# Comparative Advantages and Gains from Immigration*

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**Abstract**

Many workers with low levels of educational attainment immigrated to the United States in recent decades. If these immigrants compete with native-born workers of comparable educational attainment for similar jobs, wages paid to less-educated American workers would decline, and wages paid to more educated workers would rise. Using individual data on the task intensity of occupations across US states from 1960-2000, however, we show that foreign and native-born workers with low levels of education supply very different occupational skills. Immigrants specialize in manual tasks such as cleaning, cooking, and building. Native-born workers – who have a better understanding of local networks, rules, customs, and language – respond to immigration by specializing in interactive tasks such as coordinating, organizing, and communicating. This increased specialization in tasks complementary to those performed by immigrants implied that wages paid to native workers with little formal education have experienced little reduction both in the aggregate and in states with large immigration.

**Key Words**: Less Educated Immigrants, Native Wages, Manual Tasks, Interactive Tasks, Comparative Advantages, Gains.

**JEL Codes**: F22, J61, J31, R13.

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# 1 Introduction

Documented and undocumented immigration has significantly affected US labor supply during the last few decades, though the economic effects of this immigration remain subject to debate. The most contentious issue is whether the particularly large inflow of immigrants with low levels of schooling has decreased the wage of native-born workers with similarly low educational attainment. If workers' skills are differentiated only by their level of educational attainment, and workers of different skill levels are imperfectly substitutable, then a large flow of immigrants with limited schooling should reward more educated natives and hurt less educated ones. This intuitive approach receives support in papers by George Borjas (2003, 2006) and George Borjas and Larry Katz (2005), which argue that immigration reduced real wages paid to native-born workers with no high school degree by four to five percent between 1980 and 2000. In contrast, Card (2001) and Lewis and Card (2005) employ city and state level data and find almost no effect of immigration on the relative wages of less educated workers. Moreover, their results are robust to the migration decisions of native-born workers, as they find that natives do not choose to move to areas with fewer immigrants. Thus, the relationship between immigration and wages appears to be more nuanced.

Ottaviano and Peri (2006) note that the effect of immigration crucially depends upon the degree of substitution between native and foreign-born workers *within* each education group. That is, workers' skills may be differentiated by more than traditional measurable characteristics such as educational attainment (and experience level). Native and foreign-born workers may have quite different skills, leading them to specialize in different productive tasks. For example, immigrants – particularly those with low levels of formal schooling – are likely to have inadequate language skills, imperfect knowledge of productive networks, and only limited awareness of social norms and intricacies of productive interactions. However, they have manual and physical skills similar to those of native-born workers. Therefore, foreign-born workers have a comparative advantage in occupations performing manual labor-intensive tasks. On the other hand, native workers with little education will have an advantage in performing interactive and coordination tasks. If less educated immigrants work in occupations that mostly perform manual tasks, natives move to occupations requiring more interactive tasks, and the two types of tasks are complements in production, then native workers can protect themselves against wage competition and benefit from immigration through specialization.

Though the assumptions in Ottaviano and Peri (2006) seem reasonable and are supported by qualitative evidence, they require empirical verification. This paper employs US data for all 50 states (plus the District of Columbia) from 1960 to 2000 to determine whether task-specialization among native and foreign-born workers truly occurs. Suppose immigrants at low levels of educational attainment have a comparative advantage in performing manual tasks. Then an increase in their supply would also increase the supply of manual skills in their state of residence. This reduces the compensation paid to manual tasks and increases the compensation for interactive-coordination tasks. Natives, including those with low levels of schooling, have a relative advantage in these tasks and should respond to increased immigration accordingly. The increase in wages native-born workers earn by choosing occupations demanding interactive tasks shields them from the negative wage effects of immigration. It may even increase aggregate wages paid to native-born workers with limited educational attainment.

We use the variation of foreign-born workers with low levels of educational attainment across US states from 1960-2000 to estimate the response of native-born workers. To measure the intensity of manual versus interactive tasks supplied by workers, we employ a dataset assembled by Autor, Levy, and Murnane (2003). They merged data on job task requirements based upon the US Department of Labor's *Dictionary of Occupational Titles* (DOT) with census occupation classifications. We primarily focus on two of their variables: one that captures the "nonroutine manual" content of each job (called eye-hand-foot coordination skills) and one accounting for the "nonroutine interactive" content of each job (called direction-control-planning). Using IPUMS microdata from the census (Ruggles et. al. (2005)), we then construct the supply of each type of task for native and foreign-born workers by state, as well as the changes in task supply over time.

The data strongly support three key implications of our theory, which we formalize in a simple model in the Section 3. In states with large inflows of less educated immigrants: i) less educated native-born workers *shifted their supply towards interactive tasks*; ii) the *total* supply of manual relative to interactive skills increased at a faster rate than in states with low immigration and iii) the *wage paid to manual relative to interactive tasks decreased*. Less educated natives have responded to immigration by upgrading their occupations. That is, they leave manual task-intensive occupations for interaction-intensive ones. Given the positive wage effect of specializing in interactive skills, this shift augmented real wages paid to native-born workers. This response was large and involved shifts both for the new cohorts of native individuals joining the labor market (relative to the previous cohorts) and for cohorts over time. Moreover, the findings are robust to instrumental variable estimation (following a strategy similar to Card (2001), Card and Di Nardo (2000) and Cortes (2006)) that uses the imputed share of the number of Mexicans living in a state as proxy for the share of immigrants among workers with a high school degree or fewer years of schooling.

Finally, we use the structure of our model and our empirical results to calculate the effect of immigration and the related adjustment in task supply on average wages paid to native-born workers with a high school degree or less. Task complementarities and changes in native-born task supply together imply that the negative wage impact of immigration is quite small. These findings agree with those of Card (2001), Card and Lewis (2006), and Ottaviano and Peri (2006). At the same time they enrich the structural framework to analyze the effect of immigration first proposed by Borjas (2003) and then used in Borjas and Katz (2005), Ottaviano and Peri (2006), and Peri (2007).

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the theoretical model and its main testable implications. In Section 4 we describe the data and the details of the construction of our manual and interactive task supply indices. We also present some suggestive preliminary correlations. Section 5 provides the empirical analysis of the main propositions, as well as several robustness checks. In Section 6 we use the structural model to estimate the wage effects of the change in task supply caused by immigration. Section 7 concludes the paper.

## 2 Literature Review

There is a large body of literature analyzing the effect of immigration on labor market outcomes of natives. Economists agree that in the long run immigration does not affect the average wage in the US since physical capital adjustment implies that the marginal productivity of labor and average wage are determined only by total factor productivity. However, immigration may change the relative supply of skills and the relative wages of workers. Borjas (2003) analyzes the relative effects of immigration on wages paid to different education and experience groups between 1980 and 2000. Borjas and Katz (2005) identify the impact of Mexican immigration on the relative wages of native workers with different education levels. Both studies assume that workers are perfectly substitutable within education and experience groups, but are complementary between groups. After accounting for the negative competition effects within groups and the positive complementary effects between groups, they estimate that immigration reduced wages paid to native-born workers without a high school degree by four to five percent. In contrast, Ottaviano and Peri (2005, 2006) observe that immigrants choose occupations that are much different from those of native-born workers with similar education and experience levels. Thus, they assume that native and foreign-born workers within the same education and experience group are imperfect substitutes. Compared to earlier studies, they find that immigration produces a smaller negative wage effect on native-born workers, but a larger one on previous immigrants who possess similar jobs and occupations.

We inform this debate by evaluating the substitutability of native and foreign-born workers who maintain identical levels of educational attainment. In particular, we focus on workers with little formal education and measure the skills and tasks these individuals perform in their occupations. If native and foreign-born workers specialize in different tasks that are not perfectly substitutable in production, and each group has comparative advantage in one type of task, this implies that immigration encourages native-born workers to specialize and that foreign-born workers create little adverse wage consequences for natives.

We assume that labor supplies a combination of a few basic functions – particularly manual or interactive tasks – as defined by Autor, Levy, and Murnane (2003). *A priori*, we believe that native-born workers' familiarity with language, local customs, social norms, and cultural values will give them a comparative advantage in interactive tasks, while immigrants would have a comparative advantage in manual tasks. Our analysis empirically verifies this assumption and three important implications derived from it. Recently the trade literature has also addressed the issue of international productive specialization as a process of specialization in different tasks. Comparative advantages across nations can be defined in terms of task performance, rather than final good prodcution. For example, an interesting new theory of off-shoring (Grossman and Rossi-Hansberg (2006)) builds upon a process of international task division that has some features and implications similar to the one developed in this paper. The division of tasks between natives and immigrants can be seen as a form of "in-shoring" services provided by foreign-born workers.

By arguing that natives specialize in interactive production tasks, this paper also provides a potential explanation for earlier findings that increased immigration among less educated workers in a locality (e.g., a state or a city) neither reduces the relative wage of less educated native-born workers, nor induces their out-migration.[1] Wages paid to natives with low levels of education do not decrease much since immigrants adopt manual task-intensive occupations. Not only do native wages remain stable, but workers also have no incentive to move to new locations as a consequence of immigration. This explanation complements Lewis (2005), which argues that the adoption of techniques in a locality is affected by the local supply of skills so that an increase in less educated workers will increase the adoption of low skill-intensive techniques.

## 3 Theoretical Model

Our model provides a simple general equilibrium illustration of the mechanism of specialization and wages that we test in the empirical section. The model generates predictions that we test using cross-state data in Section 5. We also use the structure of the model and the estimated elasticities in Section 6 to evaluate the effects of immigration on the wage paid to less educated native-born workers.

### 3.1 Production

Consider an economy that produces two final goods, $Y_H$ and $Y_L$, that are consumed by individuals who maximize the utility function in Equation (1).

$$C = \left[\beta Y_L^{\frac{\sigma-1}{\sigma}} + (1-\beta) Y_H^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$C$ is a composite consumption good that provides one unit of utility. The parameter $\sigma$ measures the elasticity of substitution between the two goods in consumption. Denoting the prices of goods $Y_L$ and $Y_H$ by $P_L$ and $P_H$, the unit price of $C$ equals the price index $P_C = \left[\beta^\sigma P_L^{1-\sigma} + (1-\beta)^\theta P_H^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$, which we standardize to equal 1.

[1] See Card (2001), Lewis (2003), and Peri (2006).

The two goods are produced by workers of different education levels. $Y_L$ is produced by workers with lower levels of educational attainment. The total supply of these workers before immigration is $L_D$ (the subscript indicating "domestic" supply). Good $Y_H$ is produced by workers with higher levels of education whose total domestic supply is $H_D$. In the process of producing each good, workers have to perform two types of tasks. To produce $Y_L$, workers of lower educational levels have to provide manual and interactive tasks. For instance, construction workers build houses by setting up scaffoldings, laying bricks, and pouring concrete (manual tasks). However, they also need to talk to plumbers, inform the supervisor about their progress, and coordinate their efforts (interactive tasks). Hence, we call $M_L$ the total supply of manual-task inputs provided by less educated workers, and $I_L$ represents the total supply of interactive-task inputs provided by less educated workers. They combine to produce good $Y_L$ according to the $CES$ function in Equation (2), where $\beta_L$ captures the relative productivity of each task input and $\theta_L$ captures the substitutability between the two types of tasks in the production of good $Y_L$.

$$Y_L = \left[\beta_L M_L^{\frac{\theta_L - 1}{\theta_L}} + (1-\beta_L) I_L^{\frac{\theta_L - 1}{\theta_L}}\right]^{\frac{\theta_L}{\theta_L - 1}} \tag{2}$$

We similarly assume that the production of $Y_H$ requires the combination of two types of tasks; highly educated workers perform both interactive and quantitative-analytical skills. For instance, to produce financial services agents need to decide how to diversify their portfolio and how to use information to best achieve their goals (quantitative-analytical tasks). They must also communicate with their customers, manage their subordinates, and network with other agents (interactive tasks). Denoting the total supply of interactive tasks by highly educated workers as $I_H$ and the total supply of quantitative-analytic tasks as $Q_H$, they combine in the production of $Y_H$ according to Equation (3), where $\beta_H$ captures the relative productivity of interactive versus analytical tasks, while $\theta_H$ measures the elasticity of substitution between the two tasks.

$$Y_H = \left[\beta_H I_H^{\frac{\theta_H - 1}{\theta_H}} + (1-\beta_H) Q_H^{\frac{\theta_H - 1}{\theta_H}}\right]^{\frac{\theta_H}{\theta_H - 1}} \tag{3}$$

Just as we assume that educated and less educated workers are two different production inputs (as they produce different goods), we assume that the interactive tasks performed by less educated ($I_L$) and more educated workers ($I_H$) are different. Optimizing consumers and competitive producers of $Y_L$ and $Y_H$ generate the following equilibrium conditions.

$$\frac{P_H}{P_L} = \frac{(1-\beta)}{\beta}\left(\frac{Y_H}{Y_L}\right)^{-\frac{1}{\delta}} \tag{4}$$

$$\frac{M_L}{I_L} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\theta_L}\left(\frac{w_{ML}}{w_{IL}}\right)^{-\theta_L} \tag{5}$$

$$\frac{I_H}{Q_H} = \left(\frac{\beta_H}{1-\beta_H}\right)^{\theta_L}\left(\frac{w_{IH}}{w_{QH}}\right)^{-\theta_H} \tag{6}$$

Equating the marginal utility of a good to its price generates Expression (4), which shows the relationship between the relative price of final goods and their relative production quantity. Equations (5) and (6) express the relative demand for the two types of tasks needed in the production of $Y_L$ and $Y_H$, respectively. The variables $w_{ML}$ and $w_{IL}$ denote the compensation paid to the provider of one unit of manual or interactive task (respectively) in sector $Y_L$. Similarly, $w_{IH}$ and $w_{QH}$ denote the compensation paid to the provider of one unit of interactive and quantitative tasks (respectively) in sector $Y_H$.

### 3.2 Supply of Tasks and Equilibrium without Immigration

Each domestic agent of education level $L$ is able to supply both manual and interactive tasks. Similarly, each domestic agent with education level $H$ can provide coordination and analytical tasks. We now describe the task-provision decisions of less educated agents ($L$).[2] Domestic agents are characterized by a given level of productivity (effectiveness) in performing each of the two tasks.[3] The unit of labor supplied by each less educated domestic worker can be fully used to provide $m_D$ units of manual tasks or $i_D$ units of interactive tasks. Hence $m_D$ and $i_D$ are the effectiveness of a domestic worker in performing manual and interactive tasks respectively. However, decreasing returns to time performing each task implies that a worker would optimize its allocation of time between manual and interactive functions.

Let $l_m$ represent the hours spent by the representative domestic worker providing manual tasks, and $l_i = (1-l_m)$ is the time spent providing interactive tasks. We assume that the representative domestic worker's supply of manual tasks is given by $m_{DL} = (l_m)^{\delta} m_D$, while the supply of interactive tasks is given by: $i_{DL} = (1-l_m)^{\delta} i_D$. In each case, $\delta < 1$ captures the decreasing returns of performing one task over time. Each domestic worker takes wages for each task ($w_{ML}$ and $w_{IL}$) as given, and then chooses an allocation of time to maximize income $y_{LD} = (l_m)^{\delta} m_D w_{ML} + (1-l_m)^{\delta} i_D w_{IL}$. Altogether, Equation (7) identifies the optimal allocation of time for less educated domestic workers.

$$\frac{l_m}{1-l_m} = \left(\frac{i_D w_{IL}}{m_D w_{ML}}\right)^{\frac{1}{\delta-1}} \tag{7}$$

In the absence of foreign-born labor, the aggregate supply of manual tasks is $M_L = L_D (l_m)^{\delta} m_D$, while the total supply of interactive tasks is $I_L = L_D (1-l_m)^{\delta} i_D$, where $L_D$ represents the total number of domestic

[2] A similar framework applies to more educated agents and will be briefly presented at the end of the section.

[3] In this section, we assume a representative domestic agent exists with a given productivity level in each task. We leave to the Appendix the analysis for the case of heterogeneous domestic agents who can be arrayed according to their relative productivity in manual versus interactive tasks.

workers with low levels of education. Using these definitions and individual task supply in Equation (7), the relative total supply of tasks in the economy reduces to Equation (8).

$$\frac{M_L}{I_L} = \left(\frac{w_{ML}}{w_{IL}}\right)^{\frac{\delta}{1-\delta}} \left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}} \tag{8}$$

The relative supply of manual versus interactive skills positively depends on relative wages and the relative productivity of domestic workers. The term $(m_D/i_D)$ captures the relative productivity of less educated domestic workers in manual tasks, and it facilitates our definition of comparative advantage. A group of workers (such as foreign-born workers, denoted by an $F$ subscript) has a comparative advantage in manual tasks vis-a-vis domestic workers if their relative productivity in manual skills is larger than the relative productivity of domestic workers. That is, if $m_F/i_F > m_D/i_D$. Obviously, immigrant workers may have an absolute disadvantage in both tasks. However, due to their language barriers and limited knowledge of US society, its norms, networks, and references, immigrants are likely to have a comparative advantage in manual tasks. Expressions (5) and (8) represent the relative demand and supply for the relative task inputs in an economy without immigration. Equation (9) obtains the equilibrium relative input provision by substituting one equation into the other and solving for $\frac{M_L}{I_L}$.

$$\frac{M_L}{I_L} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\theta_L \delta}{(1-\delta)\theta_L+\delta}} \left(\frac{m_D}{i_D}\right)^{\frac{\theta_L}{(1-\delta)\theta_L+\delta}} \tag{9}$$

The equilibrium relative supply of tasks is a positive function of the relative importance of the tasks in the production of good $Y_L$ (captured by the parameter $\beta_L$), and a positive function of the relative productivity of (native) workers in each task. The strength of these relationships increases with the substitutability between the two tasks in production ($\theta_L$). Solving for the relative wages in equilibrium, we obtain Equation (10).

$$\frac{w_{ML}}{w_{IL}} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \left(\frac{m_D}{i_D}\right)^{-\frac{1}{(1-\delta)\theta_L+\delta}} \tag{10}$$

Figure 1 illustrates the labor market equilibrium for an economy without immigration. (That is, it represents the relative supply and demand of tasks among native workers only). With relative wages on the vertical axis and relative quantities on the horizontal axis (both axes in logarithmic scale), it becomes clear that skill demand and supply are log-linear functions. The equilibrium relative wages and relative task use in production are identified by point $E_0$. As indicated by the arrows, an increase in $\beta_L$ (the relative productivity of manual tasks in sector $Y_L$) will shift the demand curve to the right. This implies higher equilibrium $\frac{M_L}{I_L}$ and $\frac{w_{ML}}{w_{IL}}$ values. An increase in the relative effectiveness of workers in manual tasks ($\frac{m_D}{i_D}$) will cause a shift of the supply curve to the right, which raises equilibrium $\frac{M_L}{I_L}$ but reduces $\frac{w_{ML}}{w_{IL}}$ (since the supply of effective manual skills has increased). The relative wage paid to a worker for her manual versus interactive tasks equals $\frac{w_{ML}}{w_{IL}}\frac{m_D}{i_D}$, which rises as a result of an increase in $\frac{m_D}{i_D}$ if $\theta_L > 1$.

The demand and supply conditions in sector $Y_H$ are very similar. $H$ highly educated domestic workers supply $l_I$ units of their time to perform interactive tasks, while $(1-l_I)$ perform quantitative tasks. Similar to their less educated colleagues, their efficiency in performing a task decreases with time. If $i_D$ and $q_D$ represent their efficiency when supplying all their time in performing one task only (respectively, interactive and quantitative tasks), their income will be $y_{HD} = (l_I)^{\delta} m_D w_{IH} + (1-l_I)^{\delta} i_D w_{QH}$. The parameter $\delta$ is identical for high and low education workers, and $w_{IH}$ and $w_{QH}$ represent the unit compensation for interactive and quantitative tasks. Proceeding as above, we find that the relative supply of tasks by highly educated workers is determined by Equation (6).

$$\frac{I_H}{Q_H} = \left(\frac{w_{IH}}{w_{QH}}\right)^{\frac{\delta}{1-\delta}} \left(\frac{i_D}{q_D}\right)^{\frac{1}{1-\delta}} \tag{11}$$

The equilibrium provision of tasks in an economy without immigration is given by Equation (12), while Equation (13) identifies the equilibrium relative wage.

$$\frac{I_H}{Q_H} = \left(\frac{\beta_H}{1-\beta_H}\right)^{\frac{\theta_H \delta}{(1-\delta)\theta_H+\delta}} \left(\frac{i_D}{q_D}\right)^{\frac{\theta_H}{(1-\delta)\theta_H+\delta}} \tag{12}$$

$$\frac{w_{IH}}{w_{QH}} = \left(\frac{\beta_H}{1-\beta_H}\right)^{\frac{(1-\delta)\theta_H}{(1-\delta)\theta_H+\delta}} \left(\frac{i_D}{q_D}\right)^{-\frac{1}{(1-\delta)\theta_H+\delta}} \tag{13}$$

The equilibrium supply of interactive relative to quantitative tasks depends positively on $\beta_H$ (the relative productivity of interactive skills in the production of $Y_H$) and $\frac{i_D}{q_D}$ (the relative effectiveness of performing interactive rather than quantitative tasks). The relative unit compensation of interactive tasks is increasing in $\beta_H$ and decreasing in $\frac{i_D}{q_D}$. Recall, however, that the relative individual compensation for interactive skills is$\frac{i_D}{q_D}\frac{w_{IH}}{w_{QH}}$ and is increasing in $\frac{i_D}{q_D}$ for $\theta_H > 1$. Equation (14) expresses the equilibrium condition in terms of relative aggregate hours spent in performing each task. Relative employment in interactive tasks is a positive function of $\beta_H$ and of $\frac{i_D}{q_D}$ for $\theta_H > 1$.

$$\frac{H_{DI}}{HQ} = \frac{l_i}{1-l_i} = \left(\frac{\beta_H}{1-\beta_H}\right)^{\frac{\theta_H}{(1-\delta)\theta_H+\delta}} \left(\frac{i_D}{q_D}\right)^{\frac{\theta_H-1}{(1-\delta)\theta_H+\delta}} \tag{14}$$

### 3.3 Effects of Immigration on Native Task Supply and Wages

We now consider the effects of an inflow of immigrants on the relative wages and provision of tasks among less educated native-born workers.[4] Define immigration as an inflow of $L_F$ individuals in the market for less educated workers.[5] Importantly, we assume less educated foreign-born workers have a comparative advantage

[4] Predictions for highly educated workers are the same, provided that we consider quantitative and interactive (rather than manual and interactive) tasks.

[5] Also, $H_F$ represents the inflow of highly educated individuals.

in the provision of manual relative to interactive tasks. While there is no clear reason for immigrants to have a productive disadvantage in performing tasks such as building a wall, picking fruits, baking bread, or cutting jewelry, they will certainly not be as proficient as natives in communicating with other US-born workers, organizing people, serving customers, managing relationships, or other language-intensive and interactive tasks. Denoting with $m_F$ and $i_F$ the efficiency of foreign-born workers in performing manual and interactive tasks respectively, a foreign-born comparative advantage in manual tasks implies $m_F/i_F > m_D/i_D$.[6] Equation (15) represents the relative supply of tasks by less educated foreign-born workers.

$$\frac{M_L^F}{I_L^F} = \left(\frac{w_{ML}}{w_{IL}}\right)^{\frac{\delta}{1-\delta}} \left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}} \tag{15}$$

The relative supply of tasks by natives is still given by (8) so that for fixed $w_{ML}$ and $w_{IL}$, the comparative advantage condition implies that the relative supply of manual skills by immigrants is larger than the relative supply by natives at any level of $\frac{w_{ML}}{w_{IL}}$. From the relative supply of tasks for each group we can obtain the relative supply of tasks for the overall economy, as identified in Equation (16).

$$\frac{M_L}{I_L} = \frac{M_L^F + M_L^D}{I_L^F + I_L^D} = f\frac{M_L^F}{I_L^F} + (1-f)\frac{M_L^D}{I_L^D} \tag{16}$$

The term $0 < f < 1$ is the share of interactive tasks provided by foreign-born workers, $f = I_L^F/(I_L^F + I_L^D)$.[7] Figure 2 illustrates this case. The comparative advantage in manual tasks implies that the relative supply curve of immigrants is to the right of the relative supply curve for natives. Hence, the aggregate relative supply (represented by the dashed line) is between the native and immigrant supply and is closer to the relative supply of immigrants for larger values of $f$. The intersection between the relative demand and the aggregate relative supply (indicated as point $E_1$) identifies the equilibrium relative task compensation. For that relative wage, each curve determines the relative supply of tasks by native and immigrant workers. Mathematically, we obtain the equilibrium value by substituting (8) for domestic workers and (15) into (16), and then into the aggregate demand function (5). Thus, we obtain Equation (17).

$$\frac{w_{ML}^*}{w_{IL}^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \left[f\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}} + (1-f)\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}\right]^{-\frac{(1-\delta)}{(1-\delta)\theta_L+\delta}} \tag{17}$$

[6] On the other hand, we assume that highly educated foreign-born workers have a comparative advantage in quantitative and analytical skills. Again, while highly educated foreign-born workers come to the US with very good math, quantitative, and analytical skills, their communication, interactive, and coordination skills may not be on par with US-born professionals. In this case, $q_F/i_F > q_D/i_D$.

[7] The share of interactive tasks provided by foreign-born workers ($f$) is monotonically increasing in the share of foreign-born among less educated workers for given productivities $i_F$ and $i_D$. In particular, $f$ can be written as $\frac{L_F/(L_F+L_D)}{L_F/(L_F+L_D)+\varsigma L_D/(L_F+L_D)}$ where $\varsigma = i_{DL}/i_{FL}$ is the relative effective supply of interactive skills between native and foreign-born workers. As $\varsigma$ is a positive constant in equilibrium and $f$ is bounded between 0 and 1 it is easy to see that an increase in the share of foreign workers, $L_F/(L_F + L_D)$, is associated with a monotonic increase of $f$.

The above expression reduces to (10) for $f = 0$. It implies that $\frac{w^*_{ML}}{w^*_{IL}}$ is smaller than in the equilibrium without immigration for any $f > 0$. Comparison between Figures 1 and 2 illustrates this result by demonstrating that the relative wage of equilibrium $E_1$ is lower than that of $E_2$. This occurs because the term in square brackets is always larger than $\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}$ for $f > 0$. Moreover, the equilibrium relative wage for manual tasks is smaller for larger shares of foreign-born workers in the total employment of less educated workers. An increase of $f$ from 0 to 1 shifts the dashed line in Figure 2 toward the supply of immigrants. It is easy to show that this would decrease equilibrium wages, decrease the relative supply of natives, and increase the total relative supply of manual tasks. Substituting the expression above into the supply of domestic workers we obtain Equation (18).

$$\frac{\left(M_L^D\right)^*}{\left(I_L^D\right)^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\theta_L \delta}{(1-\delta)\theta_L+\delta}} \left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}} \left[f\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}} + (1-f)\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}\right]^{-\frac{\delta}{(1-\delta)\theta_L+\delta}} \tag{18}$$

Since the term in brackets is larger than $\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}$ for $f > 0$, the relative supply of manual tasks among natives is smaller after immigration (Expression (9)), and it is decreasing in $f$ and $\frac{m_F}{i_F}$. This is also clear by comparing Figures 1 and 2. Note that the relative supply of natives is smaller in Figure 2, and that the relative supply of natives will be smaller as the dashed line moves toward the immigrants' supply. Since the relative equilibrium wage for manual tasks is lower with immigrants and is decreasing with $f$, the total relative employment of manual tasks (from natives and immigrants) increases with more immigration. In particular, the equilibrium total relative employment of manual tasks is given by Equation (19).

$$\frac{M_L^*}{I_L^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \left[f\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}} + (1-f)\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}\right]^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \tag{19}$$

Inflows of immigrants with comparative advantages in manual tasks will allow the producers of good $Y_L$ to use more manual task inputs because these skills become cheaper. This increases the total relative quantity of manual tasks demanded. Despite the reduction in supply from native workers, immigrants more than compensate and satisfy the extra demand. The main implications of the model on relative supply and wages can be summarized by the following 4 propositions:

**Proposition 1**: For a given relative compensation of tasks, if foreign born workers have a comparative advantage in performing manual tasks, they will provide higher relative supply of manual tasks vis-a-vis natives.

This proposition derives immediately from the supply Equations (8) and (15), and from the assumption that immigrants have a comparative advantage in manual tasks: $m_F/i_F > m_D/i_D$.

**Proposition 2:** A higher share of foreign workers among the less educated labor force (because of their comparative advantage in the performance of manual tasks) induces native workers to reduce their relative supply of manual tasks.

Given the positive monotonic relation between the share of foreign-born less educated workers and $f$, this proposition derives from the negative dependence of $\frac{(M_L^D)^*}{(I_L^D)^*}$ on $f$ implied by the equilibrium supply of tasks by the native workers (18). As $m_F/i_F > m_D/i_D$ and $0 < f < 1$, increasing $f$ will put more weight on the larger term in the square brackets. Since that term is raised to negative power, this implies a negative impact on $\frac{M_L^*}{I_L^*}$.

**Proposition 3:** A higher share of foreign workers among the less educated labor force (because of their comparative advantage in the performance of manual tasks) produces higher relative supply of manual tasks in the overall economy.

Given the positive monotonic relation between the share of foreign-born less educated workers and $f$, this proposition derives from the positive dependence of $\frac{M_L^*}{I_L^*}$ on $f$ implied by the equilibrium condition in the overall relative task supply (19).

**Proposition 4:** A higher share of foreign workers among the less educated labor force (because of their comparative advantage in the performance of manual tasks) produces lower wages for manual relative to interactive tasks.

Given the positive monotonic relation between the share of foreign-born less educated workers and $f$, this proposition derives from the expression of relative equilibrium wages (17) and its negative dependence on $f$.

Similar implications are obtained for highly educated workers in comparing quantitative and interactive tasks (as opposed to manual and interactive tasks), and assuming that foreign-born workers have a comparative advantage in the first type of skills. The Appendix provides an alternative model of comparative advantage and immigration that generates very similar implications. In that model, native workers are heterogeneous in their comparative advantages in performing tasks so that $m_D/i_D$ is distributed over an interval of native workers. Immigrants may also have a distribution of relative ability, but the distribution interval is above the one for natives. Hence, it is still true that for a generic US born worker $i$ and a generic immigrant $j$, natives have a comparative disadvantage in providing manual skills ($m_{Di}/i_{Di} < m_{Fj}/i_{Fj}$). The four propositions derived above also hold in that specification.

Our empirical analysis tests these four qualitative implications using data for US states from 1960-2000. We focus on the effects of immigration among less educated workers. After estimating the relationship between immigration and task supply, we use the quantitative estimates of the parameters and the theoretical structure described in the model above to evaluate the effect of immigration on the average wages of a native workers with low levels of educational attainment.

# 4 Data and Preliminary Evidence

We must construct measures of each task supplied by native and immigrant workers to test the main implications of the model. The IPUMS dataset by Ruggles et. al. (2000) provides individual-level data on personal characteristics, employment, wages, immigration status, and occupation choice. As consistent with the literature, we identify immigrants as those who are born outside of the United States and were not citizens at birth. To focus on the period of rising immigration, we consider census years 1960, 1970, 1980, 1990 and 2000. We include only people not living in group quarters, who worked at least one week, and are between 17 and 65 years of age. Since the immigrant share of employment varies greatly across US states, we adopt states as the economic unit of analysis. This increases the number of observations to test our theoretical predictions and makes our empirical analysis comparable to area studies of the effect of immigration.[8] US states are open economies, so the effects of immigration in one state could spill into others through the migration of natives. However, most economists find that while there are very large differences in the immigrant share of employment across states, significant differences in relative wages paid to natives do not exist, nor do natives respond to immigration by moving to other states.[9] Our analysis provides an explanation for these phenomena. Native-born workers protect their wages from competition with immigrants and may benefit from their inflow by shifting to interactive tasks. States, therefore, are interesting economic units to analyze this mechanism.

## 4.1 Task Variables

We begin by measuring the task intensity of each occupation so that we can obtain aggregate task supply measures for natives and immigrants by education level and state. To do so, we use data collected and organized by Autor, Levy and Murnane (2003) (hereinafter ALM) who analyze how the diffusion of computers altered the task supply of workers from routine to non-routine tasks.[10] We merge the ALM data with individual-level census and CPS data, and then we aggregate figures to obtain the data used in regressions. We briefly describe the merging procedure and the characteristics of the task variables here. For more details on the construction of the variables, we refer to the Appendix of Autor, Levy and Murnane (2003).

Between 1939 and 1991, the US Department of Labor periodically evaluated the tasks required for more than 12,000 occupations along multiple dimensions. The published results are available in five editions of the *Dictionary of Occupational Titles* (DOT). ALM aggregate the data from each of the two most recent versions (1977 and 1991)[11] by gender and three-digit Census Occupation Codes (COC) to form five measures of occupational

[8] See Card (2001), Lewis (2003, 2005), Card and Lewis (2005), Cortes (2006), and Kugler and Yuksel (2006).

[9] See Card (2001) or Peri (2006).

[10] We are extremely grateful to David Autor for providing the data.

[11] That is, one dataset is based upon the 1977 DOT, and another uses the 1991 version. Though we will employ both series, the summaries in this section are based upon the 1977 codes.

skills.[12] Each variable takes ordinal values ranging from zero to ten, with higher values representing greater intensity of a given skill used in an occupation. One variable measures routine manual activity ($FINGDEX$, for finger dexterity), one captures nonroutine physical activity ($EHF$, for eye hand foot coordination), one represents routine cognitive tasks ($STS$, for setting tolerance and standards), one is for nonroutine interactive tasks ($DCP$, for direction, control and planning), and the final one identifies the intensity of quantitative and analytical tasks ($MATH$, for mathematical reasoning). We refer to these five measures as "task" variables.

In most of our analysis – particularly when considering less educated workers – we focus only on nonroutine manual and interactive tasks ($EHF$ and $DCP$, respectively). These two variables correspond closely to the idea of manual and interactive tasks described in our model. Also, since both both refer to nonroutine tasks, their supply was not directly displaced by the adoption of computer technology, which was a prominent phenomenon during the period considered.[13]

$DCP$ maintains high values in occupations intensive in managerial and interpersonal skills. ALM define $DCP$ as "Adaptability to accepting responsibility for the direction, control or planning of people and activitites." For example, in 1990 (the most recent date in the ALM sample) male farm workers have a $DCP$ value equal to 0.65, while farm managers have a value of 9. Similarly, $DCP$ equals 8.45 for male managers of food serving and lodging establishments, but just 0.26 for male hotel clerks and 0.10 for waiters' assistants. The highest values of $EHF$ (the "Ability to move the hand and foot coordinately with each other and in accordance with visual stimuli") occur in occupations that demand non-routine manual tasks including dancers, athletes, and firefighters. The lowest occur primarily in white-collar jobs, including a number of natural science an teaching professions.

The somewhat arbitrary scale of measurement for the task variables encourages ALM to convert the values into percentiles. We follow a similar, though not identical, approach. First, we use the ALM crosswalk to match task variable values with individual demographic information from the census in 1960, 1970, 1980, and 1990. Unfortunately, changes in the census occupation classification scheme prevent us from developing a crosswalk for the 2000 census. As an alternative, we match the ALM variables to individual-level CPS data from 1998, 1999, and 2000. We assume that these years are collectively representative of the US workforce in 2000.[14] Next, we rank occupations according to their $DCP$ values in 1960. We then calculate the percent of the 1960 labor force working in an occupation at or below a given value of $DCP$.[15] Two percent of the labor force in 1960 worked in an occupation in which $DCP$ equalled zero, for example, so each of these workers is associated with a percentile score of 0.02. Five percent worked in an occupation with a $DCP$ value of 0.33 or less, so

[12] Autor, Levy, and Murnane (2003) note that differentiation by gender within each census occupation occurs because "the gender distribution of DOT occupations differs substantially within COC occupation cells."

[13] Computer adoption can still be a confounding factor in changing the relative supply of tasks, and we control for it in our empirical analysis.

[14] Each of these census and CPS datasets is available from IPUMS. We choose to use information from several CPS years to increase the sample size. We avoid 2001 data to ensure that the events of September 11 will not affect results.

[15] Our labor force consists of non-military wage-earning employees who worked at least one week in the previous year.

individuals with a $DCP$ of 0.33 earn a percentile score of 0.05. After computing these percentiles, we match the scores with $DCP$ values in subsequent decades. Thus, a worker with a $DCP$ value equal to 0.33 would have an associated percentile score of 0.05 regardless of the decade of observation. We then develop percentiles for the other variables ($EHF$, $FINGDEX$, $STS$ and $MATH$) analogously.[16]

## 4.2 Aggregate Trends and Stylized Evidence

By construction, the median percentile values of each task variable should equal 0.50 in 1960.[17] Evolution in the occupational composition of the US workforce between 1960 and 2000 has caused median values to exhibit trends over the period. Table 1 displays the values associated with the median worker of $DCP$ and $EHF$ (measured in 1960 percentile scores). The reported values and trends are similar to those presented in Figure 1 of ALM. In particular, there has been a large decline in the supply of manual tasks as the median value declined by almost 40% (from 0.50 to 0.34) of its initial value. The US has also experienced a large increase in the supply of interactive tasks, as the median value increased by more than 33% (from 0.47 to 0.63). These trends may be due to technological change, changes in educational attainment, and/or changes in the industrial composition of the economy.

We believe it is more interesting to focus on less educated workers and show the differences in manual and interactive tasks supplied by US and foreign-born workers. We define workers with at most a high school degree as the "less educated" group. Figure 3 reports the aggregate relative supply of manual versus interactive tasks ($EHF/DCP$) for native and foreign-born workers in each decade between 1960 and 2000. We construct the aggregate relative supply for a group by dividing the average $EHF$ supply by the average $DCP$ supply for that group. The task variable definitions used are those from the 1977 DOT, hence the suffix in $EHF\_77$ and $DCP\_77$.

Three features are relevant. First, in accordance with Proposition 1, foreign-born workers with a high school degree or less *always* provided more manual tasks relative to interactive ones when compared to native workers with similar education. Second, the gap in the relative supply between native and immigrant workers has increased significantly over time, thus increasing the scope of relative specialization. In 2000, the supply of manual relative to interactive skills by immigrants was 30% higher than for natives. Third, less educated native workers have significantly decreased their relative supply of manual skills over this period. While technology may have contributed to this phenomenon, the trend for immigrant workers was the opposite. Considering that the share of immigrants among less educated workers grew substantially during the forty years analyzed, the

[16] The formal definitions of the other variables is as follows:
$MATH$: General educational development mathematics.
$STS$: Adaptability to situations requiring the precise attainment of set limits, tolerances of standards.
$FINGDEX$: Ability to move fingers and manipulate small objects with fingers rapidly or accurately.

[17] A discrete jump in labor force composition by occupation in 1960 prevents any one occupation from exhibiting a DCP value exactly equal to 0.50.

aggregate trend is consistent with Proposition 2. Native-born workers progressively left manual occupations and adopted interactive ones as immigrants increasingly satisfied the demand for manual skills. In short, this graph shows evidence that immigrants with low levels of education were quite different in their task performance from natives, differences have increased over time, and this has provided potential for gains from specialization.

Table 2 provides examples of the occupational shifts responsible for changes in the task performance of less educated native-born workers by listing selected occupations, their manual and interactive task intensity, and the percentage of foreign-born employees in each job in 2000. We highlight pairs of occupations in which each job is within the same industrial sector and has similar formal education requirements, but also requires quite different manual and interactive tasks. For example, agricultural laborers and farm coordinators are both in agriculture and do not require much formal education, however the first uses mostly manual skills (such as cultivating, picking, sorting) and the second uses mostly interactive skills (such as supervising, organizing, planning, keeping contacts). While in 1960 both occupations were filled by US born workers, in 2000 most laborers (63%) were foreign-born, but coordinators were almost exclusively US-natives (96%). As immigrants took manual jobs, native workers in agriculture could specialize in coordination and managing tasks. Thus, even within the same sector and for similar education requirements, native workers specialize in interactive tasks as immigrants use manual ones.

Figure 4 shows the relative supply of quantitative versus interactive tasks for native and foreign-born workers with some college education or more (our definition of highly educated workers). Even in this case we see a clear difference in the supply of relative skills in the direction predicted by comparative advantage and stated in Proposition 1. Immigrants supply relatively more quantitative skills. Unlike Figure 3, however, we do not observe an increase in the difference of relative skills over time. We also fail to observe a decline in the relative supply of quantitative tasks by native workers. However, technological change likely affects this aggregate trend, and we should proceed to more formal econometric analysis to test Propositions 2 through 4.

One final stylized fact attests to the cross-sectional difference in immigration and native workers' behavior across states. Figure 5 plots the share of foreign-born workers among the less educated labor force and the level of relative manual versus interactive tasks supplied by native workers for each state in 2000. While this does not control for any state-specific factor, the negative correlation is extremely evident and significant. In states with a higher share of immigrants among less educated workers, native workers perform significantly more interactive tasks relative to manual tasks. The estimated regression coefficient implies that natives supply about 25% more interactive relative to manual tasks in California (with about a 45% share of immigrants among less educated workers) than in Maine (where only 5% of the less educated labor force is foreign-born). This strongly suggests that in states with larger immigration, production has been organized to take advantage of the comparative advantages between immigrants and natives. The empirical analysis of the next section tests whether part of this remarkable difference in task specialization of native workers across states is due to immigration, and how this might affect wages paid to native-born workers.

# 5 Empirical Results: Immigration and the Response of Natives

In this section we test Propositions 2 and 3 of Section 3. In particular, we test the correlation between immigration and the relative supply of manual tasks by native workers in a series of specifications in Subsection 5.1, and the positive correlation between immigration and the aggregate relative supply of manual tasks in Subsection 5.4. In both cases we focus on workers with little educational attainment (generally defined as workers with at most a high school diploma). We also briefly analyze the implications of Proposition 2 for highly educated workers (some college or more) and their supply of quantitative versus interactive tasks. The 50 US states and the District of Columbia over the five census years between 1960 and 2000 serve as the units of observation for all regressions.

## 5.1 Immigration and Skill Supply among Native Workers

Equation (20) below represents the basic regression specification to test Proposition 2.

$$\ln\left(\frac{M_L^D}{I_L^D}\right)_{st} = \alpha_s + \beta_t + \gamma \ln(Share\_foreign\_L)_{st} + \varepsilon_{st} \tag{20}$$

$\frac{M_L^D}{I_L^D}$ is the relative supply of manual versus interactive tasks supplied by less educated native workers in state $s$ and year $t$. We set $\frac{M_L^D}{I_L^D}$ equal to the average value of $EHF$ divided by the average value of $DCP$ among native workers with at most a high school degree. $\alpha_s$ and $\beta_t$ represent 51 state fixed effects and four time fixed effects, respectively. $Share\_foreign\_L_{st}$ is the share of foreign-born workers among those with at most a high school degree in state $s$ and year $t$, and $\varepsilon_{st}$ is a non correlated zero-mean disturbance. The regression in (20) provides a key test of our assumptions. If $\gamma$ is negative and significant, then native-born workers respond to immigration by specializing in interactive tasks, which mitigates any negative effect immigration might have on wages.

The regressions in Table 3 employ the DOT 1977 definition for construction of $EHF$ and $DCP$. The first row reports the estimates for $\gamma$. We estimate several variations of (20) for robustness. In the first column (and again in Columns 3 through 7) both the dependent and explanatory variables are expressed in logs so that the coefficient represents an elasticity. Column 2 expresses both the dependent and explanatory variables in levels.[18] In the third column we weight each observation by the number of workers in the state for the given year.[19]

[18] As the dependent variable is the ratio of two values bounded between 0 and 1 and in most cases not too far from 0.5 and the dependent variable is a share the specification in levels and logs produces similar results.

[19] We obtain aggregate weights by multiplying each observation by its sample weight in the 1% census (available from IPUMS)

In the fourth and fifth column we use the information contained in the other DOT variables to construct the supply of manual and interactive tasks. In particular, in Column 4 we consider the supply of both interactive and analytical tasks as potentially capturing better the language-intensive skills in which native workers have a comparative advantage. The variable $I_L^D$ in this specification is constructed as $0.5 * MATH_{st} + 0.5 * DCP_{st}$. In Column 5 we include the routine manual and interactive tasks used by ALM, hence we define the relative supply $\frac{M_L^D}{I_L^D}$ as $(0.5 * EHF_{st} + 0.5 * FINGDEX_{st}) / (0.5 * STS_{st} + 0.5 * DCP_{st})$. Finally, Column 6 omits the year 2000 for which we have the smallest sample (due to reliance on CPS rather than census data), and Column 7 incudes state-specific time trends rather than state fixed effects.

The estimates of $\gamma$ from these specifications are always significantly negative and quantitatively large. The first five specifications find an elasticity between -0.20 and -0.27. Doubling the share of less educated immigrants in a state (a magnitude observed in many states between 1960 and 2000) decreased manual versus interactive relative task supply among less educated natives by 20-27%. This is much larger than the national decrease in relative skills (from 1.12 in 1960 to 1.04 in 2000) over the same period. The last two columns find elasticity estimates even larger in absolute value (between -0.44 and -0.67), confirming the direction and magnitude of this effect.

Rows 2 and 3 of Table 3 decompose native-born workers' relative task-supply changes into its components. The second row shows the association between immigration and average native manual skill-supply ($EHF$), and the third row shows immigration's relationship with native-born interactive skill-supply ($DCP$). Interestingly, the estimates suggest that the increased supply of interactive skills among natives drives the relative effect from Row 1. Virtually no correlation between immigration and manual skills among natives exists. Intuitively, labor force complementarities suggest that with more immigrant workers doing manual jobs, the demand for coordination, interactive, and language intensive tasks increased. Natives filled the increasing demand for those tasks. While the changes in average supplies should be interpreted with caution (by construction each average is an index between 0 and 1), it is important to emphasize that immigration does not seem to "displace" native workers in performing some tasks, but rather bolsters the native workforce by increasing demand for complementary tasks.

If states with large immigration flows also had a change in relative demand favoring interactive tasks (due to increased trade, exposure to technological flows, etc.), the estimated correlations could be spurious. However, any change in the production structure or composition (independent from immigration) that affected the relative productivity of tasks should also affect native and foreign-born task supply in a similar fashion. The last row of Table 3 shows the correlation between the share of foreign-born employment and the relative supply of manual versus interactive tasks among immigrants. States with large immigrant inflows were characterized by

and adding the number of workers in a state.

positive (rather than negative) changes in relative task supply among immigrants. Foreign-born workers have increasingly specialized in manual tasks, and do so at higher rates in states with large inflows. Immigrants and natives of similarly low levels of education had a different pattern of specialization, with immigrants specializing in manual tasks and natives in interactive tasks. It is doubtful that this can be explained by omitted state-specific technological variables, though it remains consistent with specialization driven by group-specific skills.

Tables 4 and 5 provide robustness checks by imposing two modifications to the regressions in Table 3. Table 4 defines less educated workers as those without a high school degree. This significantly reduces the number of individuals in the sample that we use to construct our average values. In later years, workers without high school degrees represent less than a third of people without any college experience. Moreover, while high school dropouts and high school graduates are sometimes considered as imperfectly substitutable in the immigration literature,[20] most US labor models that bifurcate the labor force into two schooling levels will delineate groups according to whether a person either has some college experience or is a college graduate.[21] In any case, the estimates of Table 4 closely mirror (in sign, significance, and magnitude) those of Table 3. The elasticity of relative task-supply among native tasks to immigration is even more precisely estimated and stable between -0.2 and -0.4.

Table 5 returns to our preferred definition of less educated workers (as in Table 3), and uses the task variable definitions from the 1991 DOT. No significant differences in any of the estimates emerge. The results are so similar that the remainder of the paper will use mostly the 1991 definitions of task performance.[22]

## 5.2 Immigration and Skill Supply among Subsets of Native Workers

Distributional and policy concerns demand more insight into how different groups of native-born workers respond to immigration. The previous subsection demonstrated that foreign-born workers perform manual tasks in states with high levels of immigration, and that native-born workers increasingly specialize in interactive tasks. However, it remains to be shown whether a cohort of native workers who once supplied manual skills respond to immigration by shifting their supply towards interactive tasks. It could be that this cohort is simply replaced by new native-born labor force entrants (i.e., young workers) who perform interactive tasks. In the first case, all native workers may benefit from immigration. In the latter case, immigration would create gains for the young and losses for the old.

Tables 6 and 7 address this issue. In Table 6 the dependent variable is the relative supply of manual tasks among less educated natives below 35 years old. The explanatory variable is, as above, the share of immigrants among a state's employees with a high school degree or fewer years of schooling. The estimated correlation

[20] See Borjas (2003) or Ottaviano and Peri (2006).

[21] See Katz and Murphy (1992) or Card and Lemieux (2001).

[22] We have performed several additional robustness checks (such as omitting the largest immigration states – California and New York – or including only male workers) as well, though no notable differences in estimates arise.

between immigration and the relative task supply among young workers in a state is somewhat smaller in absolute value but not significantly different from those estimated for the average worker (Table 3). They are still significant and negative.

Table 7 estimates the relationship between immigration and native-born skill-supply for the 10-year cohort of natives who were between 25 and 35 years old in 1960. Again, the reduction in supply of manual tasks for this single cohort is similar to the average response. The relative supply of interactive versus manual skills that this cohort supplied is much larger in states with high immigration. The cohort responded to immigration by significantly increasing their supply of interactive tasks (third row of Table 7), and decreasing somewhat their supply of manual tasks (second row of Table 7). In other words, the correlation between immigration and skill-supply for this cohort is similar to that of less educated native-born workers as a whole. Such a similar change in relative supply between and within cohorts implies that the whole population of less educated natives may limit wage losses and even gain from immigration (as suggested in the representative agent model developed in Section 3) rather than immigration generating some winners and losers (as in the heterogeneous agent model of the Appendix).

### 5.3 Immigration and Skill Supply among Highly-Educated Native Workers

This paper focuses on the relationship between less educated native and immigrant workers since prior studies have suggested that native-born workers with little educational attainment experience negative wage effects from immigration.[23] Nonetheless, comparative advantages and potential gains from specialization between natives and immigrants at high levels of education may exist as well.

Suppose workers with some college education use two skills in their occupations. Much like their less-educated counterparts, highly-educated workers provide interactive and communicative skills. However, they also provide quantitative and analytical skills that rely on knowledge of math, statistics, and quantitative reasoning. Again, native-born workers should have a comparative advantage in interactive and language skills. This implies that immigrants will specialize in analytical and quantitative tasks. Thus, highly educated immigrants are much more likely to be found among scientists, engineers, physicists, and researchers, while few immigrants work as lawyers, historians, literature professors, and museum curators. We consider the task variable $MATH$, which captures the quantitative skill requirements of an occupation, as the relevant measure of quantitative task supply. $DCP$ continues to measure the supply of interactive tasks. Table 8 reports the estimates of the elasticity of natives' relative supply of quantitative versus interactive tasks in response to immigration among highly educated workers. The regression, analogous to (20), is in Equation (21).

[23] See, for example, Borjas (2003) and Borjas and Katz (2005).

$$\ln\left(\frac{Q_H^D}{I_H^D}\right)_{st} = \alpha_s + \beta_t + \gamma_H \ln(Share\_foreign\_H)_{st} + \varepsilon_{st} \tag{21}$$

$\frac{Q_H^D}{I_H^D}$ is the relative supply of quantitative versus interactive tasks by highly-educated natives, and $Share\_foreign\_H$ is the share of foreign-born workers among highly educated workers in state $s$ and year $t$. The coefficients reported in the first row of Table 8 are different estimates of $\gamma_H$. Also, analogous to Table 3, the second and third row of Table 8 decompose the response of relative supply into quantitative and interactive skill effects. While the elasticity estimates are between -0.06 and -0.09 (much smaller than in Table 3), a clear tendency of native workers to specialize in interactive tasks remains. Quantitative tasks are left to foreign-born workers. The last row also confirms the opposite tendency of foreign-born workers to specialize in quantitative skills more markedly in states with high immigration. Immigration introduced opportunities for natives to specialize. Both less and more educated native-born workers seem to have seized these opportunities over the last forty years.

### 5.4 Immigration and Total Skill Supply

The previous subsections empirically verified Proposition 2 of our theoretical model. Foreign-born workers have a comparative advantage in performing manual tasks, so immigration causes the relative supply of manual tasks by natives to decline.[24] The third implication of the model, stated in Proposition 3, is that the total relative supply of manual tasks increases in economies with a larger share of immigrants. That is, the higher relative manual skill supply among immigrants more than compensates for the reduced supply among natives. The regression in Equation (22) tests this proposition.

$$\ln\left(\frac{M_L}{I_L}\right)_{st} = \alpha_s + \beta_t + \gamma_{TOT} \ln(Share\_foreign\_L)_{st} + \varepsilon_{st} \tag{22}$$

Our task measures no longer distinguish between the skills performed by native versus foreign-born workers. $\frac{M_L}{I_L}$ is the relative supply of tasks, which we obtain by aggregating the supply of manual and interactive tasks among both immigrants and natives (measured with the variables $EHF$ and $DCP$, respectively). The log specification produces an elasticity estimate, and its sign and magnitude capture the effect of immigration on the overall relative supply of these skills. Table 9 reports the estimates of $\gamma_{TOT}$ and decomposes the relative effect into the change in supply of each task. In particular, Rows 2 and 5 estimate the elasticity of the overall supply of manual tasks ($M_L$) to immigration, and Rows 3 and 6 display the elasticity of the overall supply of interactive tasks ($I_L$) to immigration.

As in Tables 3 and 5, we consider workers with at most a high school degree, and we estimate several specifications for robustness. The specification in Column 1 of Table 9 expresses the variables in natural

[24] Section 5.5 will confirm that the observed effect is causal.

logarithms, while the specification in Column 2 expresses them in levels. Column 3 weights each cell by employment. In Column 4 we include analytical tasks in the measure of interactive skills supplied, and in Column 5 we include routine tasks in the measurement of manual ($FINGDEX$) and interactive ($STS$) skills. Finally, in Column 6 we omit year 2000 data since it is less precisely measured. In the top three rows of the table we measure task variables using the 1991 DOT definition, and in the last three rows we use the 1977 DOT definition.

In the overwhelming majority of specifications (all except one) we estimate a significantly positive association between immigration and the relative supply of manual versus interactive tasks. We also find a significant increase in the supply of manual tasks and a nonnegative relationship with the overall supply of interactive tasks. In states where the foreign-born share of workers among less educated employees is high, the overall supply of manual tasks is also high, and the relative intensity of manual tasks increased in equilibrium. Thus, we find evidence supporting Proposition 3.

## 5.5 Instrumental Variable Estimation and Technological Change

Regional (e.g., state-level) analyses of immigration must be particularly careful in establishing causality. We must ask whether our estimates in Sections 5.1 and 5.4 represent the response of native and total supply to immigration. That is, does immigration cause skill supply to change? An especially relevant concern in our case is whether unobserved technological changes, which may vary across states due to heterogeneity in industrial sector composition, have simultaneously increased the productivity of interactive tasks and attracted immigrants.[25] We address this issue in two ways. First we re-estimate our basic regressions using an instrumental variables (IV) technique that proxies the share of foreign-born employees among less educated workers with the imputed share of Mexican-born workers in the total employment of a state. We construct these values using the 1960 distribution of Mexican workers across states and their rate of increase nationwide. Second, the analysis in Autor, Levy and Murnane (2003) causes us to be particularly concerned with the effect of information technology on the change in demand for tasks. Therefore, we also control for the share of less educated workers using computers at work – a value that evolves considerably over time.

### 5.5.1 Endogeneity

Beginning with Card (2001), several studies[26] of immigration's effect on state or city economies have used instrumental variable techniques that exploit two facts. First, new immigrants – especially those with lower education – tend to move to the same areas in which previous immigrants from their country live. Second, the

[25] As pointed out in Section 5.1, such an explanation conflicts with our finding that states attracting a larger share of immigrants also attracts immigrants who supply relatively more manual skills.

[26] Also see Cortes (2006), Lewis (2003, 2005), Ottaviano and Peri (2006), Peri (2006), and Saiz (2003).

countries of origin among foreign-born workers have changed drastically in the 1960-2000 period. The US has experienced a large increase of immigrants from Mexico and Latin America, a moderate increase of immigrants from China and Asia, and a drastic decrease of immigrants from Europe. Together, these facts provide a way to use location preferences as factors affecting the supply of foreign-born workers across states and time that are uncorrelated with state-specific demand (productivity).

We impute the share of Mexican workers in total employment within a state and use this measure as an instrument for the share of immigrants among workers with at most a high school degree. To do so, we first record the actual share of Mexicans in the employment of state $s$ in 1960 ($sh\_MEX_{s,1960}$), and then assume that the growth rate of the Mexican share of employment between 1960 and year $t$ was equal across states. Thus, the imputed share in year $t$ becomes:

$$\widehat{sh\_MEX}_{s,t} = sh\_MEX_{s,1960} \frac{(1 + g\_MEX)_{1960-t}}{(1 + g\_US)_{s,1960-t}}$$

where $(1 + g\_MEX)_{1960-t}$ is the growth factor of Mexican-born employment nationwide between 1960 and year $t$, and $(1 + g\_US)_{s,1960-t}$ is the growth factor of US born workers in state $s$ between 1960 and year $t$.

Since we use the distribution of Mexican shares across states in 1960, we must omit 1960 data from the regressions so that all observations for the instrumental variable are imputed. The identification power of the instrument is based on the fact that some states (such as California and Texas) had a larger share of Mexican immigrants in 1960 relative to others. These states will also have larger imputed shares of Mexicans in 1970 to 2000 and, due to the educational composition of this group, will have a larger immigrant share among less educated workers and larger supply of manual tasks.

Table 10 shows the results of the IV estimates of the coefficient $\gamma$ in Equation (20) using $\widehat{sh\_MEX}_{s,t}$ as an instrument for $\ln(Share\_foreign\_L)_{st}$. Column 1 shows the OLS estimates of a specification identical to the one in the first row and first column of Table 5, but restricted to the period 1970-2000. A doubling in the share of foreign-born employment is associated with a 37% decline in the relative supply of manual versus interactive tasks among native-born workers. The next column shows the IV estimates of the same specification. The point estimate (-0.39) barely changes and the standard error increases only moderately. The first stage demonstrates the strength of the instrument (F-test of 12) and the high positive correlation between the imputed share of Mexicans and the share of immigrants among less educated workers. Thus, a doubling of immigration causes native-born workers to respond by reducing their relative supply of manual versus interactive tasks by 39%.

Columns 3, 4 and 5 are the usual robustness checks that use cell weighting, the inclusion of analytical tasks (among the interactive ones), and the inclusion of routine task performance. The regressions estimate between a -0.2 and -0.4 elasticity of natives' relative task supply in response to immigration. Each coefficient is significant. Rows 2 and 3 also show that the negative relative effect is due to a positive and significant increase in the supply of interactive tasks by native workers. The manual task supply response is negative but not significant.

The last column confirms that immigration increases the overall relative supply of tasks. While the IV point estimates are in the low range of the OLS estimates (Table 9) and the standard errors are larger, we cannot reject the hypothesis that they are equal to the OLS estimates. Moreover, the decomposition of relative supply clearly shows that the IV estimates confirm the positive and significant effect of immigration on the total supply of manual tasks, while the supply of interactive tasks does not exhibit any significant change. Altogether, the IV estimates confirm the OLS ones, and indicate that the estimates in Section 5.1 are not a result of endogeneity bias.

#### 5.5.2 Omitted Variables

Our period of analysis (1970-2000) is associated with a large change in production technologies, mostly linked to the diffusion of information technologies and the use of computer. As Autor, Levy, and Murnane (2003) show, this change had a large effect in shifting demand from routine tasks to non-routine tasks. Our analysis includes measures of manual and interactive tasks that are both non-routine, so our analysis may not be affected by such change. However, the strong evidence of increased demand of non-routine interactive tasks due to complementarities with computers requires further examination of our results. Our regressions therefore control for the diffusion of IT among the less-educated workers in a state by including the share of workers (with at most a high school degree) who use a computer at work. This data is available in CPS Merged Outgoing Rotation Group Surveys in 1984, 1997 and 2001. We match the 1984 computer data to the 1980 census data, the 1997 computer-use data to the 1990 census, and the 2001 computer-use data to the 2000 CPS data. We impute a share of 0 for the use of computer in all states in 1970, as the PC was first introduced in year 1981.

The results of the regressions estimated over the 1970-2000 period using OLS and IV techniques are reported in Table 11. The table mirrors Table 10. Equation (20) still describes the regression specification, except that now we include the share of workers (with at most an high school degree) using computer at work as an extra control variable. The first row of Table 11 reports the elasticity of natives' relative task supply to the share of foreign-born workers in employment. The second row reports the elasticity with respect to computer adoption. Three results are clear. First, the introduction of computers at different rates across states significantly decreased the relative supply of manual versus interactive tasks among native workers. Second, the estimated effect of immigration on natives' relative supply of tasks does not change when we include this control. Third, while IT negatively affected both the relative task supply of natives (Columns 1 through 5) and the overall relative supply (Column 6), immigration *decreased* the relative supply of manual tasks among natives but it *did not decrease* the overall relative supply of manual tasks. All these results are consistent with a story in which technology has increased the demand for interactive tasks. However, immigration induced specialization among natives and had a significant effect, separate from technology, in further reducing the supply of manual tasks by natives. If one compares the elasticities estimated in Column 2, the magnitude of the effect from immigration is similar to the effect from the introduction of computers.

# 6 Empirical results: Immigration and Relative Wages

Our last objective is to estimate the effect of immigration and the consequent reallocation of tasks on wages paid to less educated native-born workers. Proposition 4 of our model suggests that by increasing the relative supply of manual tasks, immigrants have decreased the wage paid to manual tasks relative to interactive ones. In this section we proceed to estimate the effect of immigration on the wages paid to manual and interactive tasks. We then combine this with the shift in relative task supply among natives to estimate the effect of immigration on wages paid to less educated native-born workers.

## 6.1 Estimating the Elasticity of Substitution between Manual and Interactive Tasks

The relative task demand function in Equation (5) for state $s$ during year $t$ implies that Equation (23) describes the relationship between the relative supply of manual versus interactive tasks among low education workers ($\frac{M_L}{I_L}$) and the relative wage paid for these skills ($\frac{w_{ML}}{w_{IL}}$).

$$\ln\left(\frac{w_{ML}}{w_{IL}}\right)_{st} = \ln\left(\frac{\beta_L}{1-\beta_L}\right)_{st} - \frac{1}{\theta_L}\ln\left(\frac{M_L}{I_L}\right)_{st} \tag{23}$$

We allow relative productivity ($\beta_L$) to vary systematically across states (due to differences in industrial sector composition) and over time (due to technological change). We also permit a random, zero-mean, idiosyncratic component in relative productivity. Exogenous shifts in the overall relative supply of manual versus interactive tasks ($\frac{M_L}{I_L}$) across states can identify the coefficient $\frac{1}{\theta_L}$, where $\theta_L$ represents the elasticity of substitution between manual and interactive tasks, in two stage least squares regressions of Equation (24).

$$\ln\left(\frac{w_{ML}}{w_{IL}}\right)_{st} = \alpha_s + \beta_t - \frac{1}{\theta_L}\ln\left(\frac{M_L}{I_L}\right)_{st} + \varepsilon_{st} \tag{24}$$

The dependent variable $\frac{w_{ML}}{w_{IL}}$ is the wage paid to manual relative to interactive tasks. Exogenous shifts in the share of foreign-born workers will affect the aggregate relative supply of skills, $\frac{M_L}{I_L}$. Hence, we can estimate $\frac{1}{\theta_L}$ by employing the share of foreign-born workers as instrument for $\frac{M_L}{I_L}$.

While we calculated the relative supply $\frac{M_L}{I_L}$ in the previous sections by state, aggregation of the individual supply of manual ($EHF$) and interactive ($DCP$) tasks for the labor force prohibits observation of the relative wage $\frac{w_{ML}}{w_{IL}}$. However, the IPUMS data contains individual-level information on wages and other individual characteristics that we can merge to an individual's supply of $EHF$ and $DCP$.

Measurement of $w_{ML}$ and $w_{IL}$ for each state and year requires two steps for each year in our sample. First, we select only workers with at most a high school degree and regress, by year, the natural logarithm of individual real weekly wages[27] on indicator variables for the number of years of education (12 indicators from 0 to 12), years of experience (40 indicators from 1 to 40), a gender dummy, and a race dummy (white versus non-white).[28] The residuals of these individual-level wage regressions represent individual wages after controlling for personal characteristics. We label these residuals $\ln(wage\_clean)_{ist}$ for individual $i$ residing in state $s$ in census year $t$.

In the second step, we transform the wages into levels and regress them on the individual measures of manual tasks ($EHF$) and interactive tasks ($DCP$) by WLS. We allow the coefficients on $EHF$ and $DCP$ to vary across the 51 states so that they capture the price of manual and interactive tasks in each state. Therefore, by separately estimating the second stage regression in Equation (25) for $t = 1960$, 1970, 1980, 1990 and 2000, we can identify the state and year-specific wages received for supplying manual $(w_{ML})_{st}$ and interactive $(w_{IL})_{st}$ tasks.

$$wage\_clean_{ist} = (w_{ML})_{st} * EHF_{ist} + (w_{IL})_{st} DCP_{ist} + \varepsilon_{ist} \tag{25}$$

Regression of Equation (25) allows us to construct estimates for the wages paid to manual and interactive tasks ($(\widehat{w_{ML}})_{st}$ and $(\widehat{w_{IL}})_{st}$). We can then substitute these values into Equation (24) to estimate $\frac{1}{\theta_L}$. Table 12 reports these estimates. The first stage F-test shows that the foreign-born employment share is an excellent instrument for the relative supply of manual tasks by state (as we already knew from the previous section). The estimated relative wage elasticities ($1/\theta_L$) using various definitions of manual and interactive tasks are between 0.85 and 1.6 so that the implied elasticity of substitution ($\theta_L$) ranges from 0.6 to 1.2. The standard errors of the estimates, however, are large enough that we can never exclude a value of 1 as the elasticity of substitution. These estimates indicate a very large degree of complementarity between manual and interactive tasks. While we believe that values below 1 (e.g., those equal to the typical elasticity assumed between physical capital and aggregate labor) are too low to be reasonable, an elasticity between 1 and 1.2 is plausible. The elasticity of substitution between less educated and more educated workers is usually estimated between 1 and 2, and often centers around 1.5.[29] In the following calculations of the effect of immigration on wages paid to less educated

[27] Real weekly wages are calculated by dividing the yearly salary income by the number of weeks worked in the year. The nominal figures are converted into real figures using the CPI-U deflator published by the Bureau of Labor Statistics and available at www.bls.gov/cpi.

[28] We also weight each individual by its census sample weight (measured by the variable PERWT in the IPUMS dataset).

[29] See Katz and Murphy (1992) or Angrist (1995).

native workers, we will assume values of the elasticity of substitution between manual and interactive tasks near 1.2.

## 6.2 Effects of Immigration on Wages of Less Educated Native-Born Workers

The estimates of Section 5 and the production structure described in Section 3 allow us to calculate the effect of immigration on wages paid to less educated native-born workers. Consider immigration during the period 1990-2000 (the decade with the largest inflow of less educated immigrants). The estimates in Tables 3 through 5 provide estimates of the change in the relative supply of tasks among native workers with a high school degree or less. The regressions in Section 6.1 suggest the elasticity of substitution between manual and interactive tasks ($\theta_L$) is approximately 1.2. Economists commonly estimate the elasticity between more and less educated workers ($\sigma$) to be between 1 and 2, so we assume it equals the median value 1.5. These parameters and the change in the supply of tasks allow us to obtain the change in compensation paid to manual and interactive tasks. Denoting with $w_{ML}$ and $w_{IL}$ the unit compensation for (and marginal productivity of) manual and interactive tasks, we can use the production functions in Equations (1), (2), and (23) to calculate wages and their percentage change as a consequence of immigration.

$$\begin{aligned}\frac{\Delta w_{ML}}{w_{ML}} &= -\frac{1}{\theta_L}\frac{(\Delta M_L)_{FOR}}{M_L} + \left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right)\left(\frac{s_{IL}}{s_L}\frac{(\Delta I_L)_{FOR}}{I_L} + \frac{s_{ML}}{s_L}\frac{(\Delta M_L)_{FOR}}{M_L}\right) + \\ &\quad + \frac{1}{\sigma}\left[s_L\frac{(\Delta Empl_L)_{FOR}}{Empl_L} + s_H\frac{(\Delta Empl_H)_{FOR}}{Empl_H}\right]\end{aligned} \tag{26}$$

$$\begin{aligned}\frac{\Delta w_{IL}}{w_{IL}} &= -\frac{1}{\theta_L}\frac{(\Delta I_L)_{FOR}}{I_L} + \left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right)\left(\frac{s_{IL}}{s_L}\frac{(\Delta I_L)_{FOR}}{I_L} + \frac{s_{ML}}{s_L}\frac{(\Delta M_L)_{FOR}}{M_L}\right) + \\ &\quad + \frac{1}{\sigma}\left[s_L\frac{(\Delta Empl_L)_{FOR}}{Empl_L} + s_H\frac{(\Delta Empl_H)_{FOR}}{Empl_H}\right]\end{aligned} \tag{27}$$

The terms $\frac{(\Delta M_L)_{FOR}}{M_L}$ and $\frac{(\Delta I_L)_{FOR}}{I_L}$ represent, respectively, the change of aggregate manual and interactive task supply among less educated workers due to immigration. Similarly, $\frac{(\Delta Empl_L)_{FOR}}{Empl_L}$ and $\frac{(\Delta Empl_H)_{FOR}}{Empl_H}$ represent the change in employment for each of the two education groups due to immigration. The parameters $s_{IL}$ and $s_{ML}$ represent, respectively, the share of wages paid to interactive and manual tasks performed by less educated workers. Finally, $s_L$ and $s_H = (1 - s_L)$ measure the share of wages paid to less educated and more educated workers overall.

Using the data on the change in employment for groups $L$ (high school or less) and $H$ (more than high school), in addition to the data on the average supply of $M_L$ and $I_L$ by native and foreign-born workers, we find that $\frac{(\Delta M_L)_{FOR}}{M_L} = 0.11$, $\frac{(\Delta I_L)_{FOR}}{I_L} = 0.09$, $\frac{(\Delta Empl_L)_{FOR}}{Empl_L} = 0.10$, and $\frac{(\Delta Empl_H)_{FOR}}{Empl_H} = 0.071$ between 1990 and 2000. Moreover, year 2000 data implies $s_L = 0.31$, $s_H = 0.69$, and $s_{IL}/s_L = 0.51$. Substituting $\theta_L = 1.2$ and $\sigma = 1.5$, we find that the real wage for manual task performance declined by 2.1% and the wage paid to interactive tasks fell by 0.5%. (Wages paid to both tasks fall because immigrants in this period tended to have low levels of education). The complementarities between the two tasks, however, mitigates the interactive task wage decrease and augments manual-task wage losses for less educated workers. If the two tasks were perfect substitutes, average wages paid to less educated workers would have fallen by 1.3% for each task. By moving their supply toward interactive tasks, native-born workers shield themselves from larger wage losses, and instead only incur a slight wage decline of 0.5%.

We now need to carefully examine how much the shift in skill-supply helps native-born wages. The wage of a US-born worker with a high school degree or less equals $w_{D,L} = \widetilde{m}_{DL} w_{ML} + \widetilde{i}_{DL} w_{IL}$, where $\widetilde{m}_L$ and $\widetilde{i}_L$ represent the average supply of effective manual and interactive tasks among native-born workers with a high school degree or less, respectively. As Section 5 documented, both $\widetilde{m}_{DL}$ and $\widetilde{i}_{DL}$ change as a consequence of immigration. The compensation of each skill changes according to Equations (26) and (27). Combining the effects, one can obtain the change in the wage of the representative US-born worker with high school degree or less from Equation (28).

$$\frac{\Delta w_{US,L}}{w_{US,L}} = \frac{\Delta w_{ML}}{w_{ML}} sh_{MDL} + \frac{\Delta w_{IL}}{w_{IL}}(1 - sh_{MDL}) + \frac{w_{ML}}{w_{US,L}} \Delta\widetilde{m}_{DL} + \frac{w_{IL}}{w_{US,L}} \Delta\widetilde{i}_{DL} \tag{28}$$

The change in wages paid to the typical US-born worker with a high school degree or less results from four terms. The first two capture the change in compensation for each task resulting from changes in the overall supply of skills. The changes in compensation paid to each task supplied by the average less educated US native worker, weighted by the wage share paid to each task, ($sh_{MDL}$ and $sh_{IDL} = 1 - sh_{MDL}$, respectively) combine to reduce wages 1.3%. The third and fourth terms capture the wage effects caused by the changed composition in tasks performed by native workers, weighted by the relative compensation of each type of task. The terms $\Delta\widetilde{m}_{DL}$ and $\Delta\widetilde{i}_{DL}$ can be obtained from the responses to immigration estimated in the previous sections. Using the IV estimate in Column 2 of Table 10 (-0.39) and the 60% increase of the foreign-born share of less educated workers (from 0.10 in 1990 to 0.16 in 2000), we obtain that the shift corresponds to a 24% decrease in relative supply. This translates to $\Delta\widetilde{m}_{DL} = -0.06$ and $\Delta\widetilde{i}_{DL} = +0.06$. Weighting the first change by $\frac{w_{ML}}{w_{US,L}} = 0.97$ (which is the relative manual wage level in year 2000) and the second change by $\frac{w_{IL}}{w_{US,L}} = 1.04$ (which is the relative interactive wage in year 2000), we capture the second effect of the shift of relative task supply among natives. The sum of the two effects raises wages by 0.6%. Altogether, Equation (28) implies that the overall wage change among less educated native-born workers due to immigration equals -1.3% + 0.6% = -0.7%.

The reallocation of skill supply cuts native-born wage losses by half. Total immigration between 1990 and

2000 reduced wages paid to less educated native-born workers by 0.7%. Consistent with findings in Card (2001) and Lewis and Card (2005), the effect of immigration on native-born workers with a high school education or less is very small.

# 7 Conclusions

The most contentious issue in the debate about the economic effects of immigration is whether immigrants hurt the wages of native-born workers with low levels of educational attainment. The effects depend upon two critical factors. The first is whether immigrants take jobs similar to those of native workers, or instead take differing jobs due to inherent comparative advantages between native and foreign-born employees. The second is whether US-born workers respond to immigration and adjust their occupation choices to shield themselves from competition with, and possibly complement, immigrant labor.

This paper provides a theoretical framework and empirical evidence to analyze these two issues. We argue that production combines different labor skills. Immigrants with little educational attainment have a comparative advantage in manual and physical tasks, while natives have a comparative advantage in language-intensive and interactive tasks. Native and foreign-born workers specialize in these complementary skills accordingly. When immigration generates large increases in manual task supply, compensation paid to interactive tasks will rise, thereby rewarding native workers who progressively move to interactive-intensive jobs.

Our empirical analysis employed a dataset developed by Autor, Levy, and Murnane (2003) that measures the task-content of occupations in the United States between 1960 and 2000. We find strong evidence supporting three implications of our theoretical model:

i) On average, less educated immigrants supplied more manual relative to interactive tasks than natives supplied. This tendency became stronger during the 1980s and 1990s.

ii) In states with large immigration among the less educated labor force, native workers shifted to occupations intensive in interactive tasks, thereby reducing native workers' relative supply of manual tasks. In states with low immigration, native-born workers maintained a higher relative supply of manual tasks.

iii) In states with large immigration among the less educated labor force, there is a larger relative supply of manual production tasks than in states with low levels of immigration. This implies that immigrants more than compensate for the reduced manual skill supply among natives, and it ensures that manual task-intensive occupations earn lower wages.

Since native-born workers respond to inflows of immigrant labor by specializing in interactive tasks, wage losses associated with immigration are minimal. Immigration caused wages paid to native-born workers with less than a high school degree to drop by just 0.7% between 1990 and 2000.

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# 8 Appendix: Model with Heterogeneous Agents

Domestic agents, (denoted with an $H$ superscript when we need to distinguish them from immigrants), are heterogeneous in their relative efficiency in providing the two types of skills. Each agent $i$ provides an amount $m_i$ of effective manual tasks, per unit of labor, and/or $c_i$ units of coordinative tasks per unit of labor. Therefore, the one unit of labor supplied by each individual $i$ can be split as $L_i = [\lambda_i m_i, (1-\lambda_i)c_i]$. Individuals can be ordered along a continuum of increasing values of the variable $\omega = (c/m)$, ranging between 0 and infinity. Individuals associated with lower $\omega$ have low relative coordinative-interactive skills and high manual skills. The domestic labor force has a distribution over the range of relative skills $\omega = (c/m) \in [\underline{\omega}, \overline{\omega}]$ that is represented by the "density function" $g$ so that $\int_{\underline{\omega}}^{\overline{\omega}} g(\omega)d\omega = L$. Assuming that people receive the wage $w_M$ and $w_C$ for one unit of manual or interactive task, respectively, then the decision of which skills/tasks to supply is easy and implies that for a given relative wage $w_M/w_C$ individual $\omega$ (i.e. with a relative efficiency of tasks, $c/m = \omega$) supplies her single labor unit as $C$ if $w_M/w_C < \omega$, while she supplies her single labor unit as $M$ if $w_M/w_C < \omega$. Hence, denoting with $m(\omega)$, $m' > 0$ the increasing individual supply of effective manual skills of workers of type $\omega$, and with $c(\omega)$, $c' < 0$ the decreasing individual supply of effective interactive skills by workers of type $\omega$, for relative wages $w_M/w_C$ equal to $\omega^* \in [\underline{\omega}, \overline{\omega}]$ the supply of effective manual tasks from native workers is given by the following expression::

$$M^H = \int_{\underline{\omega}}^{w*} m(s)g(s)ds \tag{29}$$

and the number of workers providing manual tasks is: $L_M^H = \int_{\underline{w}}^{w*} g(s)ds$. The total supply of interactive tasks is given by:

$$C^H = \int_{w*}^{\overline{w}} c(s)g(s)ds \tag{30}$$

and the number of workers providing interactive tasks is: $L_C^H = \int_{w*}^{\overline{w}} g(s)ds$.

Cost-minimizing firms demand labor inputs to produce $Y$ up to the point that the marginal productivity of a task is equal to its cost. This provides the following relative demand condition:

$$\frac{w_C}{w_M} = \frac{1-\beta}{\beta}\left(\frac{C}{M}\right)^{-\frac{1}{\theta}} \tag{31}$$

Clearly once the equilibrium value of $w^*$ is determined, the relative supply of manual and interactive skills and the distribution of workers between one or the other task is also determined. In a closed economy (where $C = C^H$ and $M = M^H$ as there are only native workers) the equilibrium $w^*$ is given by the following condition obtained by substituting (29) and (30) into equation (31). Rearranging the terms slightly we obtain:

$$\left(\frac{\beta}{1-\beta}\right)^{\theta} \int_{\omega*}^{\overline{\omega}} c(s)g(s)ds = (w^*)^{\theta} \int_{\underline{\omega}}^{\omega*} m(s)g(s)ds \tag{32}$$

In this very simple framework the following statement is a direct consequence of our definition:

**PROPOSITION 1**: A decrease in the equilibrium value of $w^*$ decreases the supply of manual tasks $M^H$ and of native workers providing them $L_M^H$, while it increases the supply of interactive tasks $C^H$ and of native workers providing them. It also increases the wage of workers performing interactive tasks $w_C$ relative to the wage of workers performing manual task $w_M$.

Let us now consider the effect of an inflow of immigrants. The crucial assumption that we make about immigrants is that they have a strong advantage in performing manual tasks relative to natives. Namely, we assume that all immigrants entering the country have a value of the relative efficiency in performing interactive-coordinative tasks $\omega$ in the interval $[0.\underline{\omega}]$. This implies that all immigrants have a relative disadvantage in working in interactive tasks with respect to natives. This does not imply that they have absolute advantages in manual tasks, as they may be less productive in each task, in which case the values of $c_F$ and $m_F$ are smaller for immigrants than natives, as is the wage immigrants receive (since each immigrant embodies fewer efficiency units in each task). It seems very likely that as interactive tasks (communicating, mediating, managing, teaching, convincing, etc.) rely heavily on knowledge of language, common references, and local network connections, almost any native will be better positioned in relative terms than an immigrant in performing them. Let us define the total supply of manual skills of immigrants as:

$$M^F = \int_0^{\underline{w}} m_F(s)g_F(s)ds = \widetilde{\omega}^F L^F \tag{33}$$

where $L^F$ is the total number of immigrant workers and $\widetilde{\omega}^F$ is their average efficiency in performing manual tasks. For any equilibrium relative wage $w^*$ in the interval $(\underline{\omega}, \overline{\omega})$ the supply of manual skills from immigrants is $M^F$, while their supply of interactive skill is $C^F = 0$. Therefore, the equilibrium condition determining $w^*$ with immigrant workers becomes:

$$\left(\frac{\beta}{1-\beta}\right)^{\theta} \int_{\omega*}^{\overline{\omega}} c(s)g(s)ds = (w^{*})^{\theta} \left[\int_{\underline{\omega}}^{\omega*} m(s)g(s)ds + M^{F}\right] \tag{34}$$

One can use the implicit function theorem to derive how an increase in the number of immigrant workers, $L_F$ (assuming their average efficiency $\widetilde{\omega}^F$ is constant ), affects the equilibrium value of $\omega^*$ and in turn the supply of manual and interactive tasks by natives. One can easily prove equivalent Propositions to 1-4 in the text (To be done).

# Tables and Figures

**Table 1: Median Supply of Interactive and Manual Tasks, All Workers, 1960-2000**

| | **1960** | **1970** | **1980** | **1990** | **2000** |
|---|---|---|---|---|---|
| **Occupation** | Male Cabinetmakers | Female Demonstrators | Male Printing Press Operators | Male Boilermakers | Male Nursery Workers |
| **DCP_77 (interactive)** | 0.47 | 0.52 | 0.59 | 0.62 | 0.63 |
| **Occupation** | Male Office Machine Operators | Male Job & Die Setters | Male Messengers | Female Assemblers | Female Assemblers |
| **EHF_77 (manual)** | 0.50 | 0.49 | 0.35 | 0.34 | 0.34 |

**Note:** The variables DCP_77 and EHF_77 are based on the scores assigned to each occupation by the Dictionary of occupational Titles (DOT) 1977. They are converted into percentile scores using the 1960 distribution so that for 1960 the median is by construction at 0.5, or close to it in case of some discrete jump in the percentile distribution that includes 0.50. The scores obtained using the DOT 1991 definition are very similar and not reported, however many regressions in the empirical analysis are performed using each definition.

**Table 2:**
**Manual and Interactive Task Requirements and Percentage of Foreign-Born in Selected Occupations, 2000.**

| Occupation | % of Foreign-born workers, 2000 | Manual, non routine tasks: EHF_77 | Interactive non-routine tasks: DCP_77 | Relative Manual/ Interactive: EHF_77/ DCP_77 |
|---|---|---|---|---|
| | | **Agricultural Sector** | | |
| *Agricultural laborer* | 63% | 0.82 | 0.32 | 2.5 |
| *Farm Coordinator* | 4% | 0.43 | 0.99 | 0.43 |
| | | **Construction sector** | | |
| *Construction Helper* | 66% | 0.86 | 0.02 | 43 |
| *Construction Supervisor* | 8% | 0.43 | 0.96 | 0.44 |
| | | **Postal Services** | | |
| *Mail Preparer and paper handling machine operator* | 48% | 0.35 | 0.02 | 17.5 |
| *Mail clerk/ deliverer* | 7% | 0.11 | 0.65 | 0.17 |
| | | **Food preparation** | | |
| *Miscellaneous food preparation* | 33% | 0.67 | 0.41 | 1.63 |
| *Supervisor food preparation* | 14% | 0.39 | 0.67 | 0.58 |
| | | **Transportation services** | | |
| *Taxi Driver* | 40% | 0.96 | 0.02 | 49.5 |
| *Supervisor, motor Vehicle operators* | 10% | 0.44 | 0.97 | 0.45 |

**Note:** The definitions of occupations are taken from the Census definitions. The data for year 2000 are obtained averaging the CPS samples for 1998, 1999 and 2000, as described in the text.

**Table 3**
**Impact of Foreign-Born Workers on the Supply of Tasks by Less Educated Native-Born Workers**
*High school degree or less, DOT 1977 definition*

| Explanatory Variables: | In Logarithms | In Levels | Logarithm, Weighted by employment | Including Analytical tasks | Including Routine Tasks | Omitting year 2000 | Including State-specific time trends |
|---|---|---|---|---|---|---|---|
| Dependent Variable: **Relative Supply Manual/Interactive by Native Workers** | | | | | | | |
| Share of foreign born | -0.27*** | -0.24*** | -0.20*** | -0.23*** | -0.24** | -0.40*** | -0.69*** |
| | (0.09) | (0.09) | (0.07) | (0.10) | (0.05) | (0.10) | (0.13) |
| Dependent variable: **Supply of Manual Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.02 | 0.02 | -0.01 | n.a. | -0.05** | 0.01 | -0.39** |
| | (0.07) | (0.04) | (0.01) | | (0.02) | (0.06) | (0.10) |
| Dependent variable: **Supply of Interactive Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.30*** | 0.15*** | 0.21*** | 0.25*** | 0.08** | 0.42*** | 0.27** |
| | (0.06) | (0.03) | (0.06) | (0.05) | (0.03) | (0.08) | (0.10) |
| Dependent Variable: **Relative Supply Manual/Interactive by Immigrant Workers** | | | | | | | |
| Share of foreign born | 0.82** | 0.81** | 0.24 | 1.19*** | 0.01 | 1.04** | 1.61** |
| | (0.35) | (0.43) | (0.19) | (0.36) | (0.21) | (0.36) | (0.43) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the regressions of the first row is the relative supply of manual/interactive tasks for native workers with at most a high school diploma, measured using the variables EHF and DCP, respectively, and the 1977 DOT definition. The dependent variable in the second row is the supply of manual task (EHF) and in the third row is the supply of interactive tasks (DCP) for native workers. In the last row the dependent variable is the relative supply of manual/interactive tasks by immigrants. The explanatory variable is the share of foreign-born workers among those with at most a high school diploma. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 65 years of age. All regressions include state and year fixed effects, except for the regressions in the last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 4,**
**Impact of Foreign-Born Workers on the Supply of Tasks by Less Educated Native-Born Workers**
*No High school degree, DOT 1977 definition*

| Explanatory Variables: | In Logarithms | In Levels | Logarithm, Weighted by employment | Including Analytical tasks | Including Routine Tasks | Omitting year 2000 | Including State-specific time trends |
|---|---|---|---|---|---|---|---|
| Dependent Variable: **Relative Supply Manual/Interactive by Native Workers** | | | | | | | |
| Share of foreign born | -0.18* | -0.24** | -0.26** | -0.23** | -0.19** | -0.37** | -0.20** |
| | (0.10) | (0.12) | (0.07) | (0.08) | (0.07) | (0.06) | (0.10) |
| Dependent variable: **Supply of Manual Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.04 | 0.03 | -0.07** | n.a. | 0.02 | -0.01 | -0.11 |
| | (0.06) | (0.03) | (0.03) | | (0.03) | (0.05) | (0.08) |
| Dependent variable: **Supply of Interactive Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.22*** | 0.09*** | 0.19*** | 0.17** | 0.22*** | 0.36** | 0.08 |
| | (0.06) | (0.02) | (0.05) | (0.06) | (0.06) | (0.06) | (0.07) |
| Dependent Variable: **Relative Supply Manual/Interactive by Immigrant Workers** | | | | | | | |
| Share of foreign born | -0.24 | -0.47 | -0.13 | -0.16 | -0.18 | 0.24 | 0.70** |
| | (0.28) | (0.55) | (0.16) | (0.24) | (0.29) | (0.26) | (0.25) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the first row is the relative supply of manual/interactive tasks for native workers without high school diploma, measured using the variables EHF and DCP, respectively, and the 1977 DOT definition. The dependent variable in the second row is the supply of manual task (EHF) and in the third row is the supply of interactive tasks (DCP) for native workers. In the last row the dependent variable is the relative supply of manual/interactive tasks by immigrants. The explanatory variable is the share of foreign-born workers among those without a high school diploma. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 65 years of age. All regressions include state and year fixed effects, except for the regressions in the last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 5**
**Impact of Foreign-Born Workers on the Supply of Tasks by Less Educated Native-Born Workers**
*High school degree or less, DOT 1991 definition*

| Explanatory Variables: | In Logarithms | In Levels | Logarithm, Weighted by employment | Including Analytical tasks | Including Routine Tasks | Omitting year 2000 | Including State-specific time trends |
|---|---|---|---|---|---|---|---|
| Dependent Variable: **Relative Supply Manual/Interactive by Native Workers** | | | | | | | |
| Share of foreign born | -0.27*** | -0.23** | -0.19** | -0.22** | -0.25** | -0.44*** | -0.63** |
| | (0.09) | (0.09) | (0.08) | (0.10) | (0.06) | (0.10) | (0.12) |
| Dependent variable: **Supply of Manual Tasks by Native Workers** | | | | | | | |
| Share of foreign born | -0.01 | -0.01 | -0.01 | n.a. | -0.06* | -0.04 | -0.36** |
| | (0.07) | (0.03) | (0.03) | | (0.04) | (0.06) | (0.10) |
| Dependent variable: **Supply of Interactive Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.27** | 0.12** | 0.18** | 0.22** | 0.27** | 0.40** | 0.27** |
| | (0.07) | (0.03) | (0.06) | (0.06) | (0.07) | (0.08) | (0.10) |
| Dependent Variable: **Relative Supply Manual/Interactive by Immigrant Workers** | | | | | | | |
| Share of foreign born | 0.73** | 0.75* | 0.26 | 1.10** | 0.01 | 1.02** | 1.55** |
| | (0.33) | (0.40) | (0.18) | (0.34) | (0.23) | (0.37) | (0.31) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the first row is the relative supply of manual/interactive tasks for native workers with at most a high school diploma, measured using the variables EHF and DCP, respectively, and the 1991 DOT definition. The dependent variable in the second row is the supply of manual task (EHF) and in the third row is the supply of interactive tasks (DCP) for native workers. In the last row the dependent variable is the relative supply of manual/interactive tasks by immigrants. The explanatory variable is the share of foreign-born workers among those with at most a high school diploma. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 65 years of age. All regressions include state and year fixed effects, except for the regressions in last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 6:**
**Impact of Foreign-Born Workers on the Supply of Tasks by Young Less Educated Native Workers**
*High school degree or less, DOT 1991 definition, only worker below 35 years*

| Explanatory Variables: | In Logarithms | In Levels | Logarithm, Weighted by employment | Including Analytical tasks | Including Routine Tasks | Omitting year 2000 | Including State-specific time trends |
|---|---|---|---|---|---|---|---|
| Dependent Variable: **Relative Supply Manual/Interactive by Native Workers** | | | | | | | |
| Share of foreign born | -0.17** | -0.17** | -0.17** | -0.15* | -0.21** | -0.39** | -0.47** |
| | (0.08) | (0.08) | (0.06) | (0.08) | (0.05) | (0.08) | (0.06) |
| Dependent variable: **Supply of Manual Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.05 | 0.03 | -0.03 | n.a. | -0.03 | -0.06 | -0.20** |
| | (0.06) | (0.03) | (0.03) | | (0.03) | (0.05) | (0.06) |
| Dependent variable: **Supply of Interactive Tasks by Native Workers** | | | | | | | |
| Share of foreign born | 0.23** | 0.10*** | 0.14** | 0.20** | 0.23** | 0.33** | 0.26** |
| | (0.04) | (0.02) | (0.04) | (0.04) | (0.04) | (0.06) | (0.05) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the first row is the relative supply of manual/interactive tasks for native workers with at most a high school diploma between 17 and 35 years of age, measured using the variables EHF and DCP, respectively, and the 1991 DOT definition. The dependent variable in the second row is the supply of manual task (EHF) and in the third row is the supply of interactive tasks (DCP) for native workers between 17 and 35 years of age. In the last row the dependent variable is the relative supply of manual/interactive tasks by immigrants between 17 and 35 years of age. The explanatory variable is the share of foreign-born workers among those with at most a high school diploma. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 35 years of age. All regressions include state and year fixed effects, except for the regressions in the last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 7:**

**Impact of Foreign-Born Workers on the Supply of Tasks by One Cohort of Less Educated Native-Born Workers**

*High school degree or less, DOT 1991 definition, only workers belonging to the cohort 25-35 years of age in 1960*

| Explanatory Variables: | In Logarithms | In Levels | Logarithm, Weighted by employment | Including Analytical tasks | Including Routine Tasks | Include state-specific time trends |
|---|---|---|---|---|---|---|
| | Dependent Variable: **Relative Supply Manual/Interactive by Native Workers** | | | | | |
| **Share of foreign born** | -0.25** | -0.22** | -0.27** | -0.24** | -0.17** | -0.07 |
| | (0.08) | (0.08) | (0.04) | (0.08) | (0.04) | (0.07) |
| | Dependent variable: **Supply of Manual Tasks by Native Workers** | | | | | |
| **Share of foreign born** | -0.07* | -0.03 | -0.09** | n.a. | -0.06** | -0.05 |
| | (0.04) | (0.02) | (0.03) | | (0.02) | (0.03) |
| | Dependent variable: **Supply of Interactive Tasks by Native Workers** | | | | | |
| **Share of foreign born** | 0.18** | 0.08** | 0.18** | 0.17** | 0.17** | 0.01 |
| | (0.05) | (0.02) | (0.01) | (0.05) | (0.05) | (0.03) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the first row is the relative supply of manual/interactive tasks for native workers with at most a high school diploma in the cohorts of workers aged 25-35 in 1960, measured using the variables EHF and DCP, respectively, and the 1991 DOT definition. The dependent variable in the second row is the supply of manual task (EHF) and in the third row is the supply of interactive tasks (DCP) for native workers in the cohorts aged 25-35 in 1960. In the last row the dependent variable is the relative supply of manual/interactive tasks by immigrants in the cohorts of workers aged 25-35 in 1960. The explanatory variable is the share of foreign-born workers among those with at most a high school diploma. We only include individuals who worked for at least one week, did not reside in group quarters and were in the cohorts of workers aged 25-35 in 1960. All regressions include state and year fixed effects, except for the regressions in the last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 8:**
**Impact of Foreign-Born Workers on the Supply of Tasks among Highly Educated Native-Born Workers**
*Some College education or more, DOT 1991 definition*

| | In Logarithms weighted | In Levels | In Logarithm With state specific time trends |
|---|---|---|---|
| Dependent Variable: **Relative Supply Quantitative/Interactive by Native Workers** | | | |
| **Share of foreign born** | -0.06** | -0.06** | -0.09** |
| | (0.02) | (0.02) | (0.04) |
| Dependent variable: **Supply of Quantitative Tasks by Native Workers** | | | |
| **Share of foreign born** | 0.02 | 0.02 | 0.31 |
| | (0.03) | (0.03) | (0.07) |
| Dependent variable: **Supply of Interactive Tasks by Native Workers** | | | |
| **Share of foreign born** | 0.08** | 0.07** | 0.60** |
| | (0.02) | (0.02) | (0.15) |
| Dependent Variable: **Relative Supply Quantitative/Interactive by Immigrant Workers** | | | |
| **Share of foreign born** | 0.35** | 0.42** | -0.16 |
| | (0.12) | (0.14) | (0.18) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the first row is the relative Supply of quantitative/interactive tasks for native workers with at least some college education, measured using the variables MATH and DCP, respectively, and the 1991 DOT definition. The dependent variable in the second row is the Supply of analytic (quantitative) tasks (MATH) and in the third row is the supply of interactive tasks (DCP) by native workers. In the last row the dependent variable is the relative supply of manual/interactive tasks by immigrants. The explanatory variable is the share of foreign-born workers among those with at least some college education. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 65 years of age. All regressions include state and year fixed effects, except for the regressions in the last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 9**
**Impact of Foreign-Born Workers on the Overall Relative Supply of Tasks by Less Educated Workers**
*High school degree or less*

| Explanatory variable | In Logarithms (non-weighted) | In Levels (non-weighted) | In Logarithm, Weighted by employment | Including Analytical tasks | Including Routine Tasks | Omitting 2000 |
|---|---|---|---|---|---|---|
| Dependent Variable: **Relative Supply Manual/Interactive by All Workers , DOT 91** | | | | | | |
| **Share of foreign born** | 0.19** | 0.23** | 0.32** | 0.36** | 0.10 | 0.21* |
| | (0.08) | (0.09) | (0.09) | (0.09) | (0.06) | (0.11) |
| Dependent Variable: **Supply of Manual Tasks by All Workers, DOT 91** | | | | | | |
| **Share of foreign born** | 0.31** | 0.16*** | 0.31** | n.a. | 0.12** | 0.33** |
| | (0.05) | (0.02) | (0.04) | | (0.03) | (0.07) |
| Dependent Variable: **Supply of Interactive Tasks by All Workers, DOT 91** | | | | | | |
| **Share of foreign born** | 0.12** | 0.06** | -0.01 | -0.05 | 0.03 | 0.11 |
| | (0.06) | (0.03) | (0.06) | (0.06) | (0.03) | (0.13) |
| Dependent Variable: **Relative Supply Manual /Interactive by All Workers , DOT 77** | | | | | | |
| **Share of foreign born** | 0.21** | 0.24** | 0.31** | 0.37** | 0.09 | 0.19* |
| | (0.08) | (0.09) | (0.09) | (0.09) | (0.06) | (0.11) |
| Dependent Variable: **Supply of Manual Tasks by All Workers, DOT 77** | | | | | | |
| **Share of foreign born** | 0.34** | 0.17** | 0.31** | n.a. | 0.07** | 0.37** |
| | (0.05) | (0.03) | (0.04) | | (0.02) | (0.07) |
| Dependent Variable: **Supply of Interactive Tasks by All Workers, DOT 77** | | | | | | |
| **Share of foreign born** | 0.13** | 0.06* | 0.01 | -0.04 | -0.02 | 0.18 |
| | (0.06) | (0.03) | (0.06) | (0.04) | (0.03) | (0.16) |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1960-2000 for a total of 255 observations. The dependent variable in the first and fourth rows is the relative Supply of manual/interactive tasks for all workers with at most a high school diploma, measured using the variables EHF and DCP, respectively, and the 1991 and 1977 DOT definition, respectively. Similarly in the second and fifth row the dependent variable is the Supply of manual tasks for all workers and in the third and sixth row the dependent variable is the Supply of interactive tasks by all workers. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 65 years of age. All regressions include state and year fixed effects, except for the last column in which we include state-specific time trends. The reported standard errors are heteroskedasticity robust.

**Table 10**
**IV Estimates of the Impact of Foreign-Born Workers on the Relative Supply of Tasks by Less Educated Workers**
*High school degree or less, DOT 1991 definition*

| Explanatory Variables: | **Native Workers** In Logarithms (non-weighted) **OLS** 1970-2000 | **Native Workers** In Logarithms (non-weighted) **IV** 1970-2000 | **Native Workers** In Logarithm, Weighted by employment **IV** 1970-2000 | **Native Workers** Including Analytical tasks **IV** 1970-2000 | **Native Workers** Including Routine Tasks **IV** 1970-2000 | **All Workers** In Logarithms (non-weighted) **IV** 1970-2000 |
|---|---|---|---|---|---|---|
| | Dependent Variable: **Relative Supply Manual /Interactive** | | | | | |
| **Share of foreign-born** | -0.37** | -0.39** | -0.38** | -0.31** | -0.18** | 0.15 |
| | (0.11) | (0.13) | (0.13) | (0.12) | (0.05) | (0.14) |
| | Dependent Variable: **Supply of Manual Tasks** | | | | | |
| **Share of foreign-born** | 0.07 | -0.15* | -0.11 | -0.11 | -0.09 | 0.19*** |
| | (0.07) | (0.08) | (0.08) | (0.08) | (0.05) | (0.07) |
| | Dependent Variable: **Supply of Interactive Tasks** | | | | | |
| **Share of foreign-born** | 0.44** | 0.24** | 0.25*** | 0.19** | 0.09** | 0.05 |
| | (0.11) | (0.08) | (0.06) | (0.05) | (0.03) | (0.07) |
| | **First Stage for the share of foreign-born among less educated** | | | | | |
| **Imputed Share of Mexican in total employment** | NA | 2.70** | 1.95*** | 1.95*** | 1.95*** | 1.95*** |
| | | (0.78) | (0.40) | (0.40) | (0.40) | (0.40) |
| **F-test** | NA | 12.00*** | 22.72*** | 22.72*** | 22.72*** | 22.72*** |
| **Number of observations** | 204 | 204 | 204 | 204 | 204 | 204 |

**Note:** Each cell contains the estimate from a separate regression. The units of observation in each regression are U.S. states in a census year. The sample is a panel of 50 states plus DC over the period 1970-2000 for a total of 204 observations. The dependent variable in the first row, column 1-5 is the relative Supply of manual/interactive tasks for native workers with at most a high school diploma measured using the 1991 DOT definition. The dependent variable in the second row (column 1-5) is the Supply of manual tasks (EHF) and in the third row is the Supply of interactive tasks (DCP) by native workers. In the last column the dependent variables are relative to all workers, Natives and immigrants. The explanatory variable is the share of foreign-born workers among those with at most a high school diploma. The Instrument used is the imputed share of Mexican workers in the state, constructed as described in the main text. We only include individuals who worked for at least one week, did not reside in group quarters and had between 17 and 65 years of age.. All regressions include state and year fixed effects. The reported standard errors are heteroskedasticity robust.

**Table 11**
**Controlling for IT through the Use of Computers**
*High school degree or less, DOT 1991 definition*

| Explanatory Variable | In Logarithms (non-weighted) **OLS** 1970-2000 | In Logarithms (non-weighted) **IV** 1970-2000 | In Logarithm, Weighted by employment **IV** 1970-2000 | Including Analytical tasks **IV** 1970-2000 | Including Routine Tasks **IV** 1970-2000 | Total Supply (Native + foreign born) In Logarithms (non-weighted) IV 1970-2000 |
|---|---|---|---|---|---|---|
| **Share of Foreign Born** | -0.47** | -0.44** | -0.47** | -0.38** | -0.22** | 0.10 |
| | (0.10) | (0.12) | (0.12) | (0.10) | (0.06) | (0.12) |
| **Share of Workers using Computer at work** | -0.39** | -0.38** | -0.51** | -0.36** | -0.18** | -0.46** |
| | (0.12) | (0.12) | (0.13) | (0.11) | (0.06) | (0.13) |
| **First Stage** | | | | | | |
| **Constructed Share of Mexican (total employment)** | NA | 2.70** | 1.95** | 1.95** | 1.95** | 1.95** |
| | | (0.78) | (0.40) | (0.40) | (0.40) | (0.40) |
| **F-test** | NA | 12.00*** | 22.72*** | 22.72*** | 22.72*** | 22.72*** |
| **Number of observations** | 204 | 204 | 204 | 204 | 204 | 204 |

**Note**: Specifications and Samples are as in the first row of Table 10. We include the share of workers using a computer at work (as reported by CPS data) to control for IT adoption. The variable on Computer use is the share of workers with high school diploma or less who use computer at work (in a state and year. The data on computer use in 1970 are set equal to 0, for 1980 we use the survey of 1984, for 1990 we use the survey of 1997 and for 2000 we use the survey of 2001.

**Table 12**
**Estimates of the Relative Wage Elasticity of Manual versus Interactive Tasks**
*High school degree or less*

| | DOT 91 | | | DOT 77 | | |
|---|---|---|---|---|---|---|
| | Basic IV | Including analytic Tasks | Including Routine | Basic IV | Including analytic Tasks | Including Routine |
| **$1/\theta_L$** | 1.22** | 0.85** | 1.39* | 1.24** | 0.86** | 1.67* |
| | (0.62) | (0.44) | (0.80) | (0.63) | (0.44) | (0.90) |
| **State Dummies** | Yes | Yes | Yes | Yes | Yes | Yes |
| **Year Dummies** | Yes | Yes | Yes | Yes | Yes | Yes |
| **First Stage** | | | | | | |
| **Share of Foreign-Born** | 0.31*** | 0.45** | 0.27** | 0.31** | 0.46** | 0.23** |
| | (0.09) | (0.09) | (0.08) | (0.09) | (0.09) | (0.08) |
| **F-test** | 11.2*** | 22.5*** | 11.0*** | 11.5*** | 24.2*** | 7.9*** |

**Note:** The Dependent Variable is the logarithm of the relative compensation of manual and interactive tasks, calculated as described in the main text. The explanatory variable is the negative of the logarithm of the relative total Supply of manual and interactive tasks. In the calculation of supply and wages only workers with at most a high school degree are included. The method of estimation used is 2SLS, including state and year fixed effects. We use the share of foreign-born as instrument for the relative Supply of manual/interactive tasks in the state. The coefficient reported is the estimated relative wage elasticity taken with the positive sign. The reported standard errors are heteroskedasticity robust. Observations are 50 US states plus DC over five census years; 1960 to 2000.

**Figure 1: Equilibrium without Immigrants; Relative Task Demand/Supply**

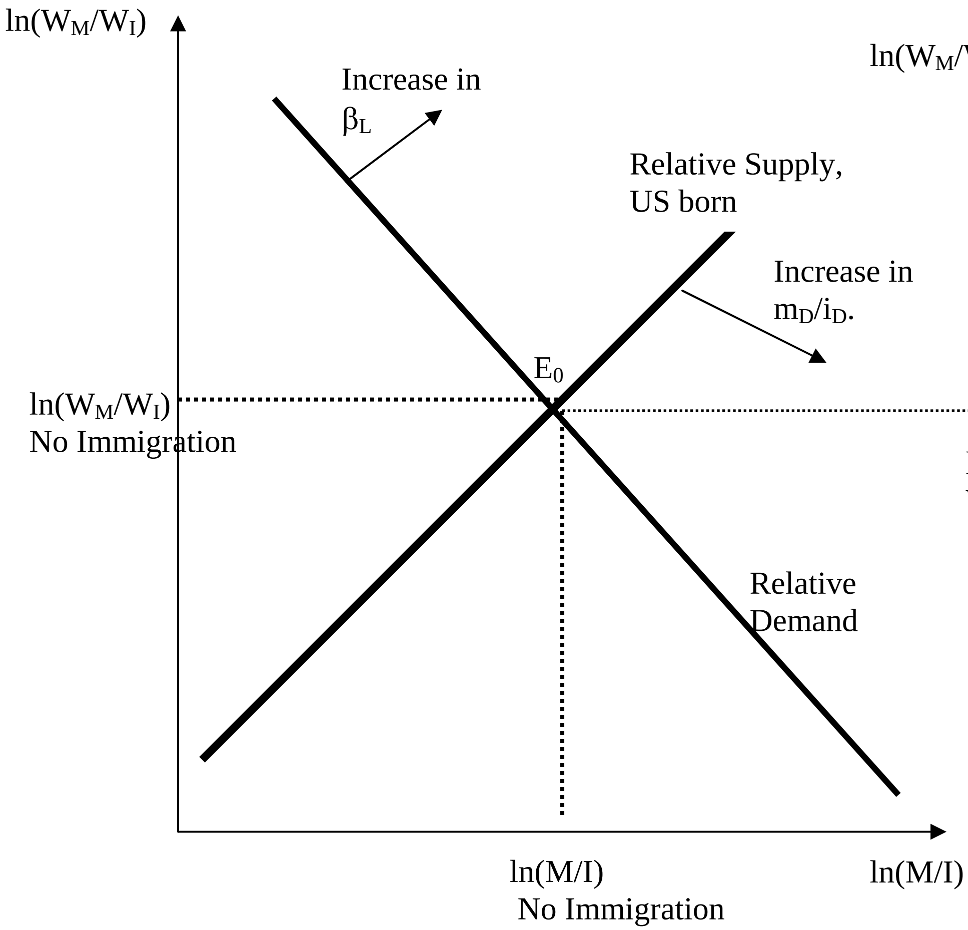



**Figure 2: Equilibrium with Immigrants; Relative Task Demand/Supply**

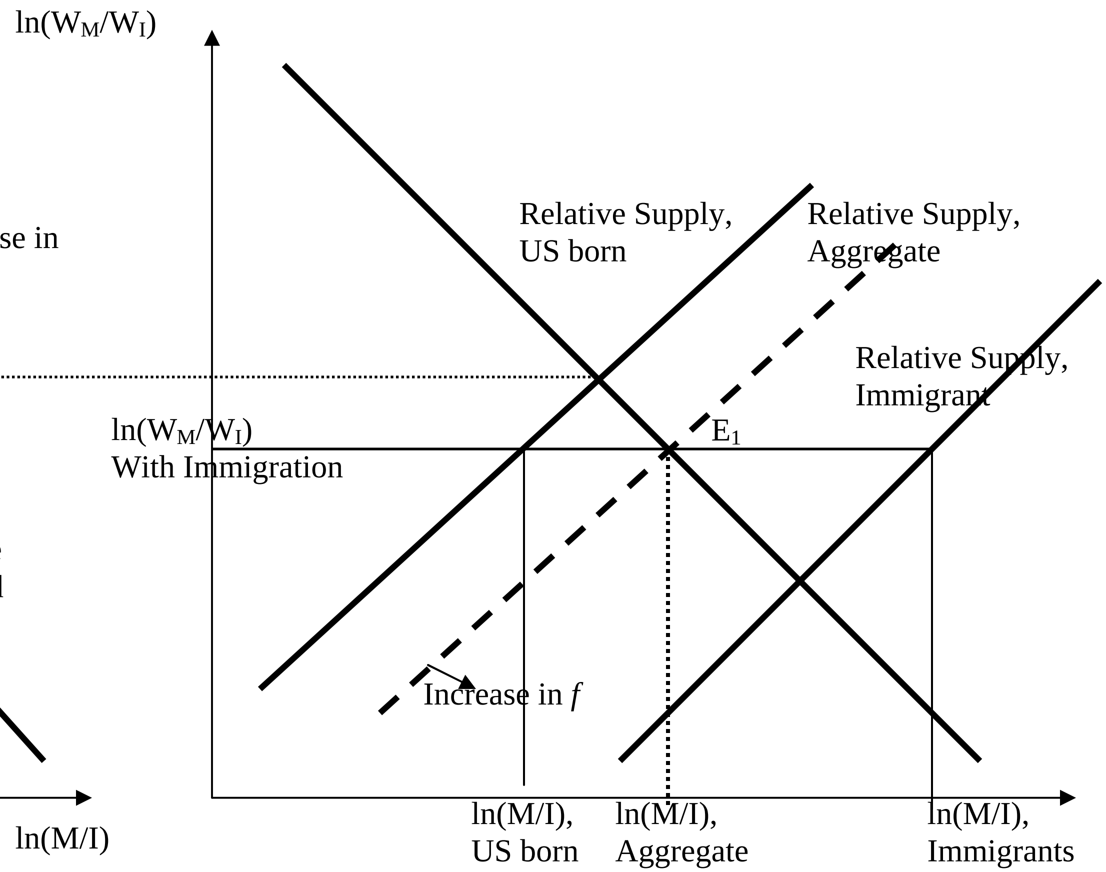
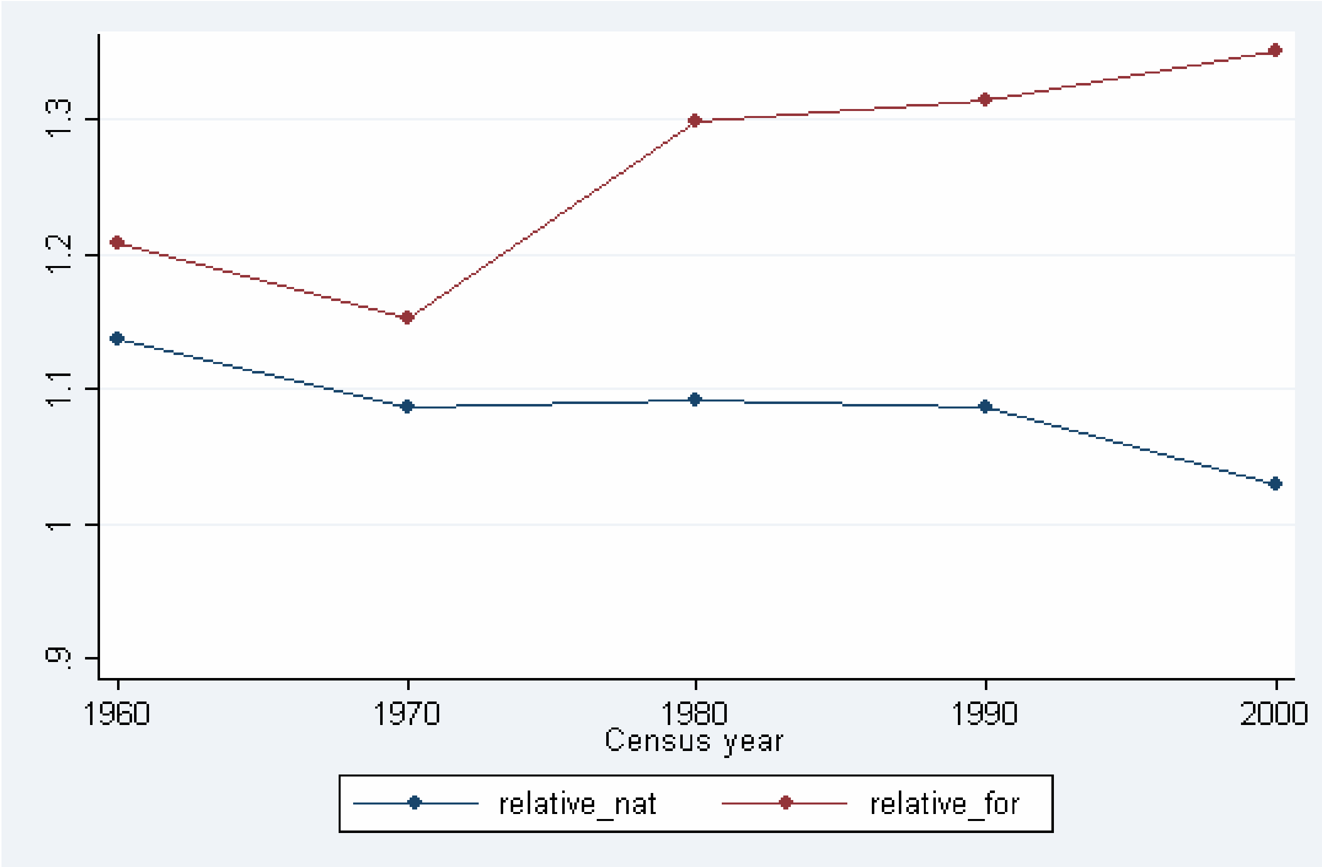
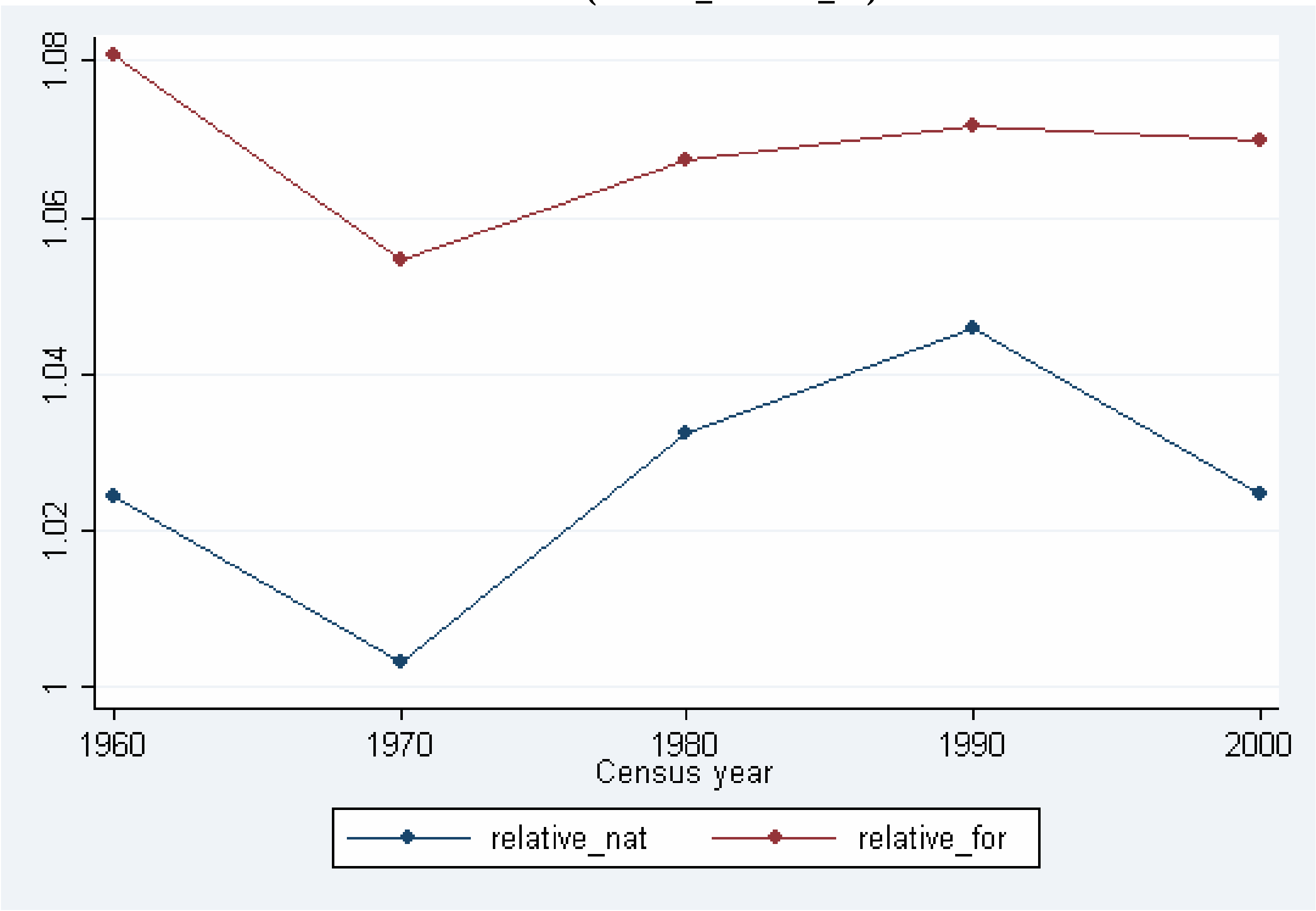


**Figure 3**
**Relative Supply of Manual/Interactive Tasks, Native and Foreign with at Most a High School Degree, 1960-2000 (EHF_77/DCP_77)**




**Note:** The construction of the relative Supply of tasks for native and foreign born is described in the text. The suffix _77 indicates that the task variable used is constructed from the 1977 DOT scores.

**Figure 4**
**Relative Supply of Quantitative/Interactive Tasks, Native and Foreign-Born with at Least Some College Education, 1960-2000 (MATH_77/DCP_77)**




**Note:** The construction of the relative Supply of tasks for native and foreign born is described in the text. The suffix _77 indicates that the task variable used is constructed from the 1977 DOT scores.

**Figure 5**
**Share of Foreign-Born Workers and the Relative Supply of Manual/Interactive Tasks by Natives, High School Degree or Less, US States, 2000**