaged in. Since information on tasks is not available in the data this section is necessarily more speculative. However, the model does speak to the differential effect immigration has on hire and separation rates and the associated wage changes described in Section 3. The idea that natives may respond to immigration by changing the type of tasks they are engaged in is based on work by Autor, Levy and Murnane (2003), though these authors are thinking about the impact of technology rather than immigration shocks. Cortes (2006) and Peri and Sparber (2007) apply this idea to the effects of immigration. Using US data they find evidence in favor of native task specialization in response to immigration. In this section I derive explicit expressions for the elasticities of derived demand in a model with task specialization. Moreover, given some strong assumptions, I am able to estimate this model without data on actual tasks.

5.1 Setup

5.1.1 Firms

Consider an economy with a large number S of small competitive industries in R regions producing final goods Y_{rs}, sold at prices p_s and produced using a two-level nested CES-aggregation of manual tasks M, interactive tasks X and capital K.

$$\begin{aligned} Y_{rs} &= F^{Y}\left(Q_{rs}, K_{rs}\right) \\ &= F^{Y}\left(F^{Q}\left(M_{rs}, X_{rs}\right), K_{rs}\right) \end{aligned} \tag{19}$$

σ_{mx} is the elasticity of substitution between manual and interactive skills and σ_{qk} is the elasticity of substitution between labor and capital. The inverse demand function for the output of a sector is the same as in the previous model, see equation (10). The derivation of all results in this section are in Appendix B.

5.1.2 Native Workers

Native workers, as before, have a choice of industry and region within which to work. In addition, they have a choice of task τ, manual m or interactive x. For every worker it is possible to choose any combination of industry $s \in S$, region $r \in R$ and task $\tau \in \{m, x\}$ within which to work. I assume that the utility of worker j in industry s, region r and task τ can be expressed as

$$U_{jrs\tau} = \ln \alpha_j + \ln \alpha_{rs\tau} + \ln w_{jrs\tau} + \varepsilon_{js} + \varepsilon_{jr} + \varepsilon_{j\tau} + \varepsilon_{jrs} + \varepsilon_{jr\tau} + \varepsilon_{js\tau} + \varepsilon_{jrs\tau}, \quad \forall j \in N_L$$

In what follows I suppress the j subscript wherever possible. I further assume that $var\left(\varepsilon_{\tau}\right) = var\left(\varepsilon_{\tau s}\right) = var\left(\varepsilon_{r\tau}\right) = 0$ and $var\left(\varepsilon_{s}\right) = 0$. Thus

$$U_{rs\tau} = \ln \alpha + \ln \alpha_{rs\tau} + \ln w_{rs\tau} + \varepsilon_{r} + \varepsilon_{rs} + \varepsilon_{rs\tau} \tag{20}$$

where I assume that ε_τ, $\varepsilon_{s\tau}$ and $\varepsilon_{rs\tau}$ are independent for all industries, regions and tasks in workers' choice sets, $\varepsilon_{rs\tau}$ is independent and identically Gumbel (Extreme Value Type I) distributed with a scale parameter μ^τ, the scale of $\varepsilon_{rs} + \varepsilon_{rs\tau}$ is denoted by μ^s and the scale of $\varepsilon_r + \varepsilon_{rs} + \varepsilon_{rs\tau}$ by μ^r. This three-level nested formulation is equivalent to native workers first choosing a region, then an industry and finally a task to work in. The own-wage elasticity of labor supply to a certain task in an industry-region is

$$\phi_\tau^\tau = \mu^\tau \left(1 - P\left(\tau|r,s\right)\right) + \mu^s \left(1 - P\left(s|r\right)\right) P\left(\tau|r,s\right) + \mu^r \left(1 - P\left(r\right)\right) P\left(\tau|r,s\right) P\left(s|r\right), \quad \tau = (m,x) \tag{21}$$

where $P\left(\tau|r,s\right)$ is the conditional probability a worker chooses a certain task given a choice of industry-region, $P\left(s|r\right)$ is the probability of choosing an industry given a choice of region and $P\left(r\right)$ the unconditional probability of choosing a certain region. The elasticity of labor supply has three components corresponding to the response of workers within the same industry-region, the same region and different regions respectively. Also note that the elasticity of labor supply to a task from workers outside an industry-region is equal to

$$\phi_\tau^\tau + \phi_{\tau'}^\tau = \mu^s \left(1 - P\left(s|r\right)\right) P\left(\tau|r,s\right) + \mu^r \left(1 - P\left(r\right)\right) P\left(\tau|r,s\right) P\left(s|r\right), \quad \tau \neq \tau', \tau = (m,x) \tag{22}$$

where $\phi_x^m = \frac{d \ln M}{d \ln w_x}$ and $\phi_m^x = \frac{d \ln X}{d \ln w_m}$.

5.2 Effects of Immigration

To analyze the impact of immigration on native labor market outcomes I assume that low-skilled immigrants have a comparative advantage in manual tasks. Specifically, I assume that all immigrants provide manual tasks. I also assume that immigrants are perfect substitutes for natives carrying out manual tasks. In essence "manual" tasks are simply those tasks for which natives and immigrants are perfect substitutes. This assumption will be crucial to my identification strategy as it allows me to use the (instrumented) inflow of immigrants as a proxy for a shock to the supply of manual tasks in an industry-region.

The total quantity of manual labor in an industry consists of native and immigrant workers, M_N and I respectively. An arrival of immigrants will always increase the total quantity of manual tasks provided in an industry

$$\frac{d\ln M}{d\ln I} = \frac{s_i}{1 + s_n\left(\phi_m^m\left(-\frac{d\ln w_m}{d\ln M}\right) - \phi_x^m\frac{d\ln w_x}{d\ln M}\right)} > 0 \tag{23}$$

where s_i and s_n are, respectively, the shares of immigrant and native workers engaged in manual labor and $-\frac{d\ln w_m}{d\ln M} > 0$ and $\phi_x^m < 0$. The demand for each task is downward sloping, and so immigration will always decrease the wage of workers engaged in manual tasks

$$\frac{d\ln w_m}{d\ln M} = -\frac{s_m\sigma_{xm} + s_x\eta + \phi_x^x}{\eta\sigma_{xm} + \phi_x^x\left(s_m\eta + s_x\sigma_{xm}\right) - s_x\phi_m^x\left(\eta - \sigma_{xm}\right)} < 0 \tag{24}$$

where s_m and s_x are the shares of manual and interactive labor in total labor output.

The effect on wages of native workers engaged in interactive tasks is more complicated. There is both a scale effect, for a given factor ratio the cost of production falls and output expands, thereby increasing the demand for all factors; and a substitution effect, for a given level of output, there is substitution from interactive to manual tasks as the relative wage changes.

$$\frac{d\ln w_x}{d\ln M} = \frac{s_m\left(\eta - \sigma_{xm}\right) + \phi_m^x}{\eta\sigma_{xm} + \phi_x^x\left(s_m\eta + s_x\sigma_{xm}\right) - s_x\phi_m^x\left(\eta - \sigma_{xm}\right)} \tag{25}$$

If $\eta > \sigma_{xm}$ then immigrant will increase the wage of workers engaged in interactive tasks.

Note if $\phi_m^x = 0$, i.e. if there is no endogenous task choice, then these expressions simplify to the well-known derived demand elasticities of the previous section. Also note that since $\phi_m^x < 0$ the inverse derived demand elasticities are attenuated as compared to those without endogenous task choice (as long as $\eta > \sigma_{xm}$). The intuition for this result is that labor to each task is more elastically supplied if task choice is endogenous (as opposed to when it is not). As a consequence the response of task wages to an inflow of immigrants is attenuated on account of workers switching tasks within an industry (equivalently the elasticity of derived demand increases, i.e. the quantity response to a given shock in wages is higher). Similarly, while employment in a given task becomes more responsive to immigration, the effect on total employment is an industry-region is reduced, since some workers will now switch tasks instead of leaving the industry-region entirely.

As before immigration always has a positive effect on total labor output, $\frac{d\ln Q}{d\ln M} > 0$, see equation (40) in Appendix B.

While it is possible for both interactive and manual wages to fall the relative wage of interactive versus manual tasks in an industry-region will always increase

$$\frac{d}{d\ln M}\ln\left(\frac{w_x}{w_m}\right) = \frac{\eta + (\phi_m^x + \phi_x^x)}{\eta\sigma_{xm} + \phi_x^x\left(s_m\eta + s_x\sigma_{xm}\right) - s_x\phi_m^x\left(\eta - \sigma_{xm}\right)} > 0 \tag{26}$$

and so there will always be a fraction of low-skilled native workers who were previously engaged in manual tasks who will switch to carrying out interactive tasks in the same industry.

The total effect on the number of native skilled workers due to an increase in the amount of manual labor in an industry-region, which is also the elasticity of labor supply to an industry-region (for a given relative wage within that industry-region), is given by

$$\frac{d\ln(X+M_N)}{d\ln M}=(\phi_x^x+\phi_m^x)\frac{X}{X+M_N}\frac{d\ln w_x}{d\ln M}+(\phi_m^m+\phi_x^m)\frac{M_N}{X+M_N}\frac{d\ln w_m}{d\ln M} \tag{27}$$

Finally, the effect on the ratio of interactive to manual tasks among natives is

$$\frac{d\ln(X/M_N)}{d\ln M}=(\phi_x^x-\phi_x^m)\frac{d\ln w_x}{d\ln M}+(\phi_m^x-\phi_m^m)\frac{d\ln w_m}{d\ln M} \tag{28}$$

5.3 Estimation

If workers' choice of tasks is observed in the data estimating this model is not much more complicated than estimating a model without endogenous task choice. However, in the data available to me I do not observe the tasks that workers are engaged in. This obviously makes estimating this model considerably more complicated. Nevertheless, it turns out to be possible if we are willing to take the model quite literally. The key assumptions I will be making are that (1) all immigrants engage in manual labor (although this assumption can be relaxed), (2) immigrants and natives are perfect substitutes when engaged in manual tasks. Also, as previously, I assume that labor and capital are combined using a Cobb-Douglas production function σ_{qk}. Once again I use the estimates from regressions (2) to (8).

Since immigrants and natives are perfect substitutes in the provision of manual tasks the impact of immigration on manual wages is the same as the impact of immigration on immigrant wages, i.e. $\frac{d\ln w_m}{d\ln I}=\beta_3$. Any additional hires to the industry-region due to immigration must be engaged in interactive tasks (since manual wages always fall due to immigration there will be a net outflow of workers from manual tasks). Hence, any increase in wages of new hires caused by immigration must reflect a change in the wage of interactive tasks $\frac{d\ln w_x}{d\ln I} = \beta_6$. The change in the average wage in an industry-region, ignoring second-order effects, is

$$s_x \frac{d\ln w_x}{d\ln I} + s_m s_n \frac{d\ln w_m}{d\ln I} = \beta_2$$

,which combined with knowledge of the wage for manual tasks w_m (which is simply the average wage of immigrants), the total employment of natives in the industry $(X + M_N)$ and total income for natives in that industry $(w_x X + w_m M_N)$ can be used to find X, M, s_m, s_n, s_i, s_x and w_x.

The elasticity of new hires and separations with respect to an inflow of immigrants are, respectively

$$\begin{aligned} \left(\phi_x^x + \phi_m^x\right) \frac{X}{X + M_N} \frac{d\ln w_x}{d\ln I} &= \beta_4 \\ \left(\phi_m^m + \phi_x^m\right) \frac{M_N}{X + M_N} \frac{d\ln w_m}{d\ln M} &= -\beta_5 \end{aligned}$$

Since task inputs are not observed it is difficult to credibly identify both the elasticity of substitution and the cross-elasticity of labor supply between two tasks within the same industry-region. To simplify identification I assume that manual and interactive labor are combined using a Cobb-Douglas production function, i.e. $\sigma_{mx} = 1$. Using this fact, allows for identification of the elasticities of labor supply. Finally, the elasticity of product demand can then be estimated from the change in the total native wage bill in an industry-region due to immigration

$$\frac{d\ln\left(w_m M_N + w_x X\right)}{d\ln I} = \beta_1 + \beta_2$$

This estimation procedure is not as neat as that in the previous section. However, intuitively, the reason it works is that despite the labor inputs being unobserved we do observe the changes in wages to manual and interactive labor (given the assumptions of the model). We can also indirectly infer the elasticities of labor supply by the differential response to immigration of wages of incumbents and new hires, as well as the total change in native employment due to immigration. This estimation procedure is clearly only feasible due to the availability of panel data.

5.4 Results

The results are summarized in Table 10. In obtaining these results I have had to deviate from the identification procedure outlined above in two ways. Firstly, the model predicts that the separation rate always increases as a result of immigration (since the wage of manual workers always falls). However, this is not true in manufacturing. Similarly, despite (very) small wage gains the hiring rate falls in services (which would require a negative elasticity of labor supply). Clearly, the distinction between hiring and separations is not as clean in the data as in the model. So I simplify identification by assuming that $\phi_x^x = \phi_m^m = \phi_n$, which also implies that $\phi_m^x = \phi_x^m$, and do not use the moment that is contradicted by the data. Second, in manufacturing I calculate the cross-wage elasticity to be slightly positive. Since this is not theoretically possible I instead constrain this parameter estimate to be equal to zero.

I find that a 10% increase in immigrants in an industry-region causes the relative wage of interactive to manual tasks to increase by 2.9% in manufacturing and 1.1% in services. Native workers respond by providing less manual and more interactive tasks in that industry-region, with the relative quantity of interactive tasks increasing by 5.5% in manufacturing and 1.4% in services. Over the entire period 1986 to 2005 the result of immigration has been a huge fall in the relative wage of manual tasks of around 30%

in manufacturing and 12% in services. This has resulted in an even larger fall in the relative supply of manual tasks of 60% in manufacturing and 15% in services. The average share of manual tasks (carried out by natives and immigrants) in total labor output in manufacturing is 27% and in services 36%.

In manufacturing this shift in what native workers do is entirely on account of manual task workers leaving the industry and interactive task workers joining, all adjustment is through changes in flows in and out of the industry. In services, in contrast, around one-third of the shift from manual to interactive tasks is due to workers switching task within the same industry-region. The elasticity of labor supply to tasks is around 1.9 in both services and manufacturing. The intuition for why it is so much lower than in the previous model is that adjustment now takes place through three channels (changes in hires, separations and internal switches between tasks), which means that there may be large changes in employment even though average wage do not change as much.

Similarly, the implied elasticity of demand for the final product for manufacturing is much lower in this model than in the previous model. The reason it is so high in the previous model is because a fall in wages for a comparatively small fraction of the workforce, namely immigrants, has to explain a large change in output. The model of endogenous task choice, however, suggests that wages for all manual workers falls, not just that of immigrants. The average share of manual workers is much higher than that of solely immigrants, around one-third as opposed to less than 10%, and consequently the observed increase in output is consistent with a lower elasticity of demand.

6 Conclusions

A large body of literature examines the average effect of immigration of native labor market outcomes. In this paper I find that the impact is highly heterogeneous across industries. I show that the varying impact of immigration cross industries can be accounted for by differences in the elasticity of substitution between immigrant and native labor, which determines the impact of immigration on natives for a constant level of output, as well as differences in the elasticity of product demand, which determines the impact of immigration for a given relative wage. In service industries immigrants displace natives because the elasticity of substitution is high and demand for output is inelastic. In manufacturing immigration results in increased hiring of natives on account of a high elasticity of demand for output, which dominates the substitution effect.

Immigration affects net employment of native workers by changing hiring and separation rates. Moreover, changes in wages are considerably more positive for new hires than incumbent workers. I explain this observation using a model of endogenous task choice, following recent work in the US literature. The model is necessarily more speculative since I do not observe tasks in the data. Nevertheless the model can be estimated and the results suggest that immigration causes large changes in the relative wages accruing to different tasks, hence inducing large changes in native relative labor supply to these tasks.

Appendix A

In this section I derive the factor demand elasticities and elasticities of labor supply for the model in Section 4. I suppress industry and region subscripts.

A.1 Elasticities of derived demand

Firms maximize profits subject to equations (9) and (10). Taking the derivative of the first-order conditions with respect to a change in the number of immigrants:

$$\begin{aligned}\frac{d\ln w_i}{d\ln I} &= \frac{d\ln Q}{d\ln I}\left(\frac{1}{\sigma_{in}}-\frac{1}{\eta}\right)-\frac{1}{\sigma_{in}} && (29)\\ \frac{d\ln w_n}{d\ln I}-\frac{d\ln w_i}{d\ln I} &= \frac{1}{\sigma_{in}}\left(1-\frac{d\ln N}{d\ln w_n}\frac{d\ln w_n}{d\ln I}\right) && (30)\end{aligned}$$

Eliminating $\frac{d\ln w_i}{d\ln I}$ using (29) and (30)

$$\frac{d\ln Q}{d\ln I}=\frac{d\ln w_n}{d\ln I}\frac{\eta\left(\sigma_{in}+\phi_n\right)}{\left(\eta-\sigma_{in}\right)} \tag{31}$$

Then I differentiate the production function and use the fact that with constant returns to scale $s_i=\frac{w_i I}{w_q Q}=\frac{w_i}{w_q}\frac{I}{Q}=\frac{F_I I}{Q}$ and $s_n=\frac{w_n N}{w_q Q}=\frac{F_N N}{w_q Q}$

$$\begin{aligned}\frac{dQ}{dI} &= F_I+F_N\frac{dN}{dw_n}\frac{dw_n}{dI} && (32)\\ \frac{d\ln Q}{d\ln I} &= s_i+s_n\phi_n\frac{d\ln w_n}{d\ln I}\end{aligned}$$

I eliminate $\frac{d\ln w_n}{d\ln I}$ using (31) and (32) to find the expression for $\frac{d\ln w_n}{d\ln I}$, see equation (13). Then substitute into (31) to find the expression for $\frac{d\ln Q}{d\ln I}$ (17). Finally, substituting this expression into (29) to obtain $\frac{d\ln w_i}{d\ln I}$ as a function of the exogenous parameters.

A.2 Native worker labor supply

A worker's chooses an industry and a region in which to work following (11). Hence, the marginal probability that a worker chooses region r is given by the probability that

$$P\left(r\right)=\Pr\left[\varepsilon_r+\max_s\left(\ln\alpha_{rs}+\ln w_{rs}+\varepsilon_{rs}\right)\geq\varepsilon_{r'}+\max_s\left(\ln\alpha_{r's}+\ln w_{r's}+\varepsilon_{r's}\right),\quad\forall r'\in R,r'\neq r\right]$$

Since ε_{rs} is Gumbel distributed with parameter μ^s the term $\max_s\left(\ln\alpha_{rs}+\ln w_{rs}+\varepsilon_{rs}\right)$ is also Gumbel distributed and can be written as $\tilde{\alpha}_r+\tilde{\varepsilon}_r$ where

$$\begin{aligned}J_r &= \left(\sum_s\left(\alpha_{rs}w_{rs}\right)^{\mu^s}\right)^{1/\mu^s}\\ \tilde{\varepsilon}_r &= \max_s\left(\ln\alpha_{rs}+\ln w_{rs}+\varepsilon_{rs}\right)-\tilde{\alpha}_r\end{aligned}$$

and $\tilde{\varepsilon}_r$ is Gumbel distributed with scale parameter μ^s. The combined disturbance $\varepsilon_r + \tilde{\varepsilon}_r$ is, as assumed, independent and identically Gumbel distributed with scale parameter μ^r for all $r \in R$, therefore

$$P(r) = \frac{e^{\mu^r \ln J_r}}{\sum_{r' \in R} e^{\mu^r \ln J_{r'}}} = \frac{J_r^{\mu^r}}{\sum_{r'} J_{r'}^{\mu^r}}$$

The conditional choice probability of choosing industry s having decided on region r is

$$P(s|r) = \Pr\left[\ln \alpha_{rs} + \ln w_{rs} + \varepsilon_{rs} \geq \ln \alpha_{rs'} + \ln w_{rs'} + \varepsilon_{rs'}, \quad \forall s' \in S, s' \neq s | r \text{ chosen}\right]$$

The components attributable to the industry cancel, so

$$P(s|r) = \frac{e^{\mu^s \ln \alpha_{rs} w_{rs}}}{\sum_{s'} e^{\mu^s \ln a_{rs'} w_{rs'}}} = \frac{(\alpha_{rs} w_{rs})^{\mu^s}}{\sum_{s'} (a_{rs'} w_{rs'})^{\mu^s}}$$

and the joint probability is

$$P(r,s) = P(s|r) P(r) = \frac{(\alpha_{rs} w_{rs})^{\mu^s}}{\sum_{s'} (a_{rs'} w_{rs'})^{\mu^s}} \frac{J_r^{\mu^r}}{\sum_{r'} J_{r'}^{\mu^r}}$$

Assuming $\bar{N}$ homogeneous workers the labor supply to a given industry and region is $N_{rs} = \bar{N} P_\tau (r,s)$. The elasticity of the labor supply to an industry-region with respect to a change in the wage is found by taking the derivative with respect to w_{rs} and is given by (12). Further, the cross-elasticity of labor supply with respect to a change in the wage of an industry in a different region is

$$\begin{aligned} \frac{d \ln P(r',s)}{d \ln w_{rs}} &= \frac{d \ln P(r')}{d \ln J_r} \frac{d \ln J_r}{d \ln w_{rs}} \\ &= -\mu^r P(r) P(s|r) = -\mu^r P(s,r) \end{aligned} \tag{33}$$

The cross-elasticity of labor supply with respect to a change in the wage of an industry in the same region is

$$\begin{aligned} \frac{d \ln P(r,s')}{d \ln w_{rs}} &= \frac{d \ln P(s'|r)}{d \ln w_{rs}} + \frac{d \ln P(r)}{d \ln J_r} \frac{d \ln J_r}{d \ln w_{rs}} \\ &= -\mu^s P(s|r) + \mu^r P(s|r)(1 - P(r)) \end{aligned} \tag{34}$$

Combining (33) and (34) yields the expression for the ratio of within region to outside of region hires (18).

Appendix B

In this section I derive the factor demand elasticities and elasticities of labor supply for the model in Section 5. I suppress industry and region subscripts.

B.1 Elasticities of derived demand

The model described by (19) and (10) is different from that in the previous section in that the supply of native labor to each task now depends on the wage of each task in an industry region. Taking derivates of the first-order conditions with respect to a change in the supply of manual tasks:

$$\frac{d\ln w_m}{d\ln M} = \left(\frac{\eta-\sigma_{xm}}{\eta\sigma_{xm}}\right)\frac{d\ln Q}{d\ln M} - \frac{1}{\sigma_{xm}} \tag{35}$$

$$\frac{d\ln w_m}{d\ln M} = \frac{\sigma_{xm}+\phi_x^x}{\sigma_{xm}-\phi_m^x}\frac{d\ln w_x}{d\ln M} - \frac{1}{\sigma_{xm}-\phi_m^x} \tag{36}$$

and taking the derivate of the production function the respect to the supply of manual tasks:

$$\frac{d\ln Q}{d\ln M} = s_m + s_x\left(\phi_x^x\frac{d\ln w_x}{d\ln M} + \phi_m^x\frac{d\ln w_m}{d\ln M}\right) \tag{37}$$

I eliminate $\frac{d\ln w_m}{d\ln M}$ in (35) and (36) to obtain

$$\frac{d\ln Q}{d\ln M} = \frac{\eta\left(s_m\sigma_{xm}-s_x\phi_m^x\right)}{\eta\sigma_{xm}-s_x\phi_m^x\left(\eta-\sigma_{xm}\right)} + \frac{s_x\eta\sigma_{xm}\phi_x^x}{\eta\sigma_{xm}-s_x\phi_m^x\left(\eta-\sigma_{xm}\right)}\frac{d\ln w_x}{d\ln M} \tag{38}$$

and using (37)

$$\frac{d\ln Q}{d\ln M} = \frac{\eta\sigma_{xm}}{\left(\eta-\sigma_{xm}\right)}\frac{\sigma_{xm}+\phi_x^x}{\sigma_{xm}-\phi_m^x}\frac{d\ln w_x}{d\ln M} - \frac{\eta\phi_m^x}{\left(\eta-\sigma_{xm}\right)\left(\sigma_{xm}-\phi_m^x\right)} \tag{39}$$

From (38) and (39) I then derive the expression for $\frac{d\ln w_x}{d\ln M}$, see equation (25) and

$$\frac{d\ln Q}{d\ln M} = \frac{s_m\eta\left(\sigma_{xm}+\phi_x^x\right)-s_x\eta\phi_m^x}{\eta\sigma_{xm}+\phi_x^x\left(s_m\eta+s_x\sigma_{xm}\right)-s_x\phi_m^x\left(\eta-\sigma_{xm}\right)} \tag{40}$$

Finally substituting (40) into (35) allows me to solve for $\frac{d\ln w_m}{d\ln M}$, see equation (24), in terms of the exogenous parameters.

B.2 Native worker labor supply

Workers have a choice of industry, region and task as described by (20). Using the same reasoning as above one can show that the probability of a worker choosing a certain task in a certain industry-region $P(r,s,\tau)$ can be expressed as

$$\begin{aligned}
P(r,s,\tau) &= P(\tau|r,s)\,P(s|r)\,P(r)\\
P(\tau|r,s) &= \frac{\left(\alpha_{rs\tau}w_{rs\tau}\right)^{\mu^\tau}}{\sum_{\tau'}\left(\alpha_{rs\tau'}w_{rs\tau'}\right)^{\mu^\tau}},\quad P(s|r)=\frac{J_{rs}^{\mu^s}}{\sum_{s'}J_{rs'}^{\mu^s}},\quad P(r)=\frac{J_r^{\mu^r}}{\sum_{r'}J_{r'}^{\mu^r}}\\
J_{rs} &= \left(\sum_\tau\left(\alpha_{rs\tau}w_{rs\tau}\right)^{\mu^\tau}\right)^{1/\mu^\tau},\quad J_r=\left(\sum_s J_{rs}^{\mu^s}\right)^{1/\mu^s}
\end{aligned}$$

where a useful property of J_r and J_{rs} is

$$\frac{d\ln J_{rs}}{d\ln w_{rs\tau'}} = \frac{(\alpha_{rs\tau'}w_{rs\tau'})^{\mu^\tau}}{\sum_\tau (\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}, \quad \frac{d\ln J_r}{d\ln w_{rs\tau'}} = \frac{d\ln J_r}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau'}} = \frac{(\alpha_{rs\tau'}w_{rs\tau'})^{\mu^\tau}}{\sum_\tau (\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}\frac{J_{rs}^{\mu^s}}{\sum_s J_{rs}^{\mu^s}}$$

The elasticity of labor supply, assuming a homogenous workers

$$\begin{aligned}
\frac{d\ln N_{rs\tau}}{d\ln w_{rs\tau}} &= \frac{d\ln P(\tau|r,s)}{d\ln w_{rs\tau}} + \frac{d\ln P(s|r)}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} + \frac{d\ln P(r)}{d\ln J_r}\frac{d\ln J_r}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} \\
&= \mu^\tau\left(1 - \frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_{\tau'}(\alpha_{rs\tau'}w_{rs\tau'})^{\mu^\tau}}\right) + \mu^s\left(1 - \frac{J_{rs}^{\mu^s}}{\sum_{s'} J_{rs'}^{\mu^s}}\right)\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} \\
&\quad + \mu^r\left(1 - \frac{J_r^{\mu^r}}{\sum_{r'} J_{r'}^{\mu^r}}\right)\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}\frac{J_{rs}^{\mu^s}}{\sum_s J_{rs}^{\mu^s}} \\
\phi_\tau^\tau &= \mu^\tau(1 - P(\tau|r,s)) + \mu^s(1 - P(s|r))P(\tau|r,s) + \mu^r(1 - P(r))P(\tau|r,s)P(s|r)
\end{aligned}$$

There are several different cross-wage elasticities of labor supply to a task in an industry-region. The elasticity of labor supply with respect to a change in the wage of the other task in the same industry and region.

$$\begin{aligned}
\frac{d\ln N_{rs\tau'}}{d\ln w_{rs\tau}} &= \frac{d\ln P(\tau'|r,s)}{d\ln w_{rs\tau}} + \frac{d\ln P(s|r)}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} + \frac{d\ln P(r)}{d\ln J_r}\frac{d\ln J_r}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} \\
&= -\mu^\tau\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} + \mu^s\left(1 - \frac{J_{rs}^{\mu^s}}{\sum_{s'} J_{rs'}^{\mu^s}}\right)\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} \\
&\quad + \mu^r\left(1 - \frac{J_r^{\mu^r}}{\sum_{r'} J_{r'}^{\mu^r}}\right)\frac{J_{rs}^{\mu^s}}{\sum_s J_{rs}^{\mu^s}}\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} \\
\phi_\tau^{\tau'} &= -\mu^\tau P(\tau|r,s) + \mu^s(1 - P(s|r))P(\tau|r,s) + \mu^r(1 - P(r))P(s|r)P(\tau|r,s)
\end{aligned}$$

Since there are only two tasks it is also true that

$$\begin{aligned}
\phi_x^x + \phi_m^x &= \phi_m^m + \phi_x^m = \mu^s(1 - P(s|r)) + \mu^r(1 - P(r))P(s|r) \\
\phi_x^x - \phi_x^m &= \phi_m^m - \phi_m^x = \mu^\tau
\end{aligned}$$

The cross-elasticity with respect to a change in the wage in a task from a different industry in the same region is

$$\begin{aligned}
\frac{d\ln N_{rs'\tau}}{d\ln w_{rs\tau}} &= \frac{d\ln P(s'|r)}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} + \frac{d\ln P(r)}{d\ln J_r}\frac{d\ln J_r}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} \\
&= -\mu^s\frac{J_{rs}^{\mu^s}}{\sum_s J_{rs}^{\mu^s}}\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} + \mu^r\left(1 - \frac{J_r^{\mu^r}}{\sum_{r'} J_{r'}^{\mu^r}}\right)\frac{J_{rs}^{\mu^s}}{\sum_s J_{rs}^{\mu^s}}\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} \\
&= -\mu^s P(s|r)P(\tau|r,s) + \mu^r(1 - P(r))P(s|r)P(\tau|r,s) \\
&= (-\mu^s + \mu^r(1 - P(r)))P(s|r)P(\tau|r,s)
\end{aligned}$$

The cross-elasticity with respect to a change in the wage of labor supply to a task in an industry in a different region is

$$
\begin{aligned}
\frac{d\ln P(r')}{d\ln w_{rs\tau}} &= \frac{d\ln P(r')}{d\ln J_r}\frac{d\ln J_r}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} \\
&= -\mu^r \frac{J_r^{\mu^r}}{\sum_r J_r^{\mu^r}}\frac{J_{rs}^{\mu^s}}{\sum_s J_{rs}^{\mu^s}}\frac{(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}}{\sum_\tau(\alpha_{rs\tau}w_{rs\tau})^{\mu^\tau}} \\
&= -\mu^r P(\tau|r,s)\,P(s|r)\,P(r) \\
&= -\mu^r P(\tau,r,s)
\end{aligned}
$$

The ratio of new hires to an industry-region from within the same region and from other regions is exactly the same as in the previous model, see equation (18).

B.3 Effects of immigration

Below I derive the results I use in Section 5.2. The supply of manual tasks consists of the sum of I, the number of immigrants, and M_N the number of natives who choose to provide manual tasks, $M = M_N + M_I$. Hence,

$$
\begin{aligned}
\frac{dM}{dM_I} &= \left(\frac{dM_N}{dw_m}\frac{dw_m}{dM} + \frac{dM_N}{dw_x}\frac{dw_x}{dM}\right)\frac{dM}{dM_I} + 1 \\
\frac{d\ln M}{d\ln M_I} &= \frac{M_N}{M}\left(\frac{d\ln M_N}{d\ln w_m}\frac{d\ln w_m}{d\ln M} + \frac{d\ln M_N}{d\ln w_x}\frac{d\ln w_x}{d\ln M}\right)\frac{d\ln M}{d\ln M_I} + \frac{M_I}{M} \\
\frac{d\ln M}{d\ln M_I} &= \frac{s_i}{1 + s_n\left(\phi_m^m\left(-\frac{d\ln w_m}{d\ln M}\right) - \phi_x^m\frac{d\ln w_x}{d\ln M}\right)}
\end{aligned}
$$

The effect of immigration on the relative wage between manual and interactive tasks is given by $\frac{d\ln\frac{w_x}{w_m}}{d\ln M} = \frac{d\ln w_x}{d\ln M} - \frac{d\ln w_m}{d\ln M}$ and using (25) and (24) simplifies to the expression in equation (26). Similarly, the effect of immigration on the relative quantity of X and M is

$$
\begin{aligned}
\frac{d\ln\frac{X}{M}}{d\ln M} &= \frac{d\ln X}{d\ln M} - \frac{d\ln M}{d\ln M} \\
&= \phi_x^x\frac{d\ln w_x}{d\ln M} + \phi_m^x\frac{d\ln w_m}{d\ln M} - 1
\end{aligned}
$$

Finally, the total effect on the number of native workers in an industry is found as follows

$$
\begin{aligned}
\frac{d\ln(X+M_N)}{d\ln M} &= \sum_{\tau=(x,m)}\left(\frac{d\ln P(s|r)}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}} + \frac{d\ln P(r)}{d\ln J_r}\frac{d\ln J_r}{d\ln J_{rs}}\frac{d\ln J_{rs}}{d\ln w_{rs\tau}}\right)\frac{d\ln w_{rs\tau}}{d\ln M} \\
&= \left(\mu^s(1-P(s|r)) + \mu^r(1-P(r))\,P(s|r)\right)\left(P(x|r,s)\,\frac{d\ln w_{rsx}}{d\ln M} + P(m|r,s)\,\frac{d\ln w_{rsm}}{d\ln M}\right) \\
&= \left(\phi_x^x + \phi_m^x\right)\left(\frac{X}{X+M_N}\frac{d\ln w_{rsx}}{d\ln M} + \frac{M_N}{X+M_N}\frac{d\ln w_{rsm}}{d\ln M}\right)
\end{aligned}
$$

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Table 1: Actual Immigration on Predicted Immigration (by 1-digit industry)

Dependent variable Log Change in Immigrant Employment

	Manufacturing	All Services	Construction	Retail Trade	Food & Accomm.	Business Services	Agriculture	All Industries
Instrument (2-digit)	0.145	0.173	0.28*	0.167	0.396	0.194	0.339	0.199**
	(0.142)	(0.107)	(0.164)	(0.131)	(0.489)	(0.21)	(0.214)	(0.079)
Instrument (1-digit)	0.181	0.158	-0.017	0.184	-0.188	0.187	-	0.104*
	(0.166)	(0.111)	(0.195)	(0.141)	(0.502)	(0.203)	-	(0.088)
R-squared	0.64	0.74	0.84	0.75	0.80	0.67	0.74	0.74
F-statistic	9.1	17.6	22.5	15.9	16.9	9.4	8.4	15.3
No. Observations	1290	1296	486	648	324	324	162	3234

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. All regressions include 2-digit industry by year fixed effects and region fixed effects.

Table 2: Correlation of Instrument with Changes in Native Wages and Employment in Pre_period (1980-85), by 1-digit industry

Dependent variable: Log Change in Native Employment / Log Change in Native Wages / Log Change in Immigrant Wages

	All Industries			Manufacturing			All Services			Construction		
	Emp.	**Wages**	**For. Wage**	**Emp.**	**Wages**	**For. Wage**	**Emp.**	**Wages**	**For. Wage**	**Emp.**	**Wages**	**For. Wage**
Instrument	-0.068***	0	-0.009	-0.099***	0.012**	-0.01	-0.05***	-0.003	-0.003	-0.036	-0.013**	-0.009
	(0.02)	(0.003)	(0.01)	(0.041)	(0.006)	(0.01)	(0.015)	(0.004)	(0.01)	(0.033)	(0.006)	(0.01)
Partial R-squared	0.080	0.000	0.030	0.120	0.060	0.010	0.110	0.000	0.000	0.070	0.060	0.030
No. Observations	900	900	135	360	360	360	360	360	360	135	135	135
	Retail Trade			**Food & Accomm.**			**Business Services**			**Agriculture**		
	Emp.	**Wages**	**For. Wage**	**Emp.**	**Wages**	**For. Wage**	**Emp.**	**Wages**	**For. Wage**	**Emp.**	**Wages**	**For. Wage**
Instrument	-0.049***	-0.001	-0.007	-0.04***	-0.01**	0.006	-0.06***	-0.001	-0.001	-0.196	-0.04**	-0.013
	(0.011)	(0.004)	(0.009)	(0.038)	(0.006)	(0.008)	(0.025)	(0.004)	(0.024)	(0.145)	(0.022)	(0.032)
Partial R-squared	0.240	0.000	0.010	0.040	0.050	0.010	0.220	0.000	0.000	0.100	0.410	0.020
No. Observations	180	180	180	90	90	90	90	90	90	45	45	45

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. I also cluster on 2-digit industry by region. All variables are demeaned at the level of a 2-digit industry in a given year.

Table 3: Impact of Immigration on Changes in Native Wages and Employment (by 1-digit industry)

Dependent variable: Log Change in Native Employment / Log Change in Native Wages

	Manufacturing		All Services		Construction		Retail Trade		Food & Accomm.		Business Services		Agriculture		All Industries	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	Change in Log Native Employment															
Δ Log Foreign Emp.	0.148***	0.121**	0.126***	-0.095**	0.043***	0.038	0.132***	-0.133**	0.036	-0.323	0.151***	0.069	-0.005	-0.096	0.118***	-0.022
	(0.022)	(0.057)	(0.027)	(0.045)	(0.014)	(0.027)	(0.042)	(0.057)	(0.023)	(0.204)	(0.03)	(0.047)	(0.019)	(0.084)	(0.015)	(0.03)
R-squared	0.5	0.5	0.62	0.5	0.66	0.66	0.47	0.26	0.72	0.44	0.72	0.7	0.66	0.63	0.6	0.54
No. Observations	1296	1290	1296	1296	486	486	648	648	324	324	324	324	162	162	3240	3234
	Change in Log Native Wages															
Δ Log Foreign Emp.	0.004	0.01	0.007	-0.023	0.009	-0.003	0.019*	-0.003	0.014	-0.132	-0.024	-0.036	0.017*	0.085	0.007	-0.012
	(0.006)	(0.015)	(0.009)	(0.015)	(0.006)	(0.009)	(0.01)	(0.013)	(0.015)	(0.089)	(0.024)	(0.03)	(0.01)	(0.067)	(0.005)	(0.009)
R-squared	0.77	0.77	0.85	0.84	0.89	0.89	0.86	0.86	0.88	0.82	0.8	0.8	0.79	0.76	0.85	0.84
No. Observations	1296	1290	1296	1296	486	486	648	648	324	324	324	324	162	162	3240	3234

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. All regressions include 2-digit industry by year fixed effects and region fixed effects.

Table 4: Impact of Immigration on Changes in Immigrant Wages (by 1-digit industry)

Dependent variable: Log Change in Immigrant Wages

	Manufacturing		All Services		Construction		Retail Trade		Food & Accomm.		Business Services		Agriculture		All Industries	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Δ Log Foreign Emp.	-0.082***	-0.228***	-0.055**	-0.105***	-0.042***	-0.046*	-0.025	-0.098**	-0.015	-0.164*	-0.135**	-0.089	-0.178***	-0.137	-0.065***	-0.122***
	(0.013)	(0.057)	(0.022)	(0.041)	(0.015)	(0.026)	(0.023)	(0.047)	(0.017)	(0.089)	(0.057)	(0.09)	(0.029)	(0.142)	(0.011)	(0.028)
R-squared	0.37	0.15	0.45	0.43	0.62	0.62	0.35	0.32	0.7	0.55	0.51	0.5	0.49	0.48	0.45	0.42
No. Observations	1296	1290	1296	1296	486	486	648	648	324	324	324	324	162	162	3240	3234

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. All regressions include 2-digit industry by year fixed effects and region fixed effects.

Table 5: Impact of Immigration on Changes in Native Wages and Employment (by 1-digit industry)

	Manufacturing				All Services				All Industries			
Dependent variable:	Employment		Wages		Employment		Wages		Employment		Wages	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
					Without Region Fixed Effects							
∆ Log Foreign Emp.	0.161***	0.14***	0.004	0.009	0.143***	-0.071*	0.002	-0.027**	0.132***	0.022	0.005	-0.012**
	(0.021)	(0.047)	(0.005)	(0.013)	(0.023)	(0.04)	(0.008)	(0.011)	(0.013)	(0.026)	(0.004)	(0.007)
R-squared	0.46	0.46	0.76	0.76	0.59	0.46	0.84	0.84	0.58	0.54	0.84	0.84
No. Observations	1296	1290	1296	1290	1296	1296	1296	1296	3240	3234	3240	3234
					Changes in Levels							
∆ Log Foreign Emp.	1.601***	0.824			0.941***	-1.439			1.253***	-0.109		
	(0.195)	(0.709)			(0.159)	(1.109)			(0.264)	(0.697)		
R-squared	0.5	0.45			0.59	0.45			0.57	0.48		
No. Observations	1296	1296			1296	1296			3240	3240		

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. All regressions include 2-digit industry by year fixed effects and region fixed effects.

Table 6: Impact of Immigration on Changes in Native Wages and Employment by Education (by 1-digit industry)

	Manufacturing				All Services				All Industries			
Dependent variable:	**Employment**		**Wages**		**Employment**		**Wages**		**Employment**		**Wages**	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**
					Low Skilled Natives							
Δ Log Foreign Emp.	0.19***	0.144**	0.004	0.016	0.159***	-0.104**	0.006	-0.023	0.152***	-0.007	0.005	-0.012
	(0.023)	(0.062)	(0.005)	(0.018)	(0.03)	(0.054)	(0.014)	(0.02)	(0.016)	(0.036)	(0.007)	(0.013)
R-squared	0.49	0.49	0.63	0.63	0.64	0.53	0.77	0.77	0.63	0.59	0.77	0.77
No. Observations	1296	1290	1296	1290	1296	1296	1296	1296	3240	3234	3240	3234
					Higher Skilled Natives							
Δ Log Foreign Emp.	0.133***	0.101*	0.004	0.004	0.117***	-0.097**	0.01	-0.022	0.108***	-0.033	0.009**	-0.012
	(0.021)	(0.057)	(0.005)	(0.014)	(0.026)	(0.044)	(0.008)	(0.014)	(0.014)	(0.03)	(0.004)	(0.008)
R-squared	0.49	0.48	0.78	0.78	0.61	0.49	0.86	0.85	0.57	0.51	0.85	0.85
No. Observations	1296	1290	1289	1285	1296	1296	1296	1296	3240	3234	3233	3229

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. All regressions include 2-digit industry by year fixed effects and region fixed effects.

Table 7: Impact of Immigration on Hire and Separation Rates and Wage Changes for Hires and Incumbent Workers (by 1-digit industry)

	Manufacturing				All Services				All Industries			
	New Hires											
Dependent variable:	**Employment**		**Wages**		**Employment**		**Wages**		**Employment**		**Wages**	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**
Δ Log Foreign Emp.	0.059***	0.089***	0.001	0.058	0.054***	-0.059**	0.005	0.004	0.048***	-0.014	-0.006	0.011
	(0.011)	(0.038)	(0.022)	(0.065)	(0.01)	(0.024)	(0.03)	(0.064)	(0.007)	(0.018)	(0.016)	(0.041)
R-squared	0.42	0.41	0.38	0.37	0.84	0.81	0.77	0.77	0.83	0.82	0.7	0.7
No. Observations	1296	1290	1296	1290	1296	1296	1296	1296	3240	3234	3240	3234
	Separations / Incumbents											
	Separations		**Incumbent Wages**		**Separations**		**Incumbent Wages**		**Separations**		**Incumbent Wages**	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**	**OLS**	**IV**
Δ Log Foreign Emp.	-0.091***	-0.039	0.001	0.001	-0.079***	0.041	0.011	-0.023	-0.075***	0.015	0.009**	-0.015
	(0.015)	(0.054)	(0.005)	(0.016)	(0.023)	(0.041)	(0.008)	(0.015)	(0.012)	(0.027)	(0.004)	(0.01)
R-squared	0.49	0.48	0.71	0.71	0.6	0.56	0.81	0.81	0.61	0.59	0.81	0.81
No. Observations	1296	1290	1296	1290	1296	1296	1296	1296	3240	3234	3240	3234

* signficant at 10%; ** significant at 5%, *** significant at 1%. Unit of analysis is a 2-digit industry in a region in a year. Observations are weighted by the number of employees in each cell and estimates are robust to heteroscedasticity. All regressions include 2-digit industry by year fixed effects and region fixed effects.

Table 8: Parameter Estimates for Framework I

	Manufacturing	Services	All Industries
Elasticity of Substitution (σ_{in})	3.7	13.4	9.3
Elasticity of Product Demand (ψ)	22.1	0.4	5.0
Elasticity of Labor Demand (η)	15.8	0.6	3.8
Elasticity of Labor Supply (ϕ_n)	12.1	4.1	1.8
Within region scale parameter (μ_s)	11.4	3.9	1.8
Between region scale parameter (μ_r)	5.2	1.5	0.4
Hire (s'|r) / Hire (r')	2	2	2
Immigrant labor share (s_i)	0.097	0.103	0.111
Native labor share (s_n)	0.903	0.897	0.889
Total labor share (s_q)	0.7	0.7	0.7
Capital share (s_k)	0.3	0.3	0.3

Table 9: Parameter Estimates for Framework II

	Manufacturing	Services	All Industries
Share of manual tasks in labor output	0.27	0.36	0.30
Elasticity of relative wage	0.29	0.11	0.13
Elasticity of relative native task supply	0.55	0.14	0.08
Own-wage elasticity of labor supply	1.22	1.29	1.23
Cross-wage elasticity of labor supply	2.53	0.83	1.39
Total labor share (s_q)	0.7	0.7	0.7
Capital share (s_k)	0.3	0.3	0.3

I assume that both elasticities of substitution σ_{mx} and σ_{qk} are equal to one.

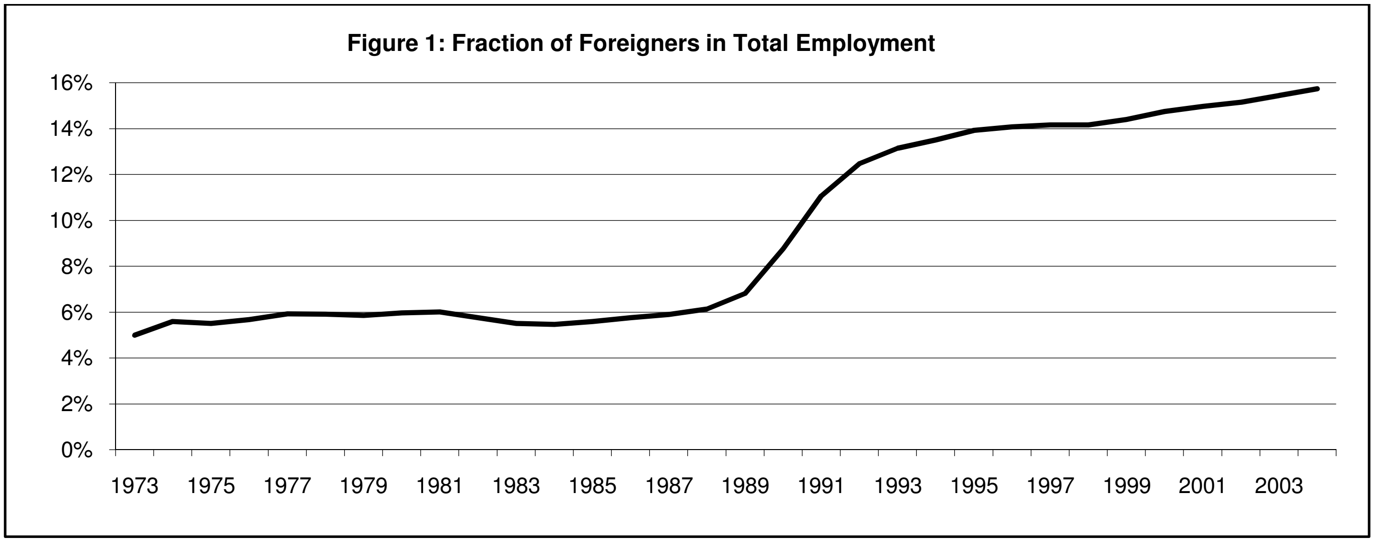
Figure 1: Fraction of Foreigners in Total Employment
16%
14%
12%
10%
8%
6%
4%
2%
0%
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

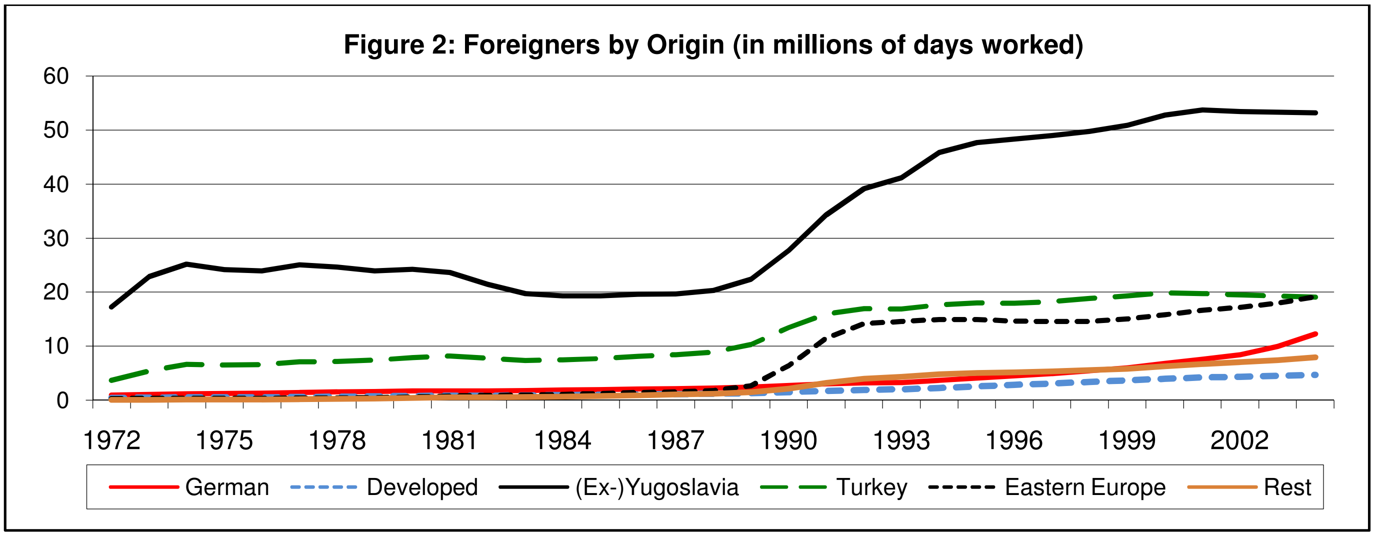
Figure 2: Foreigners by Origin (in millions of days worked)
60
50
40
30
20
10
0
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
German
Developed
(Ex-)Yugoslavia
Turkey
Eastern Europe
Rest

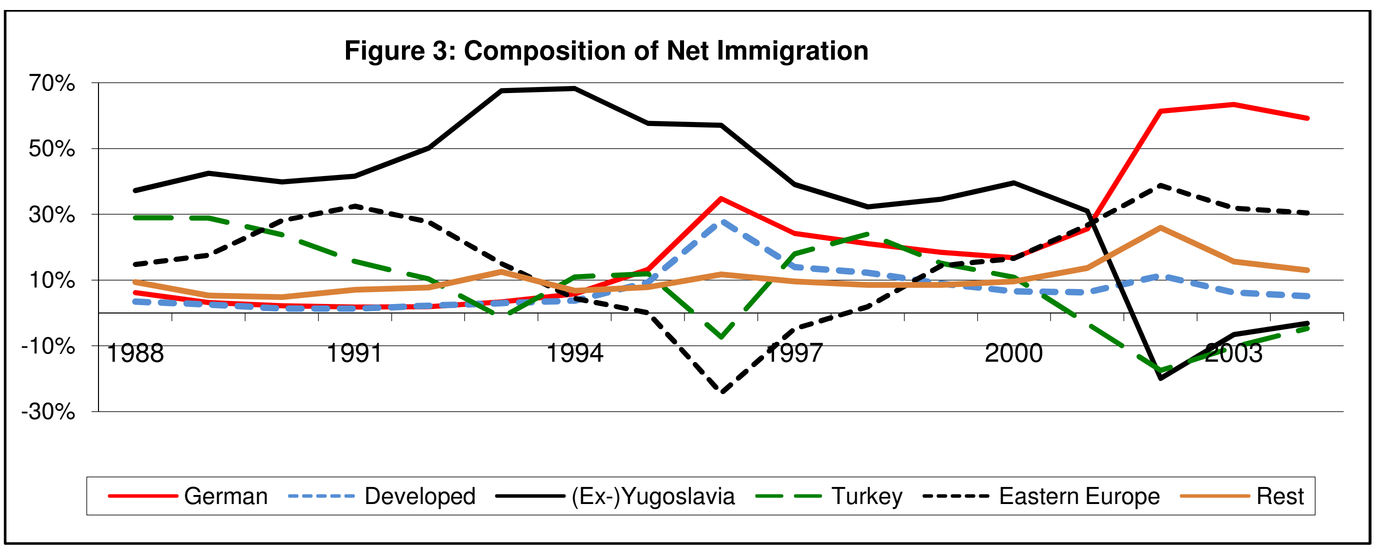
Figure 3: Composition of Net Immigration
70%
50%
30%
10%
-10%
-30%
1988
1991
1994
1997
2000
2003
German
Developed
(Ex-)Yugoslavia
Turkey
Eastern Europe
Rest

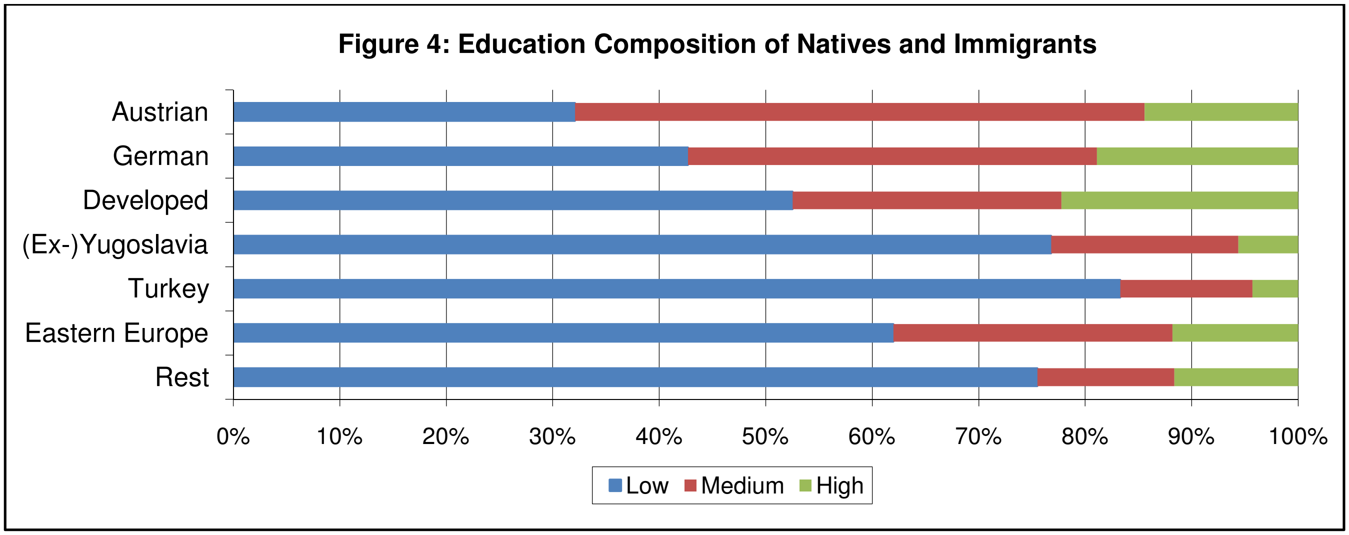
Figure 4: Education Composition of Natives and Immigrants
Austrian
German
Developed
(Ex-)Yugoslavia
Turkey
Eastern Europe
Rest
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Low
Medium
High

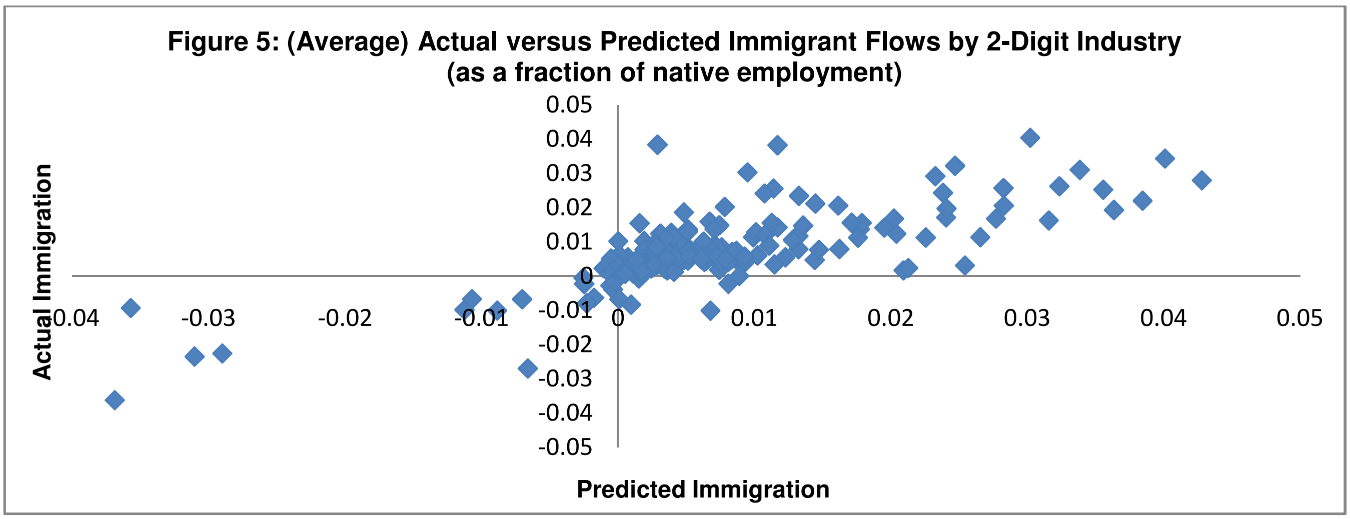
Figure 5: (Average) Actual versus Predicted Immigrant Flows by 2-Digit Industry
(as a fraction of native employment)
Actual Immigration
Predicted Immigration
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05