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ABSTRACT

Many workers with low levels of educational attainment immigrated to the United States in recent decades. Large inflows of less-educated immigrants would reduce wages paid to comparably-educated native-born workers if the two groups compete for similar jobs. In a simple model exploiting comparative advantage, however, we show that if less-educated foreign and native-born workers specialize in performing complementary tasks, immigration will cause natives to reallocate their task supply, thereby reducing downward wage pressure. Using individual data on the task intensity of occupations across US states from 1960-2000, we then demonstrate that foreign-born workers specialize in occupations that require manual tasks such as cleaning, cooking, and building. Immigration causes natives -- who have a better understanding of local networks, rules, customs, and language -- to pursue jobs requiring interactive tasks such as coordinating, organizing, and communicating. Simulations show that this increased specialization mitigated negative wage consequences of immigration for less-educated native-born workers, especially in states with large immigration flows.

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1 Introduction

Immigration has significantly affected the US labor supply during the last few decades, particularly among workers with limited formal schooling. Economists continue to debate the wage effects of these large inflows on native-born workers. If workers' skills are differentiated mainly by their level of educational attainment, and workers of different education levels are imperfectly substitutable, then a large flow of immigrants with limited schooling should increase wages paid to highly-educated natives and reduce wages paid to less-educated ones. This intuitive approach receives support in Borjas (2003, 2006) and Borjas and Katz (2005). They use US national data to argue that immigration reduced real wages paid to native-born workers without a high school degree by four to five percent between 1980 and 2000. In contrast, area studies by Card (2001, 2007), Card and Lewis (2007), and Lewis (2005) employ city and state level data and find almost no effect of immigration on the wages of less-educated native workers. Ottaviano and Peri (2006) note that the effects of immigration crucially depend upon the degree of substitution between native and foreign-born workers *within* each education group. That is, native and foreign-born workers of comparable educational attainment might possess unique skills that lead them to specialize in different occupations, which would mitigate wage losses from immigration.[1]

We advance this debate by providing a theory to explain why native and foreign-born workers with little formal education may be imperfect substitutes in production. We then measure the tasks these individuals perform in their occupations so that we can estimate the effect of immigration on wages. We argue that immigrants are likely to have imperfect language skills, incomplete knowledge of productive networks, and only scant awareness of social norms and the intricacies of productive interactions. However, they have manual and physical skills similar to those of native-born workers. Therefore, they have a comparative advantage in occupations requiring manual labor-intensive tasks, while less-educated native-born workers will have an advantage in jobs demanding interactive and language-intensive tasks. Immigration encourages specialization so that foreign-born workers create little adverse wage consequences for less-educated natives.

We begin in Section 2 by developing a simple model of comparative advantage and incomplete specialization of workers. Workers' skill endowments imply that immigration reduces the compensation paid to manual tasks and increases the compensation paid to interactive ones. The complementary nature of the two skills and the reallocation of native workers toward interactive tasks favor wages paid to native workers. The effects compensate (in part or entirely) for the depressing effect of immigration on the wage paid to manual tasks.

Next, Section 3 describes data for the 50 US states (plus the District of Columbia) from 1960 to 2000 that we use to test our model. To measure the intensity of manual and interactive tasks supplied by workers, we use a

[1] Manacorda et. al. (2006) find similar imperfect substitutability between native and immigrant workers for the UK. Other important contributions to the literature on immigration and wages include Altonji and Card (1991), Borjas (1994), (1995), (1999), Borjas, Freeman, and Katz (1997), Butcher and Card (1991), Card (1990), Friedberg and Hunt (1995), Friedberg (2001), and National Research Council (1997).

dataset assembled by Autor, Levy, and Murnane (2003) that merges data on job task requirements based upon the US Department of Labor's *Dictionary of Occupational Titles* (DOT) with Census occupation classifications. We adopt two of their variables; one captures the manual labor content of each job (called "eye-hand-foot coordination" skills), and the other accounts for an occupation's interactive content (called "direction-control-planning"). Using IPUMS microdata from the Census (Ruggles et. al. (2005)), we then construct the supply of each task for native and foreign-born workers by state, as well as the change in tasks supplied over time.

The empirical analysis in Section 4 strongly supports three key implications of our theory. In states with large inflows of less-educated immigrants: i) less-educated native-born workers shifted their supply toward interactive tasks at a faster rate than in states with low immigration; 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 more than in states with low immigration. Less-educated natives have responded to immigration by leaving manual task-intensive occupations for interaction-intensive ones. These results are upheld by two stage least squares regressions that instrument for the variation of less-educated immigrants across states using two different sets of exogenous variables, both of which exploit the increased level of Mexican immigration as an exogenous supply shift. The first instrument follows a strategy similar to Card (2001), Card and Di Nardo (2000), and Cortes (2006) by using the imputed share of Mexican workers (based upon 1960 state demographics and subsequent national growth rates) as a proxy for the share of less-educated immigrants in a state. The second set of instruments interacts decade indicator variables with the distance of a state's center of gravity to the Mexico-US border, its square, and a border dummy.

Critics of past area studies have argued that the methodology fails to identify wage losses because the effects of immigration are diffused nation-wide through internal migration. However, Section 4.2.3 demonstrates that increased immigration among less-educated workers in a state neither reduces the relative wage of less-educated native-born workers nor induces their out-migration.[2] Our paper provides a new potential explanation for this phenomenon – rather than flee their home states for new locales, natives respond to immigration by specializing in jobs that are intensive in interactive production tasks. This stabilizes native-born wages, and removes their incentive to migrate.

Given the positive wage effect of specializing in interactive skill-intensive occupations, native-born reallocation of productive task supply has protected their real wages and mitigated losses due to immigration. In Section 5, we use the parameters of our model and our empirical results to calculate the effect of immigration on average wages paid to native-born workers with a high school degree or less. Task complementarities and increasing specialization among native-born workers imply that the wage impact of immigration on less-educated natives, while usually negative, is quite small. These findings agree with those of Card (2001), Card and Lewis (2007),

[2]See Card (2001), Lewis (2003), and Peri (2007) for further defense of area studies.

and Ottaviano and Peri (2006) and enrich the structural framework to analyze the effect of immigration used in Borjas (2003), Borjas and Katz (2005), Ottaviano and Peri (2006), and Peri (2007).

2 Theoretical Model

We advocate a simple general equilibrium model of comparative advantages in task performance, rather than final goods production, to illustrate the effects of immigration on specialization and wages.[3] We develop the model here, and provide more detailed derivations of the equations in the Appendix. We will test the model's implications in Section 4, and use its structure and empirically-estimated elasticities to evaluate the effects of immigration on wages paid to less-educated native-born workers in Section 5.

2.1 Production

Consider an economy that combines two intermediates, Y_H and Y_L, in a CES production function to produce the final consumption good, Y, according to Equation (1).

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

The parameter $\sigma \in (0, \infty)$ measures the elasticity of substitution between the two intermediate goods, while β and $(1-\beta)$ capture the relative productivity of Y_L and Y_H in the production of Y. We choose Y to be the numeraire, and assume it is assembled by perfectly competitive firms that minimize costs and earn no profits. This ensures that the prices of Y_L and Y_H (denoted P_L and P_H) are equal to their marginal products.

The intermediate goods are produced by workers of different education levels. Low education workers (with total labor supply equal to L) produce Y_L, and high education workers (H) produce Y_H. While CES production functions combining the services of high and low education labor are widely used in economics,[4] we add to the framework by assuming that less-educated workers must perform both "manual" and "interactive" tasks to produce Y_L. Manual tasks include functions such as building, moving, and operating equipment, while interactive tasks involve coordinating, directing, and organizing people. Let less-educated workers supply M manual-task inputs and I interactive-task inputs. These tasks combine to produce Y_L according to the CES function in Equation (2), where $\beta_L \in (0, 1)$ captures the relative productivity of manual skills and $\theta_L \in (0, \infty)$ measures the elasticity of substitution between M and I.

[3] Grossman and Rossi-Hansberg (2006) develop an interesting new theory of off-shoring that builds upon a process of international task division. Their model has features and implications similar to the one developed in this paper.

[4] See the literature on cross-country income differences (Acemoglu and Zilibotti, 2001; Caselli and Coleman, 2006), technological change (Acemoglu,1998; 2002), and labor economics (Katz and Murphy, 1992; Card and Lemieux, 2001).

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

Highly-educated workers similarly perform two tasks to produce Y_H. Like less-educated workers, highly-educated workers supply interactive skills. Rather than perform manual functions, however, highly-educated workers supply analytical (or quantitative) skills. To simplify the analysis and focus on the role of less-educated workers in production (and on the impact of immigrants on those workers), we assume that interactive and analytical skills are perfectly substitutable in the production of Y_H. Thus, Y_H is produced according to a linear technology equal to the total supply of highly-educated workers. That is, $Y_H = H$.[5]

Competitive labor markets and producers of Y_L and Y_H yield the relative task demand function in Equation (3), where w_M and w_I denote the compensation paid to the provider of one unit of manual and interactive task, respectively.

$$\frac{M}{I} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\theta_L} \left(\frac{w_M}{w_I}\right)^{-\theta_L} \tag{3}$$

2.2 Relative Supply of Tasks with Heterogeneous Workers

Each highly-educated worker is identical from a productive point of view and supplies one unit of task input to produce one unit of good Y_H. The wage of each highly-educated worker equals the marginal productivity of Y_H in (1) so that $W_H = P_H$. In contrast, less-educated workers are heterogeneous and differ from each other in their relative task productivity. In particular, each agent j is characterized by a specific level of effectiveness in performing the two tasks. Let m_j and i_j represent the effectiveness of worker j in performing manual and interactive tasks, respectively. The one unit of labor supplied by less-educated worker j can be fully used to provide m_j units of manual tasks or i_j units of interactive tasks. Workers with higher effectiveness in a particular task will spend relatively more of their labor endowment performing it, but we assume that decreasing returns imply that an agent will not choose to fully specialize.

Let l_j be the share of personal labor endowment (share of time) worker j spends performing manual tasks so that $1 - l_j$ is the time spent performing interactive tasks. Worker j's supply of manual task units is indicated by $\mu_j = (l_j)^{\delta} m_j$, while its supply of interactive task units is $\iota_j = (1-l_j)^{\delta} i_j$. The parameter $\delta \in (0,1)$ captures the decreasing returns from performing a single task. Each worker takes the wages paid to tasks as given and chooses an allocation of labor between manual and interactive tasks to maximize her labor income given in Equation (4).

[5] A previous version of this paper permitted imperfect substitutability between interactive and analytical tasks. For this version, however, we intend to focus empirically on the effect of less-educated immigrants. Since the richer model of Y_H has no implications for less-educated workers, we leave it and the empirical analysis of task specialization and complementarities among highly- educated workers to a different paper.

$$W_{L,j} = (l_j)^{\delta} m_j w_M + (1 - l_j)^{\delta} i_j w_I. \tag{4}$$

By maximizing wages with respect to l_j, we can identify the equilibrium relative supply of manual versus interactive task-units for worker j (Equation (5)), which depends positively on relative task compensation and the worker's efficiency in performing manual relative to interactive tasks, (m_j/i_j).[6]

$$\frac{\mu_j}{\iota_j} = \left(\frac{w_M}{w_I}\right)^{\frac{\delta}{1-\delta}} \left(\frac{m_j}{i_j}\right)^{\frac{1}{1-\delta}} \tag{5}$$

Aggregate task supply simply equals the summation over all less-educated workers. That is, $M = \sum_j \mu_j = L\overline{\mu}$ and $I = \sum_j \iota_j = L\overline{\iota}$, where $\overline{\mu}$ and $\overline{\iota}$ represent the average unit-supply of manual and interactive tasks. Aggregate relative task supply (Equation (6)) is then a function of relative wages and the average relative effectiveness of workers (defined in Equation (7)), where $\vartheta_j = (\iota_j/I)$ is worker $j's$ share in the total supply of interactive tasks.

$$\frac{M}{I} = \frac{\sum_j \mu_j}{\sum_j \iota_j} = \sum_j \vartheta_j \frac{\mu_j}{\iota_j} = \left(\frac{w_M}{w_I}\right)^{\frac{\delta}{1-\delta}} \overline{\left(\frac{m}{i}\right)}^{\frac{1}{1-\delta}} \tag{6}$$

$$\overline{\left(\frac{m}{i}\right)} = \left[\sum_j \left(\vartheta_j \left(\frac{m_j}{i_j}\right)^{\frac{1}{1-\delta}}\right)\right]^{1-\delta} \tag{7}$$

In equilibrium, relative task provision (Equation (8)) is a positive function of both the relative productivity of the tasks in the production of Y_L and the average relative effectiveness of workers. An increase in β_L raises $\frac{M}{I}$ demand, while an increase in $\overline{\left(\frac{m}{i}\right)}$ raises supply. Relative compensation (Equation (9)) is also a positive function of β_L, but it depends negatively on $\overline{\left(\frac{m}{i}\right)}$; a population that is more effective in manual task performance (on average) would supply more of those tasks, thereby decreasing their relative price.

$$\frac{M^*}{I^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \overline{\left(\frac{m}{i}\right)}^{\frac{\theta_L}{(1-\delta)\theta_L+\delta}} \tag{8}$$

$$\frac{w_M^*}{w_I^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \overline{\left(\frac{m}{i}\right)}^{-\frac{1}{(1-\delta)\theta_L+\delta}} \tag{9}$$

All workers receive the same relative compensation in equilibrium. Equation (10) identifies an individual worker's relative supply of tasks, which is positively related to its effectiveness in performing them. In contrast, the average worker's relative effectiveness will negatively affect an individual's supply. This is because a

[6] In practice (and in anticipation of our empirical strategy), workers are likely to select different allocations of their time between manual and interactive tasks according to their occupation choice. Thus, we assume each unique allocation represents a different occupation. A worker will choose an occupation with the time allocation $(l, 1-l)$ that maximizes its wage income, which depends on its relative efficiency (m_j/i_j) of task performance. For given relative wages, there is a one-to-one correspondence between relative efficiency and occupation choice, as well as between relative efficiency and the relative supply of tasks (Equation (5)). Hence, the choice of occupation reveals the comparative advantage of a worker.

population with higher manual abilities would supply more units of manual tasks and depress its relative wage, thereby inducing the individual to shift supply from manual toward interactive tasks.

$$\frac{\mu_j}{\iota_j} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \overline{\left(\frac{m}{i}\right)}^{-\frac{\delta}{[(1-\delta)\theta_L+\delta](1-\delta)}} \left(\frac{m_j}{i_j}\right)^{\frac{1}{1-\delta}} \tag{10}$$

The left panel of Figure 1 illustrates the wage and provision of tasks for an economy. Bold lines represent (in logarithmic scale) aggregate relative task supply and demand. Point E_0 identifies the equilibrium corresponding to Equations (8) and (9). Dotted lines to the left and right of the aggregate supply curve represent relative individual task supply for workers j_1 (with low manual effectiveness) and j_2 (high manual effectiveness). The equilibrium supply for each type of worker is identified by the point where its individual supply curve crosses the level of equilibrium compensation (at points 1 and 2, respectively). Intuitively, an increase in β_L would shift aggregate demand to the right, increase the equilibrium relative compensation for manual tasks, and increase the relative supply of manual tasks for each worker. An increase in $\overline{\left(\frac{m}{i}\right)}$ would shift aggregate supply to the left, decrease the relative compensation for manual tasks, and reduce the relative supply of manual tasks for each worker of a given relative effectiveness.

2.3 Two Types of Workers: Effects of Immigration on Relative Task Supply and Returns to Tasks

The model in Section 2.2 analyzes average wages and task provision for a single group of heterogenous workers. In this section, we expand the model to incorporate a second heterogenous group that differs from the first only in its average manual to interactive effectiveness $\overline{\left(\frac{m}{i}\right)}$. Suppose the initial group of less-educated "domestic" (or native-born) workers has size L_D and average effectiveness $\overline{\left(\frac{m_D}{i_D}\right)}$. Now allow immigration so that a new group of less-educated "foreign-born" (or immigrant) workers of size L_F and effectiveness $\overline{\left(\frac{m_F}{i_F}\right)}$ enters the labor force. While there is no clear reason for immigrants to be less productive in performing manual tasks such as building a wall, picking fruits, or cutting jewelry, they are certainly not as proficient as natives in communicating with other native-born workers, organizing people, serving customers, managing relationships, or other interactive tasks that require mastery of the language and knowledge of personal customs and networks. Therefore, we assume $\overline{\left(\frac{m_F}{i_F}\right)} > \overline{\left(\frac{m_D}{i_D}\right)}$. In other words, foreign-born workers have, on average, comparative advantages in performing manual tasks, while native workers have comparative advantages in performing interactive tasks.[7] This assumption allows us to analyze how immigration affects wages and task provision.

Equation (3) continues to describe relative aggregate demand. Equation (11) represents the relative supply of tasks in the economy obtained by summing the skills provided by each group.

[7] We make no assumptions regarding whether one group has an absolute advantage in both tasks.

$$\frac{M}{I} = \frac{M_F + M_D}{I_F + I_D} = f\frac{M_F}{I_F} + (1-f)\frac{M_D}{I_D} \tag{11}$$

The term $0 < f = I_F/(I_F + I_D) < 1$ is the share of interactive tasks supplied by foreign-born workers. It is a simple monotonically increasing transformation of the share of foreign-born among less-educated workers, $s = L_F/(L_F + L_D)$. Hence, the aggregate relative supply of tasks in the economy is a weighted average of each group's supply, and the weights are closely related to the share of each group in employment. The relative supply for foreign and native-born workers is given by Equation (6), with $\overline{\left(\frac{m_F}{i_F}\right)}$ and $\overline{\left(\frac{m_D}{i_D}\right)}$ substituting for $\overline{\left(\frac{m}{i}\right)}$, respectively. Equation (12) describes the equilibrium relative compensation of tasks when the average manual versus interactive task effectiveness of the population equals $\left[f\overline{\left(\frac{m_F}{i_F}\right)}^{\frac{1}{1-\delta}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)}^{\frac{1}{1-\delta}}\right]^{(1-\delta)}$.

$$\frac{w_M^*}{w_I^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \left[f\overline{\left(\frac{m_F}{i_F}\right)}^{\frac{1}{1-\delta}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)}^{\frac{1}{1-\delta}}\right]^{-\frac{(1-\delta)}{(1-\delta)\theta_L+\delta}} \tag{12}$$

By substituting this wage equilibrium into aggregate relative supply (6) for domestic workers, we find their equilibrium relative provision of tasks (Equation (13)). The weighted average of $\frac{M_D^*}{I_D^*}$ and $\frac{M_F^*}{I_F^*}$ (according to Equation (11)) identifies the equilibrium aggregate relative provision of tasks in Equation (14).

$$\frac{M_D^*}{I_D^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \left[f\overline{\left(\frac{m_F}{i_F}\right)}^{\frac{1}{1-\delta}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)}^{\frac{1}{1-\delta}}\right]^{-\frac{\delta}{(1-\delta)\theta_L+\delta}} \overline{\left(\frac{m_D}{i_D}\right)}^{\frac{1}{1-\delta}} \tag{13}$$

$$\frac{M^*}{I^*} = \left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \left[f\overline{\left(\frac{m_F}{i_F}\right)}^{\frac{1}{1-\delta}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)}^{\frac{1}{1-\delta}}\right]^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \tag{14}$$

The right panel of Figure 1 illustrates the equilibrium in an economy with native and foreign-born labor. Due to comparative advantages in manual tasks, immigrants' supply is to the right of domestic workers' supply. The overall relative supply (represented by the thickest line in the panel) is a weighted average of the two – the distance of the average supply curves from those of immigrants and domestic workers is proportional to f and $1-f$, respectively. An increase in the share of foreign-born employment (which would raise f) would shift the overall relative supply closer to that of foreign-born workers. Point E_1 represents the equilibrium with immigrants. Immigration reduces compensation paid to manual relative to interactive tasks, while also increasing the relative provision of the skills. However, the average manual versus interactive task supply of native workers (point D) is smaller than in the case without immigration. Finally, the manual versus interactive task supply of immigrants (point F) is larger than for native workers.

The equilibrium results summarized in Equations (12), (13), and (14) provide the basis for comparing economies differing from each other in the presence of foreign-born workers. As f increases from 0 (only domestic workers) to positive values, our model has specific comparative static implications for the relative task supply of natives, overall relative task supply, and relative task compensation. We summarize the main implications in three propositions that will motivate our empirical analysis. We begin with a Lemma, to be empirically validated, that states our comparative advantage assumption.

Lemma: The comparative advantage of foreign-born workers in performing manual tasks, $\overline{\left(\frac{m_F}{i_F}\right)} > \overline{\left(\frac{m_D}{i_D}\right)}$, implies that they supply relatively more manual versus interactive tasks than domestic workers provide. That is, $\frac{M_F}{I_F} > \frac{M_D}{I_D}$.

Proof: Consider individual supply (10) for the average immigrant and domestic worker. The two expressions will share the term $\left(\frac{\beta_L}{1-\beta_L}\right)^{\frac{\theta_L \delta}{(1-\delta)\theta_L+\delta}} \overline{\left(\frac{m}{i}\right)}^{-\frac{\delta}{[(1-\delta)\theta_L+\delta](1-\delta)}}$, but the comparative advantage assumption implies $\overline{\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}} > \overline{\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}}$. Therefore, $\frac{\overline{\mu_F}}{\overline{\iota_F}} > \frac{\overline{\mu_D}}{\overline{\iota_D}}$. Multiplying the numerator and the denominator of the first ratio by L_F, and the numerator and the denominator of the second ratio by L_D we obtain $\frac{M_F}{I_F} > \frac{M_D}{I_D}$. *QED.*

The relative effectiveness of workers is not observable empirically, but occupation choices reveal their intensity of task supply. Thus, we can compare the relative task supply of natives and immigrants to test whether the main assumption of our model is correct. The assumption also facilitates the following three propositions.

Proposition 1: A higher foreign-born share (s) of less-educated workers in an economy induces lower aggregate supply of manual relative to interactive tasks among less-educated native workers, $\frac{M_D^*}{I_D^*}$.

Proof: Consider Equation (13). The assumption $\overline{\left(\frac{m_F}{i_F}\right)} > \overline{\left(\frac{m_D}{i_D}\right)}$ implies that $\left[f\overline{\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}}\right]$ is monotonically increasing in f. The share f, in turn, depends positively on s (specifically, $\partial f/\partial s = \frac{\overline{\iota_F}\,\overline{\iota_D}}{(s\overline{\iota_F}+(1-s)\overline{\iota_D})^2} > 0$) so that the expression in square brackets above is increasing in s. Since this expression is raised to a negative power $\left(-\frac{\delta}{(1-\delta)\theta_L+\delta}\right)$ and is the only portion of (13) that depends upon s, it implies that $\frac{M_D^*}{I_D^*}$ is a negative function of s. *QED.*

Proposition 2: A higher foreign-born share (s) of less-educated workers in an economy induces a larger supply of manual relative to interactive tasks among less-educated workers overall, $\frac{M^*}{I^*}$.

Proof: Consider equation (14). It contains the same expression $\left[f\overline{\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}}\right]$ as above, which is monotonically increasing in s. As it is raised to a positive power $\left(\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}\right)$, $\frac{M^*}{I^*}$ depends positively on s. *QED.*

Proposition 3: A higher foreign-born share (s) of less-educated workers in an economy induces lower compensation paid to manual relative to interactive tasks , $\frac{w_M^*}{w_I^*}$.

Proof: Consider equation (12). It also contains $\left[f\overline{\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}}\right]$ raised to a negative power $\left(-\frac{(1-\delta)}{(1-\delta)\theta_L+\delta}\right)$. Hence, the overall expression $\frac{w_M^*}{w_I^*}$ depends negatively on s. *QED.*

Notice also that an increase in the average relative task ability of immigrants $\overline{\left(\frac{m_F}{i_F}\right)}$ would have very similar effects to those of an increase in f. Specifically, from conditions (12), (13) and (14) one can easily show that an increase in $\overline{\left(\frac{m_F}{i_F}\right)}$ would decrease the compensation paid to manual relative to interactive tasks $\left(\frac{w_M^*}{w_I^*}\right)$, decrease the supply of manual relative to interactive tasks among less-educated native workers $\left(\frac{M_D^*}{I_D^*}\right)$, and increase the supply of manual relative to interactive tasks among less-educated workers overall $\left(\frac{M^*}{I^*}\right)$. Section 3 will demonstrate that f and $\overline{\left(\frac{m_F}{i_F}\right)}$ have been rising together over time and exhibit a mild positive correlation across states so that they are likely to reinforce each-other.

In our empirical analysis, we first check the validity of the inequality expressed in the Lemma. Then we test the qualitative predictions of the three propositions using data for US states from 1960-2000.

2.4 Effect of Immigration on Real Wages

The model above has clear qualitative predictions for how immigration affects the relative supply and compensation of tasks. We can use the model to simulate immigration's effect on the average wage of highly-educated workers, less-educated workers, less-educated native-born workers, and workers employed in specific occupations (i.e., for individual j) once we have estimated the parameters and measured how M, I, and H have responded to immigration.

Competitive markets ensure that inputs will earn wages equal to their marginal products. On average, both highly-educated and less-educated workers earn the unit price of the intermediate good they produce. The logarithmic differential of their marginal products provides the measures of immigration's effect on these groups expressed in Equations (15) and (16), where $\varkappa_H = \left(\frac{W_H H}{Y}\right)$ is the income share paid to highly-educated workers and $1 - \varkappa_H$ is the share paid to less-educated workers.

$$\frac{\Delta \overline{W}_H}{\overline{W}_H} = \frac{\Delta P_H}{P_H} = -\frac{1}{\sigma}\frac{\Delta H}{H} + \frac{1}{\sigma}\left(\varkappa_H \frac{\Delta H}{H} + (1-\varkappa_H)\frac{\Delta Y_L}{Y_L}\right) \tag{15}$$

$$\frac{\Delta \overline{W}_L}{\overline{W}_L} = \frac{\Delta P_L}{P_L} = -\frac{1}{\sigma}\frac{\Delta Y_L}{Y_L} + \frac{1}{\sigma}\left(\varkappa_H \frac{\Delta H}{H} + (1-\varkappa_H)\frac{\Delta Y_L}{Y_L}\right) \tag{16}$$

Equation (15) provides a direct measure of immigration's effect on highly-educated labor. More interestingly, however, we can decompose the effect on wages paid to less-educated workers into its manual and interactive components. Equations (17) and (18) obtain values for $\left(\frac{\Delta w_M}{w_M}\right)$ and $\left(\frac{\Delta w_I}{w_I}\right)$ from logarithmic differentials of their marginal products. Equation (19) then represents wages paid to less-educated workers as the average manual and interactive wage effects weighted by their respective supplies, where $\varkappa_M = (w_M M / \overline{W}_L L)$ is the manual task share of wages paid to less-educated workers and $(1 - \varkappa_M)$ equals the share compensating interactive tasks.

$$\frac{\Delta w_M}{w_M} = \frac{1}{\sigma}\left(\varkappa_H \frac{\Delta H}{H} + (1-\varkappa_H)\frac{\Delta Y_L}{Y_L}\right) + \left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right)\frac{\Delta Y_L}{Y_L} - \frac{1}{\theta_L}\frac{\Delta M}{M} \tag{17}$$

$$\frac{\Delta w_I}{w_I} = \frac{1}{\sigma}\left(\varkappa_H \frac{\Delta H}{H} + (1-\varkappa_H)\frac{\Delta Y_L}{Y_L}\right) + \left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right)\frac{\Delta Y_L}{Y_L} - \frac{1}{\theta_L}\frac{\Delta I}{I} \tag{18}$$

$$\frac{\Delta \overline{W}_L}{\overline{W}_L} = \frac{\Delta w_M}{w_M}\frac{w_M}{\overline{W}_L}\overline{\mu} + \frac{\Delta w_I}{w_I}\frac{w_I}{\overline{W}_L}\overline{\iota} = \varkappa_M \frac{\Delta w_M}{w_M} + (1-\varkappa_M)\frac{\Delta w_I}{w_I} \tag{19}$$

Calculations of the effect of immigration on the average native-born less-educated worker then requires two additional steps. First we weight the change in compensation by the average task supply of natives ($\overline{\mu_D}$ and $\overline{\iota_D}$) rather than by $\overline{\mu}$ and $\overline{\iota}$. This implies a higher relative weight on $\frac{\Delta w_I}{w_I}$ and lower one on $\frac{\Delta w_M}{w_M}$ since native workers supply relatively more interactive tasks. Second, the reallocation of native-born task provision generates wage effects equal to $(\Delta\overline{\mu})\, w_M + (\Delta\overline{\iota})\, w_I$.[8] Altogether, Equation (20) expresses the net effects of immigration on average wages paid to less-educated native-born workers.

$$\frac{\Delta \overline{W}_D}{\overline{W}_D} = \frac{\Delta w_M}{w_M}\frac{w_M}{\overline{W}_D}\overline{\mu_D} + \frac{\Delta w_I}{w_I}\frac{w_I}{\overline{W}_D}\overline{\iota_D} + (\Delta\overline{\mu_D})\frac{w_M}{\overline{W}_D} + (\Delta\overline{\iota_D})\frac{w_I}{\overline{W}_D} \tag{20}$$

To obtain the effect of immigration on the wage paid to occupation j, we weight the percentage wage changes by the supply of each task in that occupation (Equation (21)). There is no second order effect because the expression analyzes the outcome for workers in a specific occupation, so the supply of tasks is fixed.

$$\frac{\Delta \overline{W}_j}{\overline{W}_j} = \frac{\Delta w_M}{w_M}\frac{w_M}{\overline{W}_j}\overline{\mu_j} + \frac{\Delta w_I}{w_I}\frac{w_I}{\overline{W}_j}\overline{\iota_j} \tag{21}$$

We will use the expressions (15), (16), (20) and (21) in Section 5 to evaluate the impact of immigration between 1990 and 2000 on average wages paid to highly-educated workers, less-educated workers, less-educated native workers, and specific occupational groups at the national level and for selected US states. Note that expressions (17) and (18) contain the unmeasurable term $\frac{\Delta Y_L}{Y_L}$. Since Y_L is produced under perfect competition using services of less-educated workers only, however, the total income generated in this sector will be distributed to less-educated workers. This allows us to relate changes in the production of Y_L to small changes of inputs M and I as in Equation (22); the percentage change in Y_L is equal to the sum of the percentage changes of inputs M and I weighted by the income share of each factor.

$$\frac{\Delta Y_L}{Y_L} = \frac{w_M \Delta M + w_I \Delta I}{P_L Y_L} = \varkappa_M \frac{\Delta M}{M} + (1-\varkappa_M)\frac{\Delta I}{I} \tag{22}$$

[8] While in the theoretical model the change in task supply generates only a second order effect, in the empirical analysis it is important to control for differences in w_M and w_I that may be due to a host of causes not necessarily captured by this model.

3 Data Description and Preliminary Evidence

This section describes how we construct measures of task supply to test the main implications of the model. The IPUMS dataset by Ruggles et. al. (2005) 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 from 1960 to 2000. We include only non-military wage-earning employees who were eighteen years of age or older and had worked at least one week prior to the census year.

Since the immigrant share of employment varies greatly across US states, we adopt states as the econometric unit of analysis.[9] One critique of this approach is that US states are open economies, so the effects of immigration in one state could spill into others through the migration of natives. We demonstrate in Section 4.2.3, however, that natives do not respond to immigration by moving.[10] Instead, our analysis provides a new explanation for the observed small wage and employment response: Native-born workers protect themselves from competition with immigrants (and partly benefit from their inflow) by specializing in interactive task-intensive occupations. State-level regressions, therefore, remain informative.

3.1 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.[11] We merge the ALM data with individual-level Census and CPS data, and then aggregate figures to obtain the data used in regressions. We briefly describe the merging procedure and the characteristics of the task variables here.[12]

Between 1939 and 1991, the US Department of Labor periodically evaluated the tasks required for more than 12,000 occupations. 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) by gender and three-digit Census Occupation Codes (COC) for five occupational skills.[13] We restrict our focus to the two variables that best capture the interactive and manual tasks described in our model.

We measure the interactive skill content of an occupation by the level of Direction, Control, and Planning

[9] Also see Card (2001, 2007), Lewis (2005), Card and Lewis (2007), Cortes (2006), and Kugler and Yuksel (2006).

[10] Card (2001, 2007) and Peri (2007) provide concurring evidence.

[11] We are extremely grateful to David Autor for providing the data, which has also been used recently by Bacolod and Blum (2006) to analyze skill premia and the gender wage gap and by Bacolod et al. (2006) to analyze the effect of urban agglomerations on the premium of specific skills.

[12] For more details on the construction of the variables, we refer to the Appendix of Autor, Levy and Murnane (2003).

[13] Differentiation by gender within each census occupation occurs because "the gender distribution of DOT occupations differs substantially within COC occupation cells."

(DCP) activities that it requires. DCP takes ordinal values ranging from zero to ten and maintains high values in occupations requiring non-routine managerial and interpersonal skills. ALM define DCP as "Adaptability to accepting responsibility for the direction, control, or planning of people and activities." The highest DCP values occur for managerial occupations, while the lowest are found among traditional blue-collar laborers. Conversely, Eye-Hand-Foot coordination (EHF) measures the occupational demand for non-routine manual skills. ALM describe EHF as the "Ability to move the hand and foot coordinately with each other and in accordance with visual stimuli." Ordinal values also range from zero to ten, but are highest in occupations that demand physical precision including dancers, athletes, and firefighters. The lowest occur primarily in white-collar jobs, including a number of natural science and teaching professions.[14]

The somewhat arbitrary scale of measurement for the task variables encourages ALM to convert the values into percentiles. We follow a similar 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 the sample obtained merging those years is collectively representative of the US workforce in 2000.[15] Next, we re-scale the task variables by assigning percentile values according to the 1960 distribution of workers. This standardization of values between 0 and 1 facilitates a more intuitive interpretation of their changes over time.[16]

Occupational percentile values facilitate construction of $\frac{M_D}{I_D}$ and $\frac{M_F}{I_F}$ ratios to match our theoretical model to the empirics. M_F and M_D represent the average (weighted by the Census weight of the individuals) EHF values for foreign and native-born workers, respectively, for the given unit of observation (usually states). Similarly, I_F and I_D are weighted averages of DCP for foreign and native-born workers.

3.2 Aggregate Trends and Stylized Evidence

By construction, the median percentile values of each task variable equals 0.50 in 1960. 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 skill values (and occupations) associated with the median worker. 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 EHF value fell by almost 35% (from 0.50 to 0.33) of its initial value. The US has also experienced a large increase in the supply of interactive tasks, as the median

[14] Note that since both DCP and EHF refer to non-routine tasks (as defined in ALM), their supply was not directly displaced by the adoption of computer technology – a prominent phenomenon during the period considered. Computer adoption or technological change can still confound the relative supply of tasks, however, so we control for it in our empirical analysis.

[15] 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.

[16] We standardize values using both the 1977 and 1991 DOT datasets. For most regression specifications, we assign percentile values based upon the 1977 DOT to individuals from 1960 to 1980, and values from the 1991 DOT to workers in 1990 and 2000.

DCP value increased by more than 24% (from 0.50 to 0.62). These trends may be due to technological change, changes in educational attainment, and/or changes in the industrial composition of the economy.

We are primarily interested in less-educated workers (i.e., those with at most a high school degree) and the differences in tasks supplied by US and foreign-born workers. Figure 2 reports the aggregate relative supply of manual versus interactive tasks for less-educated native, foreign-born, and recent immigrant workers in each decade between 1960 and 2000.[17] Three features of Figure 2 are relevant. First, in accordance with the Lemma of Section 2.3, foreign-born workers with a high school degree or less always provided, on average, more manual relative to interactive tasks when compared to native workers with similar education. This difference is even more apparent when we only consider recent immigrants. New immigrants supply a disproportionate amount of manual tasks and, over time, become more similar to natives in their task supply. Second, the gap between the relative supply among native and immigrant workers has increased significantly over time. This is due to two phenomena – the increase in the share of recent immigrants among foreign-born and the increased relative supply of manual tasks by recent immigrants. In 2000, immigrant supply of manual versus interactive skills was 30% higher than for natives. Third, less-educated native workers have significantly decreased their relative supply. While technology may have contributed to this phenomenon, immigrants exhibited the opposite trend. Considering that the share of immigrants among less-educated workers grew substantially during the forty years analyzed, and that immigrants relative specialization in manual tasks increased, the aggregate trend is consistent with Proposition 1. Native-born workers progressively left manual occupations and adopted interactive ones as immigrants increasingly satisfied the demand for manual skills.

Table 2 provides examples of occupational shifts responsible for changes in the task performance of less-educated native-born workers by listing selected occupations, their 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 education requirements, but also requires quite different tasks. For example, agricultural laborers and farm coordinators are both in agriculture and require little 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). This is confirmed by the relative manual to interactive task value of 2.5 for the first occupation and 0.43 for the second. Both occupations were filled by US-born workers in 1960. By 2000, however, most agricultural laborers (63%) were foreign-born, while farm coordinators were still almost exclusively US-natives (96%). As immigrants took manual jobs, native workers in agriculture could specialize in occupations requiring coordination and managerial tasks. Thus, even within the same sector and for similar education requirements, we see evidence of specialization.

Figure 3 provides stylized evidence on the systematic association between immigration and native workers'

[17] Recent immigrants are foreign-born workers who have been in the US less than 10 years. The 1960 Census does not report the variable "years in the U.S." for foreign-born individuals.

behavior across states. It plots the foreign-born share of less-educated workers and the level of manual versus interactive tasks supplied by less-educated native workers for each state in 2000. While this does not control for any state-specific factor, the negative correlation is clear. In states with a higher share of immigrants among less-educated workers, native workers perform significantly more interactive relative to manual tasks. The empirical analysis of the next section tests whether part of this remarkable difference in specialization of native workers across states is due to immigration, and how this might affect wages paid to native-born workers.

4 Empirical Results

In this section we test the Lemma and three Propositions of Section 2.3 for less-educated workers (generally those with a high school degree or fewer years of schooling). First, Section 4.1 verifies that foreign-born workers provide, on average, a higher relative supply of manual versus interactive tasks than native workers do. Section 4.2 then tests the correlation between the foreign born share of workers and the relative supply of tasks by native workers across states (Proposition 1). Instrumental variable regressions show that immigrant inflows cause natives to specialize. Section 4.3 tests the effect of immigration on the aggregate supply of relative tasks across states (Proposition 2). Section 4.4 performs robustness checks by controlling for exogenous demand factors, and Section 4.5 quantifies the effects of immigration on the relative compensation of manual and interactive tasks (Proposition 3).

4.1 Immigrants' Relative Supply of Tasks

The aggregate data shown in Figure 2 confirm that the relative supply of manual versus interactive tasks by foreign-born workers in the US was larger than the relative supply among native workers in each census year since 1960. This tendency also characterizes the overwhelming majority of US states. Table 3 reports the percentage of US state-year observations satisfying the inequality $\frac{M_F}{I_F} > \frac{M_D}{I_D}$. Note that for the 28 observations in which foreign-born workers were less than 1% of less-educated employment, the small sample size (often 10 to 20 individuals) would lead to massive error in the construction of $\frac{M_F}{I_F}$. Therefore, we exclude these observations from our inequality checks.

The first column of Table 3 reports that $\frac{M_F}{I_F} > \frac{M_D}{I_D}$ for 80% of the state-year observations in which more than 1% of less-educated employment was foreign-born. In column 2 we consider only the 108 observations with at least 5% of immigrants among the less-educated workers; the inequality holds in 88% of the cases. Column 3 demonstrates that all states with at least 10% of immigrants among the less-educated satisfy the inequality. Columns 4, 5, and 6 check the inequality for the same groups as columns 1, 2, and 3, but consider only recent immigrants in the construction of relative task supply. The percentage of states satisfying the inequality is, respectively, 87%, 96% and 100%. On average, an individual state's immigrants work in occupations requiring relatively more manual tasks than natives do. This relationship is stronger for recent immigrants and in states with large immigrant populations.

Figure 4 plots the values of $\frac{M_F}{I_F}$ and $\frac{M_D}{I_D}$ for observations with more than 10% of immigrants among less-educated workers. Figure 5 shows the same variables when we only include recent immigrants in the calculation of M_F and I_F. All points lie above the 45°-line since each satisfies $\frac{M_F}{I_F} > \frac{M_D}{I_D}$. Moreover, we see that in some cases the relative supply $\frac{M_F}{I_F}$ for foreign-born workers is as much as 50% larger than the corresponding supply of natives. In the case of recent immigrants, the differences can be as large as 100%.

4.2 Immigration and the Response of Natives

The regressions in this section examine the relationship between less-educated immigrants and task supply of similarly educated native workers across states (s) and time (t). We begin with the test of Proposition 1 in Equation (23)

$$\ln\left(\frac{M_D}{I_D}\right)_{st} = \alpha_s + \tau_t + \gamma\left(Share\_foreign\_L\right)_{st} + \varepsilon_{st} \tag{23}$$

The relative supply of manual versus interactive tasks by less-educated native workers equals $\left(\frac{M_D}{I_D}\right)_{st}$, and $\left(Share\_foreign\_L\right)_{st}$ represents the foreign-born share of less-educated workers.[18] We control for year (τ_t) and state (α_s) fixed effects, and ε_{st} represents a non correlated zero-mean disturbance. If γ is negative and significant, then native-born workers respond to immigration by specializing in occupations less intense in manual versus interactive tasks, and Proposition 1 holds.

Empirically, we can go beyond the simple test of Proposition 1 and determine whether immigration has a stronger relationship with the average native-born supply of manual ($\overline{\mu}_D$) or interactive ($\overline{\iota}_D$) tasks.[19] In particular, we separately regress Equations (24) and (25). Since $\ln\left(\frac{M_D}{I_D}\right)_{st} = \ln\left(\overline{\mu}_D\right)_{st} - \ln\left(\overline{\iota}_D\right)_{st}$, it must be also true that $\gamma = \gamma^M - \gamma^I$.

$$\ln\left(\overline{\mu}_D\right)_{st} = \alpha_s^M + \tau_t^M + \gamma^M\left(Share\_foreign\_L\right)_{st} + \varepsilon_{st}^M \tag{24}$$

$$\ln\left(\overline{\iota}_D\right)_{st} = \alpha_s^I + \tau_t^I + \gamma^I\left(Share\_foreign\_L\right)_{st} + \varepsilon_{st}^I \tag{25}$$

Relationships uncovered by regressions of (23) could reflect demand characteristics (such as sector composition or technology) specific to state-year observations. Though we control more formally for sector and

[18] The foreign-born share was called s in Section 2. Here we use the more explicit $Share\_foreign\_L$ to avoid confusion with the subscript s indicating states.

[19] Recall that $\overline{\mu}_D = \frac{M_D}{L_D}$ and $\overline{\iota}_D = \frac{I_D}{L_D}$.

technological variables at the state level in Section 4.4, here we note that immigration should have a similar relationship with the relative task supply of foreign-born workers as it does with natives if results arise due to technological shocks. The specification in (26) tests this possibility by replacing $\frac{M_D}{I_D}$ with $\frac{M_F}{I_F}$.[20]

$$\ln\left(\frac{M_F}{I_F}\right)_{st} = \alpha_s^F + \tau_t^F + \gamma^F\left(Share\_foreign\_L\right)_{st} + \varepsilon_{st}^F \qquad (26)$$

Table 4 presents the least squares estimates of γ, γ^M, γ^I, and γ^F in the first through fourth rows, respectively, for different samples and variable definitions. Columns 1 through 3 use EHF and DCP variables obtained from the 1991 DOT. The first specification includes all less-educated workers to construct the aggregate state-year variables and weights each observation by its employment. Column 2, in contrast, includes only male workers. Column 3 returns to the full sample of workers, but does not weight the observations in the least square estimates. Columns 4 through 6 follow the same methodologies as columns 1-3, but use the 1977 DOT definitions. Finally, columns 7 to 9 use the 1977 DOT definitions for the 1960, 1970, and 1980 observations, and the 1991 DOT for 1990 and 2000.[21]

Three important results emerge. First, the estimates of γ uphold Proposition 1. The coefficients are negative, between -0.18 and -0.29, and always significantly different from 0. Most of the weighted least squares estimates (our preferred method since it accounts for the large variation in labor market size across states) are around -0.20 and are stable across specifications. Thus, a one percentage-point increase in the foreign-born share of less-educated workers is associated with a 0.2% decline in the relative supply of manual versus interactive tasks among natives. Second, this decrease is primarily achieved through a rise in the supply of interactive tasks, rather than a fall in natives' manual task supply. A large inflow of immigrants performing manual tasks is associated with increased demand for complementary interactive tasks provided by natives. Third, there is no systematic association between the foreign-born share and their relative supply of tasks. In the few instances where the estimate of γ^F is significant, it is also positive. Thus, state-specific demand factors are unlikely to generate the negative correlation captured by γ, as they would have similar effect on task intensity of immigrants.

4.2.1 Instrumental Variable Estimation

To argue that our estimates of γ represent the response of native supply to immigration (i.e. that the direction of causation goes from immigration to a change in native skill supply), we need to ensure that the cross-state variation of less-educated immigrants is driven by supply shifts. A particularly relevant concern is whether un-

[20] Note that the theoretical model implies that increases in f for a given relative ability of immigrants, $\overline{\left(\frac{m_F}{i_F}\right)}$, would generate $\gamma^F < 0$. However, an exogenous increase in f coupled with an exogenous increase in $\overline{\left(\frac{m_F}{i_F}\right)}$ (the scenario supported by the data presented in Section 4.1) would have no clear implications for γ^F, though γ would still be negative.

[21] This last merged definition captures the changes in task supply due to changes in employment across occupations as well as the change in task supply within occupations. Hence it is our preferred definition in our analysis.

observed technology and demand factors, which may differ across states due to variation in sector composition, have simultaneously increased the productivity (demand) of interactive tasks and attracted immigrants.[22] To establish causality, we use two sets of instruments that build upon the fact that Mexican immigration, documented and undocumented, has represented a large share of the increase in less-educated immigrants to the US beginning in the 1970s and becoming more prominent in the 1980s and 1990s. This inflow, independent of state-specific demand shocks, can be exploited as an exogenous supply shift as long as we can differentiate flows across states. Thus, our two sets of instruments are the imputed share of Mexican immigrants in a state and the state's proximity to the Mexico-US border.

Beginning with Card (2001), several studies[23] of immigration's effect on state or city economies have used instrumental variables 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.[24] Second, the countries of origin among foreign-born workers have changed drastically between 1960 and 2000. 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 less-educated workers. 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, Equation (27) imputes shares in year 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. 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 through 2000 and, due to the educational composition of this group, will have a larger immigrant share among less-educated workers.

$$\widehat{sh\_MEX}_{s,t} = sh\_MEX_{s,1960}\frac{(1+g\_MEX)_{1960-t}}{(1+g\_US)_{s,1960-t}} \tag{27}$$

Our second instrument also exploits the exogenous increase in Mexican immigration and measures the distance of a state from the US-Mexico border. First, we use the coordinates of the center of gravity for the popu-

[22]Note, however, that such an explanation conflicts with our finding that states attracting a larger share of immigrants do not attract immigrants who supply more interactive skills.
[23]Also see Cortes (2006), Lewis (2003), Ottaviano and Peri (2006), Peri (2007), and Saiz (2003).
[24]This is due to information networks between immigrants and their country of origin, as well as to the immigration policy of the US. A documented less-educated immigrant is most likely to come to the US to join a family member.

lation of each US state (calculated by the US Bureau of Census for year 2000 and available at www.census.gov). Then, using the formula for geodesic distance, we calculate the distance of each state center to the closest section of the US-Mexican Border in thousands of Kilometers.[25] Since we already control for state fixed effects in the regressions, we interact the distance variable with 4 year dummies (from 1970 to 2000). This captures the fact that distance from the border had a larger effect in predicting the inflow of less-educated workers in decades with larger Mexican immigration. The resulting set of instruments then includes the distance from the border and the distance squared, both interacted with decade dummies. We also use a US-Mexico border dummy interacted with decade dummies to capture the fact that border states had larger inflows of Mexican immigration due to undocumented border crossings. Since illegal immigrants are less mobile across states, border states have experienced a particularly large exogenous supply-driven increase of less-educated immigrant workers.

The rows of Table 5 report the respective two stage least squares estimates of γ, γ^M, γ^I, and γ^F. We use the merged DOT definition to construct the task supply variables and, in turn, use the imputed share of Mexicans, the distance from the border, and the border dummy as instruments.[26] Columns 1-3 use the imputed share of Mexicans as instruments. Column 1 weights the observations by employment, column 2 includes only male workers in constructing the task supply variables, and column 3 performs unweighted OLS. Columns 4-6 use the distance from the border and its square interacted with the decade dummies as instruments, and columns 7-9 use the border dummy interacted with decade dummies.

The last row of Table 5 reports the F-test of joint significance of the instruments in explaining the endogenous variable $Share\_foreign\_L_{st}$. Notice the remarkable explanatory power of the imputed share of Mexican workers (F-statistics larger than 20) and geographic instruments (border distance and border dummy) in the employment-weighted equations. When we do not weight observations by employment, the power of the border dummy decreases significantly. This is due to the relevance of California and Texas, border states and large recipients of Mexican immigrants and among the largest states, that are weighted heavily in WLS regressions.

The 2SLS estimates confirm the OLS results of Table 4. The estimates of γ are always negative and significant. They now range between -0.15 and -0.50 with WLS estimates clustering around -0.2. In the majority of the cases, natives respond to increases in the share of foreign-born workers by significantly raising interactive task supply. The supply of manual tasks experiences an insignificant decrease. Finally, the correlation between immigration and foreign-born relative task supply is never significantly different from 0.

[25] We divide the US-Mexico border in 12 sections and calcualte the distance of each center of gravity with each section and then choose the shortest distance for each state.

[26] We also performed separate regressions exclusively using the DOT 1977 definition and the DOT 1991 definition. Each generated very similar estimates.

4.2.2 Robustness Checks and Response of Specific Groups of Native Workers

Table 6 tests the robustness of the 2SLS estimates and performs a test of exogeneity of the instruments. In particular, using the same specification as in column 1 of Table 5, the first four columns of Table 6 demonstrate how the estimates of γ, γ^M, and γ^I vary from least square estimates, to 2SLS using only imputed Mexicans as instrument (column 2), to using the geographic variables (distance and border interacted with decades), to using all of the instruments together (column 4). Specifications 5 to 8 replicate 1 to 4 but redefine less-educated workers as those with no high school diploma. The last three rows of the table report the F-test of joint significance of the instruments and the Hausman test of over-identifying restrictions that can be performed when we use more instruments than endogenous variables (columns 3, 4, 7, and 8).[27] The value reported in the second to last row is the Chi-squared test statistic under the null hypothesis that none of the instruments appear in the second stage regression. The degrees of freedom are given by the difference between the number of instruments and endogenous variables (this equals 7 in columns 3 and 7, and 8 in columns 4 and 8). The last row reports the probability of obtaining the observed value of the test statistic or higher under the null. We cannot reject the null at any level of significance, so the assumption of instrument exogeneity stands.

More importantly, the point-estimates of γ using the 2SLS method with all instruments are quite precise, not far from the OLS estimates, and significantly negative. Regardless of the definition of less-educated workers, we obtain 2SLS estimates using all instruments that are close to -0.2 (-0.22 and -0.23 respectively). The estimates with geographic instruments and those using all instruments together confirm that increased immigration produces a significant increase in interactive task supply and a less significant (often insignificant) decrease of manual task supply by natives. Reassured by the test of exogeneity and by the stability of the IV estimates, we will mostly use the geographic instruments and all instruments together in the rest of the paper.

Distributional and policy concerns often push the analysis of immigration toward its effect on specific demographic groups. It is important to understand how specific native-born age-education groups respond to immigration. Groups who specialize in interactive task-intensive occupations are better equipped to mitigate wage losses. Thus, analysis of specific groups will identify those who are at a greater risk of experiencing wage losses.

Table 7 reports estimates of γ from regression (23) for specific sub-groups of less-educated natives using 2SLS method and all the instruments together. The first three columns separate workers into three education groups (those with 0 to 4, 5 to 9, and 9 to 12 years of schooling) and two age groups (25 to 45 and 46 to 65 years old). The supply-response of natives to immigrants is large and significant for people with 9 to 12 years of education in each age sub-group. This education cohort comprised 95% of US-born workers with a high school degree or less in 2000. The intermediate group of native workers with 5 to 8 years of education also responded

[27] See Woolridge (2002).

by shifting supply to more interactive-intensive occupations. While γ for workers of all ages is close to 0.2, it is not very significant. However, γ is significant for younger workers. The group of least educated workers (0 to 4 years) does not seem to respond to immigration, however they only represent 0.5% of native workers with at most a high school diploma. Altogether, analysis of narrowly defined education and age groups reveals that most groups of native workers respond to immigration by changing their task supply.

Similarly, women have an estimated γ (reported in the last column) very similar to the value estimated for all workers (-0.22). The estimate is larger in absolute value for older (-0.46) than younger (-0.12) workers. Columns 4 reports the task supply response of less-educated native-born black workers. Previous research has emphasized a disproportionate effect of immigration on labor market outcomes of black Americans (e.g. Borjas et. al. (2006)). Interestingly, while black Americans seem to have reduced their relative supply of manual tasks in response to immigration ($\gamma = -0.16$), the estimate is not significant (standard error of 0.29). By disaggregating the effects over age groups, we see that young black workers particularly did not respond to immigration by supplying interactive tasks. Certainly, this result would imply a higher risk of competition of immigration on wages paid to black Americans.

4.2.3 Native Employment Response

The native task supply response to immigration is identified using data on working individuals in each state-year. An alternative response mechanism could be that natives lose or quit their jobs, or possibly leave their state of employment entirely. In the long run, we expect competitive labor markets will cause wages to adjust to full employment. Several studies of this displacement effect at the state or city level fail to find evidence for its existence.[28] Nonetheless, we must analyze the less-educated native-born employment and working age population $(L)_{st}$ response for completeness. Consider the regression specification in (28).

$$\ln(L)_{st} = \alpha_s^L + \tau_t^L + \eta\,(Share\_foreign\_L_{st}) + \varepsilon_{st}^L \tag{28}$$

Table 8 reports the estimates of η using both employment (columns 1 to 4) and the working age population (columns 5 to 9) to measure the dependent variable $(L)_{st}$. In the first row of Table 8 we consider all less-educated individuals. In the second and third row we consider the effect of immigration by age-group. As workers with similar education and age characteristics are more likely to compete for similar jobs, the impact of immigrants by demographic group can be larger than the overall effect. Columns 1, 2, 5 and 6 display WLS results (with employment weighted observations), while 3, 4, 7 and 8 use 2SLS using all instrumental variables together. Finally we alternatively use workers with no high school degree (columns 1, 3, 5 and 7) and workers with at most an high school degree (Columns 2, 4, 6 and 8) to define less-educated workers. The reported standard

[28] See Card (2001, 2007), Card and Lewis (2007), Ottaviano and Peri (2007) and Peri (2007).

errors are heteroskedasticity robust and are clustered by state. Regardless of the definition of less-educated workers, the method of estimation, or the age group considered, we find no significant effect of immigration on the employment and population of native workers. The estimates of η are not very precise (generally smaller than 0.4 in absolute value), often positive, and never significantly less than zero. Overall, these estimates confirm the results already found in the literature – there is no systematic displacement of native workers through job losses or out of state migration due to immigration. Instead, previous sections showed that immigration causes native workers to systematically reallocate their task supply toward interactive skills.

4.3 Immigration and Total Task Supply

The regression specification in (29) provides a test of Proposition 2, which states that the total relative supply of manual versus interactive tasks is larger in economies with a larger share of immigrants. That is, the higher relative task supply among immigrants more than compensates for the reduced supply among natives.

$$\ln\left(\frac{M}{I}\right)_{st} = \alpha_s^{TOT} + \tau_t^{TOT} + \gamma_{TOT}\left(Share\_foreign\_L_{st}\right) + \varepsilon_{st}^{TOT} \qquad (29)$$

We obtain $\left(\frac{M}{I}\right)_{st}$ by aggregating the supply of manual and interactive tasks from all less-educated workers in state s and year t. Proposition 2 implies that $\gamma_{TOT} > 0$. However, we can also test how immigration affects the average amount of manual ($\overline{\mu}$) and interactive ($\overline{\iota}$) tasks supplied in equilibrium by running two separate regressions, similar to (29), with $\ln(\overline{\mu})_{st}$ and $\ln(\overline{\iota})_{st}$ as dependent variables. Analogous to the specifications in (24) and (25), we call these coefficients γ_{TOT}^{M} and γ_{TOT}^{I}.

The first three rows of Table 9 show the parameter estimates of γ_{TOT}, γ_{TOT}^{M}, and γ_{TOT}^{I}. The last three rows show the F-test of significance for the instruments in the first stage and the test of over-identifying restrictions. Results for workers with a high school degree or less are in columns 1 to 4; columns 5 to 9 are for high school dropouts. Each 2SLS regression exhibits positive and significant estimates of γ_{TOT}, confirming the prediction of Proposition 2. For workers with high school degree or less, γ_{TOT} is estimated around 0.3. This arises due to a large increase in the average supply of manual tasks due to to immigration ($\gamma_{TOT}^{M} = 0.21$) and a small decline in interactive task supply ($\gamma_{TOT}^{I} = -0.08$). Hence, states with large inflows of less-educated immigrants experience significant increases in manual relative to interactive task supply as predicted by theory.

4.4 Controlling for Task Demand and Technological Change

Our period of analysis is associated with large changes in production technologies, particularly in the diffusion of information technologies and computer adoption. Autor, Levy, and Murnane (2003) demonstrate that this change had a large effect in shifting demand from routine tasks to non-routine tasks. Similarly, the increasing importance of advanced services, the demise of manufacturing, and other sector-shifts might have contributed substantially to differences across states in the demand for manual and interactive tasks. In this section we explicitly introduce controls for a state's technology level and sector composition that may have confounded the correlation between immigration and task intensity in our prior analysis.

We begin by including the share of workers (with at most a high school degree) who use a computer at work to control for the diffusion of information technology (IT) across states. This data is available in the 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 all states in 1970 and 1960 since the PC was first introduced in 1981.

The estimates reported in columns 1 and 4 of Table 10 are obtained with 2SLS using all instruments and weighting observations by their corresponding employment. First, the effect of immigration on the relative task supply of natives (-0.3) remains negative and significant (column 1), while the effect on aggregate relative task supply (0.21) is still positive and significant (column 4). Second, computer technology reduces relative task supply as predicted, since computers decreased the relative productivity of manual versus interactive tasks. The IT variable, interpretable as a decrease in the parameter β_L in the theoretical model, has the same effect on equilibrium task supply among natives and immigrants.

Our second control accounts more explicitly for the industrial composition of each state in 1960 and its effect on task demand. We create state-specific indices of manual versus interactive task demand driven by each state's industrial composition, $\left(\frac{M}{I}\right)^{Tech}$, by assuming that the occupational composition of industries and industry-specific employment shocks are uniform across states. First, we calculate EHF_{it} and DCP_{it} values among all workers for each industry i in year t from national data and record the corresponding ratio $\left(\frac{M}{I}\right)_{i,t}$. Next, we calculate industry-level national employment growth since 1960, $g_{i,t}$. By assuming that industries grew at their national growth rates regardless of the state in which they are located, we can predict the employment share of industries within each state in each census year, $\widehat{EmpShare}_{i,s,t}$. Finally, we calculate a state's level of relative task demand, $\left(\frac{M}{I}\right)^{Tech}$, as the average value of its industries' $\left(\frac{M}{I}\right)_{it}$, weighted by their predicted employment shares.

$$\widehat{EmpShare}_{i,s,t} = \frac{EmpShare_{i,s,1960} \cdot (1 + g_{i,t})}{\sum_{i=1}^{Ind} EmpShare_{i,s,1960} \cdot (1 + g_{i,t})} \tag{30}$$

$$\left(\frac{M}{I}\right)_{s,t}^{Tech} = \sum_{i=1}^{Ind} \widehat{EmpShare}_{i,s,1960} \cdot \left(\frac{M}{I}\right)_{i,t} \tag{31}$$

Specifications 2 and 4 of Table 10 include $ln\left(\frac{M}{I}\right)_{s,t}^{Tech}$ as a control for sector-driven changes in task intensity. Columns 3 and 6 include both $ln\left(\frac{M}{I}\right)_{s,t}^{Tech}$ and the computer use variable. When included by itself, the variable has very significant explanatory power but does not change the coefficient on the share of less-educated foreign-born workers. When included with the IT control, immigration's effect on the relative task supply of natives becomes much larger in magnitude (-0.42), while the overall effect (0.08) is reduced in size and significance. Regressions also indicate that immigration increases native-born interactive task supply, and reduces native-born manual task supply. In the aggregate, states with large immigrant shares have larger manual task supply, but interactive tasks remain unaffected.

4.5 Immigration and the Relative Compensation of Tasks

Proposition 3 suggests that by increasing the relative supply of manual tasks in a state, immigrants decrease the wage paid to manual tasks relative to interactive ones. In this section, we proceed to estimate the effect of immigration on the relative wages paid to tasks. The task demand function in Equation (3) for state s during year t implies that Equation (32) describes the relationship between the relative supply of manual versus interactive tasks among less-educated workers ($\frac{M}{I}$) and the relative wage paid for these skills ($\frac{w_M}{w_I}$).

$$\ln\left(\frac{w_M}{w_I}\right)_{st} = \ln\left(\frac{\beta_L}{1-\beta_L}\right)_{st} - \frac{1}{\theta_L}\ln\left(\frac{M}{I}\right)_{st} \tag{32}$$

We allow relative productivity (β_L) to vary systematically across states (due to differences in industrial 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 across states can identify the coefficient $\frac{1}{\theta_L}$, where θ_L represents the elasticity of substitution between the tasks. Hence we estimate Equation (33) using two stage least squares. Exogenous shifts in the share of foreign-born workers will affect the aggregate relative supply of skills. Hence, we can estimate $\frac{1}{\theta_L}$ by employing the share of foreign-born workers as instrument for $\frac{M}{I}$.

$$\ln\left(\frac{w_M}{w_I}\right)_{st} = \alpha_s + \tau_t - \frac{1}{\theta_L}\ln\left(\frac{M}{I}\right)_{st} + \varepsilon_{st} \tag{33}$$

While we calculated $\frac{M}{I}$ in the previous sections by state, aggregation of the individual supply of manual (EHF) and interactive (DCP) tasks for the labor force prohibits direct observation of the relative wage $\frac{w_M}{w_I}$. However, the IPUMS data contains individual-level information on wages and other characteristics that we can merge with an individual's supply of EHF and DCP. Measurement of w_M and w_I 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[29] on indicator variables for the

[29] 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.

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).[30] The residuals of these regressions represent individual wages after controlling for personal characteristics, which we label $\ln(wage\_clean)_{ist}$ 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 EHF and DCP using weighted least squares. We allow the coefficients on these skill variables 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 (34) for each year, we can identify the state and year-specific wages received for supplying manual $(w_{ML})_{st}$ and interactive $(w_{IL})_{st}$ tasks.

$$wage\_clean_{ist} = (w_M)_{st} * EHF_{ist} + (w_I)_{st} DCP_{ist} + \varepsilon_{ist} \tag{34}$$

Next, we substitute the estimates $\widehat{w_M}_{st}$ and $\widehat{w_I}_{st}$ into Equation (33) to estimate $\frac{1}{\theta_L}$. Table 11 reports the results for different DOT definitions (1991, 1977, and merged) as in Table 4. Columns 1, 4, and 7 report the estimates of $\frac{1}{\theta_L}$ when we exploit the result of Proposition 2 and directly use $Share\_foreign\_L_{st}$ as an instrument for $\ln\left(\frac{M_L}{I_L}\right)_{st}$. The instrument is relatively powerful (F-statistic of 14), and we obtain estimates statistically significant at the 10 or 5% level between 1.3 and 1.45.

To address the concerns that also $Share\_foreign\_L_{st}$ could be endogenous, we also instrument $\ln\left(\frac{M_L}{I_L}\right)_{st}$ with our geographic instruments in columns 2, 5, and 8. The specifications in 3, 6, and 9 use the geographic IVs and the imputed share of Mexicans. Unfortunately, the instruments are quite weak (F-statistics near 4) when used to predict $\ln\left(\frac{M}{I}\right)_{st}$, so the standard errors increase and the significance of the estimates decreases. However, the point estimates of $\frac{1}{\theta_L}$ remain consistently around one.

The 2SLS estimates using $Share\_foreign\_L_{st}$ as an instrument imply that the share of foreign-born workers reduces the relative compensation paid to manual tasks, thus confirming Proposition 3. This arises due to the positive impact of $Share\_foreign\_L_{st}$ on $\ln\left(\frac{M}{I}\right)_{st}$ and the negative and significant value of $-\frac{1}{\theta_L}$. The range of point estimates in Table 11 suggest the elasticity of substitution (θ_L) ranges between 0.7 and 1.1. Even assuming the largest estimate (1.1), manual and interactive tasks have a high degree of complementarity. These figures are comparable to commonly estimated values for the elasticity of substitution between less and more educated workers (σ) available in the literature, which fall between 1.5 and 2.[31]

[30] We also weight each individual by its Census sample weight.
[31] See Katz and Murphy (1992) or Angrist (1995).

5 Simulated Effects of Immigration on Real Wages

Our empirical analysis suggests that to understand the wage implications of immigration, simulations must account for the adjustment in native-born task supply. We do so by combining the formulas derived in Section 2 with the estimated response of $\overline{\mu}_D$ and $\overline{\iota}_D$ to immigration from Section 4.2 and the elasticity (θ_L) from Section 4.5. First, we use Equations (15), (17) and (18) and the changes in H, M, and I due to immigration between 1990 and 2000 to evaluate the effects of immigration on compensation paid to highly-educated workers, manual tasks, and interactive tasks. Then we combine those results with Equation (20) to find the overall effect of immigration on average wages paid to less-educated native workers.

The simulated effect of immigrants on average wages paid to less-educated native workers differs from the effect on average overall wages of less-educated workers $\left(\frac{\Delta \overline{W}_L}{\overline{W}_L}\right)$ for two reasons. First, the change in compensation paid to interactive tasks $\left(\frac{\Delta w_I}{w_I}\right)$ is weighted more heavily, and the change in compensation paid to manual tasks $\left(\frac{\Delta w_M}{w_M}\right)$ less heavily, for natives. Since immigrants supply more manual tasks, we know that $\frac{\Delta M}{M} > \frac{\Delta I}{I}$. This implies $\frac{\Delta w_M}{w_M}$ (which is usually negative) is smaller than $\frac{\Delta w_I}{w_I}$ (which is positive for some states). Hence, the large wage loss from manual tasks is weighted less in occupations chosen by natives. This attenuation grows larger if natives increasingly specialize in interactive tasks, and is much stronger in high immigration states.

Second, the empirical results suggest the term $(\Delta\overline{\mu_D})\,\frac{w_M}{\overline{W}_D} + (\Delta\overline{\iota_D})\,\frac{w_I}{\overline{W}_D}$ in Equation (20) also positively contributes to the average wage of natives. On one hand, immigration increases $\Delta\overline{\iota_D}$ and reduces $\Delta\overline{\mu_D}$. Unit compensation for manual tasks $\left(\frac{w_M}{\overline{W}_D}\right)$ was 10 to 20 percent smaller than unit compensation for interactive tasks $\left(\frac{w_I}{\overline{W}_D}\right)$ in 1990 and 2000.[32] Moreover, this differential was larger in high immigration states so that immigration shifted workers to occupations whose tasks were better compensated. On the other hand, the estimates from Tables 4 and 6 imply that the positive impact of immigration on $\Delta\overline{\iota_D}$ was generally larger than the negative impact on $\Delta\overline{\mu_D}$. Hence, higher demand for complementary services also had a positive effect on average wages, shifting natives to jobs with higher interactive content.

Table 12 reports the simulated effects of immigration from 1990-2000 at the national level and for states with unusually high levels of immigration. The first two columns report the increase in employment due to immigration as percentage of 1990 employment. Columns 1 and 2 consider workers with some college education $\left(\frac{\Delta H}{H}\right)$ and those with high school degree or less $\left(\frac{\Delta L}{L}\right)$, respectively. Notice that for each reported state (except New York) the percentage inflow of less-educated immigrants was larger than the inflow of more-educated ones. For Arizona, Massachusetts, and Texas the inflow of less-educated was almost four times that of more-educated workers.

[32] The estimates of $\widehat{w_M}$ and $\widehat{w_I}$ were obtained in Section 4.5 and are used in this section to calculate the shares of M and I in wages paid to less educated workers, as well as the ratios $\frac{w_I}{\overline{W}_D}$ and $\frac{w_M}{\overline{W}_D}$.

Columns 3 and 4 show the percentage change in the equilibrium supply of manual $\left(\frac{\Delta M}{M}\right)$and interactive $\left(\frac{\Delta I}{I}\right)$ tasks due to immigration. These figures are calculated by multiplying the average task-supply of immigrants by the inflow of less-educated immigrants, and then dividing by the total task supply in 1990. In each state considered, the percentage supply of manual tasks increased more than the supply of interactive tasks did. This confirms that immigrants specialized in manual-intensive occupations.

The following three columns (5, 6, and 7) apply the formulas (15), (17), and (18) to report the percentage changes in wages paid to highly-educated workers $\left(\frac{\Delta \overline{W}_H}{\overline{W}_H}\right)$ and the compensation paid to manual $\left(\frac{\Delta w_M}{w_M}\right)$ and interactive $\left(\frac{\Delta w_I}{w_I}\right)$ tasks. We assume a value of $\sigma = 1.75$ that is in the middle of the range usually estimated in the literature (1.5 to 2). We also set $\theta_L = 1$, a value implying that skills are more substitutable than most of our estimates find.

Column 5 reports the percentage wage change of highly-educated American workers due to immigration. Since the inflow of highly-educated immigrants was small relative to the inflow of less-educated ones, the wage effect on people with high education is usually positive (a gain of 1.3% at the national level).

The change in wages paid to manual versus interactive tasks (columns 6 and 7) is clearly more important for understanding the effects of immigration on less-educated workers. In Nevada, the compensation of manual tasks performed by less-educated workers decreased by 5.2%, while the compensation of interactive tasks performed by the same group increased by 0.5%. In Arizona, compensation for manual tasks decreased by almost 14%, while compensation for interactive tasks only decreased 4.6%.

Column 8 reports the resulting effect on the change in average wages paid to less-educated labor before accounting for any shift in domestic task supply $\left(\frac{\Delta \overline{W}_L}{\overline{W}_L}\right)$. That is, these figures are useful for identifying the counter-factual wage effects for less-educated native workers that are identified by models with perfect substitutability between native and foreign-born workers. Column 9, by comparison, reports the actual simulated effects of immigration on less-educated natives that account for the reallocation of tasks following immigration $\left(\frac{\Delta \overline{W}_D}{\overline{W}_D}\right)$. To calculate these figures, we use the formula in (20). We then compute the values of $\Delta \overline{\iota_D}$ and $\Delta \overline{\mu_D}$ by multiplying the change in the foreign-born share of each state between 1990 and 2000 by the average response of interactive and manual task supply to immigration from columns 1-4 of Table 6 (respectively +0.13 and -0.06). The resulting values are elasticities that, when multiplied by their initial values, equal $\Delta \overline{\iota_D}$ and $\Delta \overline{\mu_D}$.

Comparison of columns 8 and 9 highlights the most important feature of Table 12. Together they provide the difference in wage effects estimated using a simple model of homogeneous labor versus our model of comparative advantage. At the national level, specialization reduces the wage loss of less-educated native workers by about one percentage point (from -2.4% to -1.5%). In states with large immigration such as California or Arizona, task reallocation reduces the wage loss by more than three percentage points. Specialization completely eliminates the wage losses in California. Except for Arizona (whose less-educated workers experience a 5.6% wage loss), no state witnessed wage losses exceeding 2.1%. By specializing in interactive skill-intense occupations, less-educated natives reduce wage losses by two to three percentage points in many high immigration states, and one percentage point overall.

Finally the last two columns demonstrate how state-level averages still conceal a large degree of variation in wage effects across occupations. Column 10 shows the wage effect of immigration on a postal clerk with high school education or less. This is a job with relatively high interactive task intensity and low manual task intensity. In contrast, column 11 shows the effect of immigration on wages of hand packers, an occupation with relatively high manual task requirements. Occupational choice makes a huge difference in determining the wage losses in states with high immigration. In Texas, a hand packer would have suffered a 5% wage loss due to immigration, while a postal clerk would have suffered only half that effect. In Florida, the postal clerk would have actually gained 0.5% of her real wage, but the hand packer would have lost 0.8% of hers. At the national level, postal clerks only experienced a 1.2% wage decline, while hand packers lost 3.4%. In sum, less-educated natives protected themselves from most of the negative wage effects of immigration first because they have typically chosen jobs more similar to postal clerks than hand packers, and second because immigration pushed them to seek such occupations at higher rates.

6 Conclusions

The effects of immigration on wages paid to native-born workers with low levels of educational attainment 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 in performing particular productive tasks. The second is whether US-born workers respond to immigration and adjust their occupation choices to shield themselves from competition with immigrant labor.

This paper provides a simple and new theoretical framework and empirical evidence to analyze these 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 of similar levels of education have a comparative advantage in interactive and language-intensive tasks. Native and foreign-born workers specialize accordingly. When immigration generates large increases in manual task supply, the relative compensation paid to interactive tasks rises, thereby rewarding natives who progressively move to interactive-intensive jobs.

Our empirical analysis modified 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.

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 versus interactive tasks.

iii) In states with large immigration among the less-educated labor force, there is a larger relative supply of manual versus interactive tasks than in states with low levels of immigration. This implies that immigrants more than compensate for the change in 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 occupations demanding interactive tasks, the relative supply of interactive tasks by the average US-born worker has increased significantly in the recent decades. As a consequence, the wage loss of less-educated native workers in states with large immigration was much smaller than predicted by models in which the labor supplied by less-educated natives and immigrants is perfectly substitutable. In particular, we estimate that immigration of less-educated workers only reduced average real wages paid to less-educated US-born workers by 1.5% between 1990 and 2000. Without task specialization, that loss would have equaled 2.5%.

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A Appendix - Derivation of Equations from Section 2

A.1 Equations from Section 2.1

Competitive labor markets and producers of Y_L and Y_H generate equilibrium conditions for relative input prices and task compensation. By equating the marginal productivity of intermediate goods to their prices, we find the relationship between the relative price of intermediate goods and their relative demand in Equation (35). Equating the productivity of each task to its compensation produces Equation (3).

$$\frac{P_H}{P_L} = \frac{(1-\beta)}{\beta}\left(\frac{H}{Y_L}\right)^{-\frac{1}{\sigma}} \tag{35}$$

A.2 Equations from Section 2.2

Maximization of $W_{L,j}$ with respect to l_j in Equation (4) generates the optimal relative allocation of labor for worker j in Equation (36). By rearranging the definitions of unit-task supply and substituting them into this expression, we can identify an individual's equilibrium relative supply of task units in Equation (5).

$$\frac{l_j}{1-l_j} = \left(\frac{i_j w_I}{m_j w_M}\right)^{\frac{1}{\delta-1}} \tag{36}$$

A.3 Equations from Section 2.3

The equilibrium relative compensation of tasks (12) is obtained by substituting (6) for domestic and foreign workers into (11), and then equating it with the demand curve (3). Intuitively, this is the wage obtained when the average manual versus interactive task effectiveness of the population equals $\left[f\overline{\left(\frac{m_F}{i_F}\right)^{\frac{1}{1-\delta}}} + (1-f)\overline{\left(\frac{m_D}{i_D}\right)^{\frac{1}{1-\delta}}}\right]^{(1-\delta)}$.

A.4 Equations from Section 2.4

To isolate the effect of immigration on wages, first substitute (2) into the production function (1) and take the derivative with respect to the inputs M, I, and H to obtain their marginal products.

$$w_M = (\beta_L\beta)\, Y^{\frac{1}{\sigma}} Y_L^{\left(\frac{1}{\theta_L}-\frac{1}{\sigma}\right)} M^{-\frac{1}{\theta_L}} \tag{37}$$

$$w_I = (1-\beta_L)\beta Y^{\frac{1}{\sigma}} Y_L^{\left(\frac{1}{\theta_L}-\frac{1}{\sigma}\right)} I^{-\frac{1}{\theta_L}} \tag{38}$$

$$W_H = P_H = (1-\beta) Y^{\frac{1}{\sigma}} Y_H^{-\frac{1}{\sigma}} \tag{39}$$

Highly-educated workers earn the unit price of the intermediate good they produce. The logarithmic differential of (39) directly measures immigration's effect on highly-educated workers as expressed in (15).

Wages paid to less-educated workers are divided into their manual and interactive components. The first order effect of immigration is equal to the percentage change in the intermediate good price P_L. Values for $\left(\frac{\Delta w_M}{w_M}\right)$ and $\left(\frac{\Delta w_I}{w_I}\right)$ can be obtained from logarithmic differentials of (37) and (38).

Note that (19) represents the average manual and interactive wage effects weighted by their respective supplies. Thus, we can express the first order wage effect for less-educated workers by substituting Equations (17) and (18) for $\frac{\Delta w_M}{w_M}$ and $\frac{\Delta w_I}{w_I}$ and simplifying to obtain Equation (16).[33] Calculations of the effect of immigration on the average native-born less-educated worker (20) and of a worker in occupation j (21) are then described in the main text.

Derivation of $\frac{\Delta Y_L}{Y_L}$ requires several steps. First, since Y_L is produced under perfect competition using services of less-educated workers, we know that the total income generated in sector Y_L will be distributed to less-educated workers as in Equation (40).

$$P_L Y_L = \overline{W}_L L = w_M M + w_I I \tag{40}$$

This allows us to relate changes in the production of Y_L to small changes of inputs M and I as in Equation (22). The formal proof hinges only on constant returns to scale to M and I in (2). First, re-write Equation (22) by dividing by $P_L Y_L$. Then take the total differential with respect to M and I to find Equation (41).

$$\frac{dY_L}{Y_L} = \frac{d(\frac{w_M}{P_L}\frac{M}{Y_L} + \frac{w_I}{P_L}\frac{I}{Y_L})}{dM}dM + \frac{d(\frac{w_M}{P_L}\frac{M}{Y_L} + \frac{w_I}{P_L}\frac{I}{Y_L})}{dI}dI \tag{41}$$

From the definition of wages we know that $\frac{w_M}{P_L} = \frac{dY_L}{dM}$ and $\frac{w_I}{P_L} = \frac{dY_L}{dI}$. Distributing the differentiation with respect to M and I we can re-write (41) as in (42).

$$\frac{dY_L}{Y_L} = \frac{w_M M}{P_L Y_L}\frac{dM}{M} + \frac{w_I I}{P_L Y_L}\frac{dI}{I} + \left[\frac{d(\frac{dY_L}{dM})}{dM}\frac{M}{Y_L} + \frac{d(\frac{dY_L}{dI})}{dM}\frac{I}{Y_L}\right]dM + \left[\frac{d(\frac{dY_L}{dM})}{dI}\frac{M}{Y_L} + \frac{d(\frac{dY_L}{dI})}{dI}\frac{I}{Y_L}\right]dI \tag{42}$$

Due to constant returns to scale of M and I in Y_L, the expression $\frac{dY_L}{dM}\frac{M}{Y_L} + \frac{dY_L}{dI}\frac{I}{Y_L}$ equals one (Euler Condition). Constant returns also imply that the second derivatives (with respect to M or I), multiplied by the shares $\frac{M}{Y_L}$ and $\frac{I}{Y_L}$, sum to 0. Hence the two terms in brackets equal 0 so that (41) reduces to (43).

$$\frac{dY_L}{Y_L} = \frac{w_M M}{P_L Y_L}\frac{dM}{M} + \frac{w_I I}{P_L Y_L}\frac{dI}{I} \tag{43}$$

Finally, we label the term $\frac{w_M M}{P_L Y_L} = \frac{w_M M}{\overline{W}_L L}$ as $\varkappa_M$, and $\frac{w_I I}{P_L Y_L} = \frac{w_I I}{\overline{W}_L L}$ as $(1 - \varkappa_M)$. We then use Δ, rather than d, to indicate a small (rather than an infinitesimal) change to obtain equation (22).

[33]This can be checked by taking the total logarithmic differential of $P_L = \beta Y^{\frac{1}{\sigma}} Y_L^{-\frac{1}{\sigma}}$ with respect to $\frac{\Delta Y_L}{Y_L}$ and $\frac{\Delta H}{H}$.

Tables and Figures

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

	1960	**1970**	**1980**	**1990**	**2000**
Occupation	Male Hucksters, Peddlers, and Salesmen	Female Waitresses	Female Bank Tellers	Male Guards and Private Police	Male Janitors and Cleaners
DCP (Interactive Measure)	0.50	0.53	0.59	0.61	0.62
Occupation	Male Shoemakers	Male Job and Die Setters	Female Secondary School Teachers	Male Food Service and Lodging Managers	Male Food Service and Lodging Managers
EHF (Manual Measure)	0.50	0.49	0.35	0.33	0.33

Note: The variables DCP and EHF are based on the scores assigned to each occupation by the Dictionary of Occupational Titles (DOT) in 1977 for 1960, 1970, and 1980, and the scores assigned by the DOT in 1991 for 1990 and 2000. They are converted into percentile scores using the 1960 distribution so that median values equal 0.5 in 1960 by construction.

Table 2:
Relative Manual and Interactive Task Requirements
and the Percentage of Foreign-Born Workers in Selected Occupations, 2000, High School Diploma or Less

Occupation	% of Foreign-Born Workers, 2000	Relative Manual Tasks: EHF/(DCP+EHF)	Relative Interactive Tasks: DCP/(DCP+EHF)	Manual/ Interactive
		Agricultural Sector		
Agricultural Laborer	63%	0.72	0.28	2.5
Farm Coordinator	4%	0.30	0.70	0.43
		Construction Sector		
Construction Helper	66%	0.97	0.03	43
Construction Supervisor	8%	0.31	0.69	0.44
		Postal Services		
Mail Handling-Machine Operator	48%	0.94	0.06	17.5
Mail Clerk/ Deliverer	7%	0.14	0.86	0.17
		Food Preparation		
Miscellaneous Food Preparation	33%	0.56	0.44	1.63
Supervisor Food Preparation	14%	0.36	0.64	0.58
		Transportation Services		
Taxi Driver	40%	0.98	0.02	49.5
Supervisor, Motor Vehicle Operators	10%	0.31	0.67	0.45

Note: Occupations are defined by the Census. Data for the year 2000 are obtained averaging the CPS samples for 1998, 1999 and 2000 as described in the text. The indices EHF and DCP are those obtained using the 1991 DOT definitions.

Table 3
Share of State-Year Observations in which Manual/Interactive Task Supply for Immigrants is Larger than for Native-Born Workers

Sample:	State-Year Observations with Share of Less-Educated Immigrants >1%	State-Year Observations with Share of Less-Educated Immigrants >5%	State-Year Observations with Share of Less-Educated Immigrants >10%	State-Year Observations with Share of Less-Educated Immigrants >1%	State-Year Observations with Share of Less-Educated Immigrants >5%	State-Year Observations with Share of Less-Educated Immigrants >10%
	Relative Task Supply Calculated for all Less-Educated Immigrants			Relative Task Supply Calculated for Less-Educated New Immigrants (Less than 10 Years in the US)		
Percentage of State-Year Observations for which $(M_F/I_F) > (M_D/I_D)$	80%	88%	100%	87%	96%	100%
Total Number of State-Year Observations	227	108	55	227	108	55

Note For the few state-year observations in which the foreign-born share of less-educated employment was smaller than 1%, the calculation of relative task supply is noisy and unreliable because it is based on a very small sample. The relative supply of tasks for native, foreign-born, and recent immigrants equals EHF/DCP. The indices EHF and DCP are obtained using the 1977 DOT definition for 1960, 1970 and 1980 and the 1991 DOT definition for 1990 and 2000.

Table 4
Impact of Foreign-Born Workers on the Supply of Tasks of US Natives, Least Squares Estimates
Workers with a High School Degree or Less

Explanatory Variable: Foreign-Born Share of Workers with a High School Degree or Less										
DOT Definition:		1991 DOT			1977 DOT			Merged DOT		
Dependent Variable	Parameter	(1) Basic	(2) Males Only	(3) Non-Weighted	(4) Basic	(5) Males Only	(6) Non-Weighted	(7) Basic	(8) Males Only	(9) Non-Weighted
Domestic Workers	γ	-0.18**	-0.18**	-0.26**	-0.19**	-0.19**	-0.27**	-0.21**	-0.21**	-0.29**
$Ln(M_D/I_D)$		(0.05)	(0.07)	(0.09)	(0.04)	(0.07)	(0.09)	(0.05)	(0.07)	(0.09)
Domestic Workers	γ^M	-0.01	0.00	-0.01	0.00	0.01	0.02	-0.02	-0.01	-0.03
$Ln(\bar{\mu}_D)$		(0.03)	(0.03)	(0.07)	(0.03)	(0.03)	(0.07)	(0.03)	(0.02)	(0.07)
Domestic Workers	γ^I	0.17**	0.18**	0.26**	0.19**	0.20**	0.29**	0.18**	0.20**	0.27**
$Ln(\bar{\iota}_D)$		(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)
Foreign Workers	γ^F	0.21	0.09	0.69**	0.20	0.06	0.78**	0.19	0.05	0.69**
$Ln(M_F/I_F)$		(0.18)	(0.17)	(0.33)	(0.18)	(0.19)	(0.35)	(0.17)	(0.07)	(0.33)
Number of Observations		255	255	255	255	255	255	255	255	255

Note: Each cell contains estimates from separate regressions. The dependent variable in each is indicated in the first column. The explanatory variable is the foreign-born share of less-educated workers. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is least squares. In specifications (1), (2), (4), (5), (7) and (8) we weight observations by employment, and the standard errors are heteroskedasticity-robust and clustered by state. In specifications (3), (6) and (9) we perform unweighted OLS with heteroskedasticity-robust standard errors. In Specifications (1)-(3) the task supply is obtained using the 1977 DOT, in specifications (4)-(6) we use the 1991 DOT definitions, while in (6)-(9) we use the 1977 DOT definition for 1960, 1970 and 1980 and the 1991 DOT definition for 1990 and 2000.
** indicates significance at the 5% level

Table 5
Impact of Foreign-Born Workers on the Supply of Tasks of US Natives, 2SLS Estimates
Workers with a High School Degree or Less

Explanatory Variable: Foreign-Born Share of Workers with a High School Degree or Less										
Instruments		Imputed Share of Mexican Immigrants			Distance from the Border and Distance Squared Interacted with Decades			US-Mexico Border Dummy Interacted with Decades		
Dependent Variable	Parameter	(1) Basic	(2) Males Only	(3) Non-Weighted	(4) Basic	(5) Males Only	(6) Non-Weighted	(7) Basic	(8) Males Only	(9) Non-Weighted
Domestic Workers $Ln(M_D/I_D)$	γ	-0.15** (0.05)	-0.18** (0.08)	-0.24* (0.14)	-0.27** (0.09)	-0.26** (0.12)	-0.50** (0.20)	-0.22** (0.06)	-0.21** (0.09)	-0.41** (0.17)
Domestic Workers $Ln(\bar{\mu}_D)$	γ^M	-0.06 (0.05)	-0.07 (0.06)	-0.09 (0.10)	-0.15* (0.08)	-0.18 (0.12)	-0.38* (0.14)	-0.11* (0.06)	-0.09 (0.07)	-0.24** (0.12)
Domestic Workers $Ln(\bar{\iota}_D)$	γ^I	0.09** (0.03)	0.11** (0.04)	0.14** (0.07)	0.12** (0.04)	0.07 (0.06)	0.12 (0.09)	0.11** (0.03)	0.12** (0.04)	0.17** (0.06)
Foreign Workers $Ln(M_F/I_F)$	γ^F	0.08 (0.23)	-0.14 (0.23)	0.44 (0.34)	-0.07 (0.28)	0.08 (0.25)	0.13 (0.48)	0.09 (0.21)	-0.08 (0.20)	0.38 (0.28)
First Stage										
F-Test of the Instruments (p-value)		20.95 (0.000)	28.5 (0.000)	22.80 (0.000)	14.53 (0.000)	12.2 (0.000)	4.91 (0.001)	19.9 (0.000)	13.36 (0.000)	7.68 (0.000)
Number of Observations		255	255	255	255	255	255	255	255	255

Note: Each cell contains estimates from separate regressions. The dependent variable in each is indicated in the first column. The explanatory variable is the foreign-born share of less-educated workers. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is two stage least squares. Specifications (1)-(3) instrument using the imputed share of Mexican described in the main text. Specifications (2)-(4) instrument using the distance between the center of gravity of the state and the Mexico-US border, interacted with four decade dummies. Specifications (7)-(9) use a dummy equal to one for states on the US-Mexico border, interacted with four decade dummies. We use the 1977 DOT definition for 1960, 1970 and 1980 and the 1991 DOT definition for 1990 and 2000. Heteroskedasticity robust standard errors, clustered by state, are reported in parenthesis.
** indicates significance at the 5% level

Table 6
Impact of Foreign-Born Workers on the Supply of Tasks of US Natives, Multiple Instruments

		Explanatory Variable: Foreign-Born Share of Less-Educated Workers							
		Workers with a High School Degree or Less				*Workers with No High School Diploma*			
Dependent Variable	Parameter	(1) LS	(2) 2SLS Imputed Mexican Instrument	(3) 2SLS Geographic Instruments	(4) 2SLS All Instruments	(5) LS	(6) 2SLS Imputed Mexican Instrument	(7) 2SLS Geographic Instruments	(8) 2SLS All Instruments
Domestic Workers $Ln(M_D/I_D)$	γ	-0.21** (0.05)	-0.15** (0.05)	-0.22** (0.06)	-0.22** (0.06)	-0.27** (0.05)	-0.17** (0.05)	-0.24** (0.07)	-0.23** (0.07)
Domestic Workers $Ln(\bar{\mu}_D)$	γ^M	-0.02 (0.03)	-0.06 (0.05)	-0.08 (0.06)	-0.10 (0.06)	-0.07* (0.04)	-0.10** (0.03)	-0.10** (0.03)	-0.10** (0.03)
Domestic Workers $Ln(\bar{\iota}_D)$	γ^I	0.18** (0.05)	0.09** (0.03)	0.12** (0.03)	0.11** (0.03)	0.20** (0.04)	0.07* (0.04)	0.14** (0.05)	0.14** (0.04)
First Stage									
Joint F-Test of the Instruments (p-value)		NA	20.07** (0.000)	20.50** (0.000)	20.95** (0.000)	NA	16.09**	27.57** (0.000)	29.69** (0.000)
Test of Over-Identifying Restrictions (Specification in First Row)		NA	NA	3.82	8.92	NA	NA	2.55	7.65
Probability (χ^2 > test) under the Null of Exogeneity of Instruments		NA	NA	81%	35%	NA	NA	92%	47%
Observations		255	255	255	255	255	255	255	255

Note: Each cell contains estimates from separate regressions. The dependent variable in each is indicated in the first column. The explanatory variable is the foreign-born share of less-educated workers. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is two stage least squares. Each observation is weighted by employment, and the standard errors are heteroskedasticity-robust and clustered by state. The last two rows report the Hausman test of overidentifying restrictions that can be performed when we use more instruments that endogenous variables. We report the test statistic and the p-value, namely the probability that χ^2 is larger than the observed statistic under the null hypothesis of the exogeneity of the instruments.
** indicates significance at the 5% level

Table 7
Impact of Foreign-Born Workers on the Supply of Tasks of Detailed Demographic Groups

Explanatory Variable: Foreign-Born Share of Workers within a Particular Demographic Group

Dependent variable: $Ln(M_D/I_D)$ for Domestic Workers within a Particular Demographic Group

	Individuals with 0-4 Years of Schooling	Individuals with 5-8 Years of Schooling	Individuals with 9-12 Years of Schooling	African Americans With a High School Degree or Less	Women With a High School Degree or Less
All Ages	-0.03	-0.16	-0.38**	-0.16	-0.22**
	(0.31)	(0.10)	(0.08)	(0.29)	(0.10)
Age: 25-45	-0.28	-0.22*	-0.29**	-0.03	-0.12
	(0.34)	(0.10)	(0.14)	(0.43)	(0.11)
Age: 46-65	0.087	-0.04	-0.85*	-0.20	-0.46**
	(0.64)	(0.39)	(0.23)	(0.39)	(0.23)
Number of Observations	255	255	255	255	255

Note: Each cell contains the estimate of the parameter γ from a separate regression that only includes natives and immigrants belonging to the specified demographic group. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is two stage least squares using all instruments. Each observation is weighted by employment, and the standard errors are heteroskedasticity-robust and clustered by state.
** indicates significance at the 5% level

Table 8
Effects of the Foreign-Born Share of Employment on Native-Born Employment and Population.
Less-Educated Workers by Age Group

Dependent Variable:	*Ln(Employment$_D$)*				*Ln(Population$_D$)*			
	LS		2SLS		LS		2SLS	
	(1) HS or Less	(2) HS Dropouts	(3) HS or Less	(4) HS Dropouts	(5) HS or Less	(6) HS Dropouts	(7) HS or Less	(8) HS Dropouts
All Ages	-0.12	0.20	0.25	0.45	0.20	0.49**	0.55	0.53
	(0.37)	(0.24)	(0.70)	(0.42)	(0.33)	(0.19)	(0.64)	(0.31)
Age: 25-45	-0.35	-0.08	0.23	0.10	-0.07	0.08	0.48	0.25
	(0.27)	(0.28)	(0.69)	(0.42)	(0.24)	(0.24)	(0.60)	(0.32)
Age: 46-65	-0.42	-0.37	-0.36	0.03	-0.34	-0.19	-0.07	0.22
	(0.59)	(0.38)	(0.69)	(0.67)	(0.46)	(0.28)	(0.64)	(0.52)
Observations	255	255	255	255	255	255	255	255

Note: Each cell contains estimates from separate regressions. The explanatory variable is the foreign-born share of workers in the group. The dependent variable is either the logarithm of native employment (columns 1-4) or the logarithm of native population (columns 5-8) in the group. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. The method of estimation is either Least Squares (columns 1, 2, 5 and 6) or 2SLS (columns 2, 4, 6 and 8) using all the instruments. All regressions include state and year fixed effects. Each observation is weighted by employment, and the standard errors are heteroskedasticity-robust and clustered by state.

Table 9
Impact of Foreign-Born Workers on the Total Supply of Tasks

		Explanatory Variable: Foreign-Born Share of Less-Educated Workers							
		Workers with High School Degree or Less				*Workers with No High School Diploma*			
Dependent Variable	Parameter	(1) OLS	(2) IV Imputed Mexican Instrument	(3) IV Geographic Instruments	(4) IV All Instruments	(5) OLS	(6) IV Imputed Mexican Instrument	(7) IV Geographic Instruments	(8) IV All Instruments
All Workers Ln(M/I)	γ_{TOT}	0.28** (0.08)	0.38** (0.08)	0.29** (0.09)	0.29** (0.10)	0.04 (0.04)	0.13** (0.04)	0.09** (0.04)	0.09** (0.04)
All Workers Ln($\bar{\mu}$)	γ^{M}_{TOT}	0.28** (0.03)	0.26** (0.06)	0.21** (0.07)	0.21** (0.07)	0.13** (0.02)	0.10** (0.03)	0.10** (0.03)	0.10** (0.03)
All Workers Ln($\bar{\iota}$)	γ^{I}_{TOT}	0.00 (0.07)	-0.12** (0.04)	-0.08** (0.04)	-0.08* (0.04)	0.08 (0.05)	-0.03 (0.04)	0.01 (0.04)	0.01 (0.04)
First Stage									
Joint F-Test of the Instruments (p-value)		NA	20.95 (0.000)	20.50** (0.000)	20.07** (0.000)	NA	16.09**	27.57** (0.000)	29.69** (0.000)
Test of Over-Identifying Restrictions (Specification in First Row)		NA	NA	3.82	8.92	NA	NA	2.55	7.65
Probability (χ^2 > test) under the Null of Exogeneity of Instruments		NA	NA	81%	35%	NA	NA	92%	47%
Observations		255	255	255	255	255	255	255	255

Note: Each cell contains estimates from separate regressions. The dependent variable in each is indicated in the first column. The explanatory variable is the foreign-born share of less-educated workers. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is two stage least squares. Each observation is weighted by employment, and the standard errors are heteroskedasticity-robust and clustered by state. The last two rows report the Hausman test of overidentifying restrictions that can be performed when we use more instruments that endogenous variables. We report the test statistic and the p-value, namely the probability that χ^2 is larger than the observed statistic under the null hypothesis of the exogeneity of the instruments.

** indicates significance at the 5% level

Table 10
Impact of Foreign-Born Workers on the Supply of Tasks of US Natives, Controlling for Technology and Demand Factors

Dependent Variable: Relative Task Supply, Ln(Manual/Interactive)						
	Dependent Variable: Task Supply of Domestic Workers, $Ln(M_D/I_D)$			Dependent Variable: Task Supply of All Workers, Ln(M/I)		
	(1)	(2)	(3)	(4)	(5)	(6)
	IV	IV	IV	IV	IV	IV
Explanatory Variables	All Instruments	All Instruments	All Instruments	All Instruments	All Instruments	All Instruments
Foreign-Born Share of Less-Educated Employment	-0.30** (0.06)	-0.29** (0.07)	-0.42** (0.07)	0.21** (0.08)	0.20** (0.10)	0.08 (0.10)
Percentage of Workers Using a Computer	-0.35** (0.10)		-0.51** (0.09)	-0.31** (0.10)		-0.46** (0.09)
Sector-Driven Manual/Interactive Task Intensity		0.54** (0.11)	0.68** (0.10)		0.60** (0.11)	0.72** (0.10)
	Decomposition of the Effect on Manual and Interactive Tasks			Decomposition of the Effect on Manual and Interactive Tasks		
Effect of Foreign-Born Share on Ln($\bar{\mu}$)	-0.16** (0.06)	-0.12** (0.06)	-0.19** (0.07)	0.14* (0.08)	0.18** (0.07)	0.10* (0.06)
Effect of Foreign-Born Share on Ln($\bar{\iota}$)	0.14** (0.04)	0.17** (0.03)	0.22** (0.04)	-0.06 (0.05)	-0.01 (0.04)	0.02 (0.06)
Number of Observations	255	255	255	255	255	255

Note: The top three rows report estimates of the impact of the foreign-born share, percentage of computer users, and industry-driven change in relative task intensity on the relative task supply of natives (columns 1 to 3) and overall relative task supply (columns 4 to 6). The bottom two rows report the effect of immigration on the supply of manual and interactive tasks when we control for the computer use and sector-driven variables. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is two stage least squares. Each observation is weighted by employment, and the standard errors are heteroskedasticity-robust and clustered by state.

** indicates significance at the 5% level

Table 11
Estimates of the Relative Wage Elasticity of Manual versus Interactive Tasks

	Dependent Variable: Wage Paid to Manual Tasks / Wage Paid to Interactive Tasks								
	1991 DOT			1977 DOT			Merged DOT		
Instruments:	*Foreign-Born Share*	*Geographic*	*All*	*Foreign-Born Share*	*Geographic*	*All*	*Foreign-Born Share*	*Geographic*	*All*
$1/\theta_L$	1.45* (0.85)	1.04 (0.90)	0.95 (0.90)	1.33** (0.73)	0.98 (0.92)	0.90 (0.90)	1.30* (0.74)	0.95 (0.79)	0.95 (0.85)
Implied Elasticity of Substitution	0.69	0.96	1.05	0.75	1.02	1.11	0.77	1.05	1.05
F-test of Joint Significance of the Instruments	16.2	4.03	4.05	16.2	4.03	4.05	16.2	4.03	4.05
Observations	255	255	255	255	255	255	255	255	255

Note: The explanatory variable is the negative of the logarithm of the relative supply of manual versus interactive tasks among all workers. In specifications (1), (4) and (7) we use the foreign-born share of less-educated workers as an instrument for the relative supply of manual versus interactive tasks in the state. In specification (2), (5) and (8), the instrument is the portion of the foreign-born share explained by the geographic variables (border distance and border dummies). In specifications (3), (6) and (9), the instrument is the portion of the foreign-born share explained by the geographic variables plus the imputed share of Mexicans. The units of observation in each regression are U.S. states in a census year (decennial panel of 50 states plus DC from 1960-2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is two stage least squares. Each observation is weighted by employment, and the standard errors are heteroskedasticity-robust and clustered by state. In Specifications (1)-(3) the task supply is obtained using the 1977 DOT, in specifications (4)-(6) we use the 1991 DOT definitions, while in (6)-(9) we use the 1977 DOT definition for 1960, 1970 and 1980 and the 1991 DOT definition for 1990 and 2000.
** indicates significance at the 5%
* indicates significance at the 10% level

Table 12
Simulated effects of Immigration on Wages between 1990 and 2000

State	(1) $\Delta H/H$	(2) $\Delta L/L$	(3) $\Delta M/M$	(4) $\Delta I/I$	(5) $\Delta W_H/W_H$	(6) $\Delta w_M/w_M$	(7) $\Delta w_I/w_I$	(8) $\Delta W_L/W_L$	(9) $\Delta W_D/W_D$	**(10) Postal Clerk** $\mu/(\mu+\iota)=0.2$	**(11) Hand Packer** $\mu/(\mu+\iota)=0.8$
Arizona	5.7%	24.2%	32.6%	23.3%	3.6%	-13.8%	-4.6%	-9.0%	-5.6%	-6.4%	-12.0%
California	7.0%	13.9%	16.9%	12.1%	1.1%	-5.5%	-0.7%	-3.1%	0.0%	-1.7%	-4.6%
Colorado	5.3%	11.2%	14.6%	10.6%	1.0%	-5.2%	-1.2%	-3.1%	-1.7%	-2.0%	-4.4%
DC	1.2%	3.6%	4.5%	3.2%	0.3%	-1.9%	-0.7%	-1.1%	0.2%	-0.9%	-1.7%
Florida	10.6%	10.0%	11.8%	9.7%	0.0%	-1.2%	0.9%	0.0%	1.6%	0.5%	-0.8%
Illinois	2.3%	4.4%	4.9%	3.7%	0.4%	-1.3%	-0.1%	-0.8%	0.3%	-0.4%	-1.1%
Massachusetts	1.6%	7.4%	8.9%	7.1%	1.1%	-3.5%	-1.7%	-2.5%	-0.9%	-2.0%	-3.1%
Nevada	13.8%	18.6%	23.4%	17.7%	1.5%	-5.2%	0.5%	-2.4%	0.1%	-0.7%	-4.0%
New Jersey	3.7%	4.4%	5.3%	3.6%	0.1%	-1.2%	0.5%	-0.3%	1.6%	0.2%	-0.9%
New York	5.6%	4.4%	5.5%	3.7%	-0.2%	-0.6%	1.3%	0.4%	2.7%	0.9%	-0.2%
Oregon	6.4%	12.4%	16.7%	12.7%	1.6%	-5.0%	-1.0%	-3.4%	-2.0%	-1.8%	-4.2%
Texas	4.2%	13.1%	15.6%	11.7%	1.7%	-5.7%	-1.8%	-3.7%	-2.1%	-2.5%	-4.9%
United States	**4.0%**	**6.0%**	**10.2%**	**6.5%**	**1.3%**	**-4.2%**	**-0.4%**	**-2.4%**	**-1.5%**	**-1.2%**	**-3.4%**

Note: The variables and parameters used in the simulations reported above are described in the text. In particular, we assumed σ=1.75 and θ_L=1. The twelve states chosen are those with higher foreign-born employment shares or with high levels of immigration between 1990 and 2000. The parameters used to estimate the change in task-supply of native workers in response to immigration are the average estimates from columns (1)-(4) in Table 6.

Figure 1
Relative Manual/Interactive Task Supply and Demand

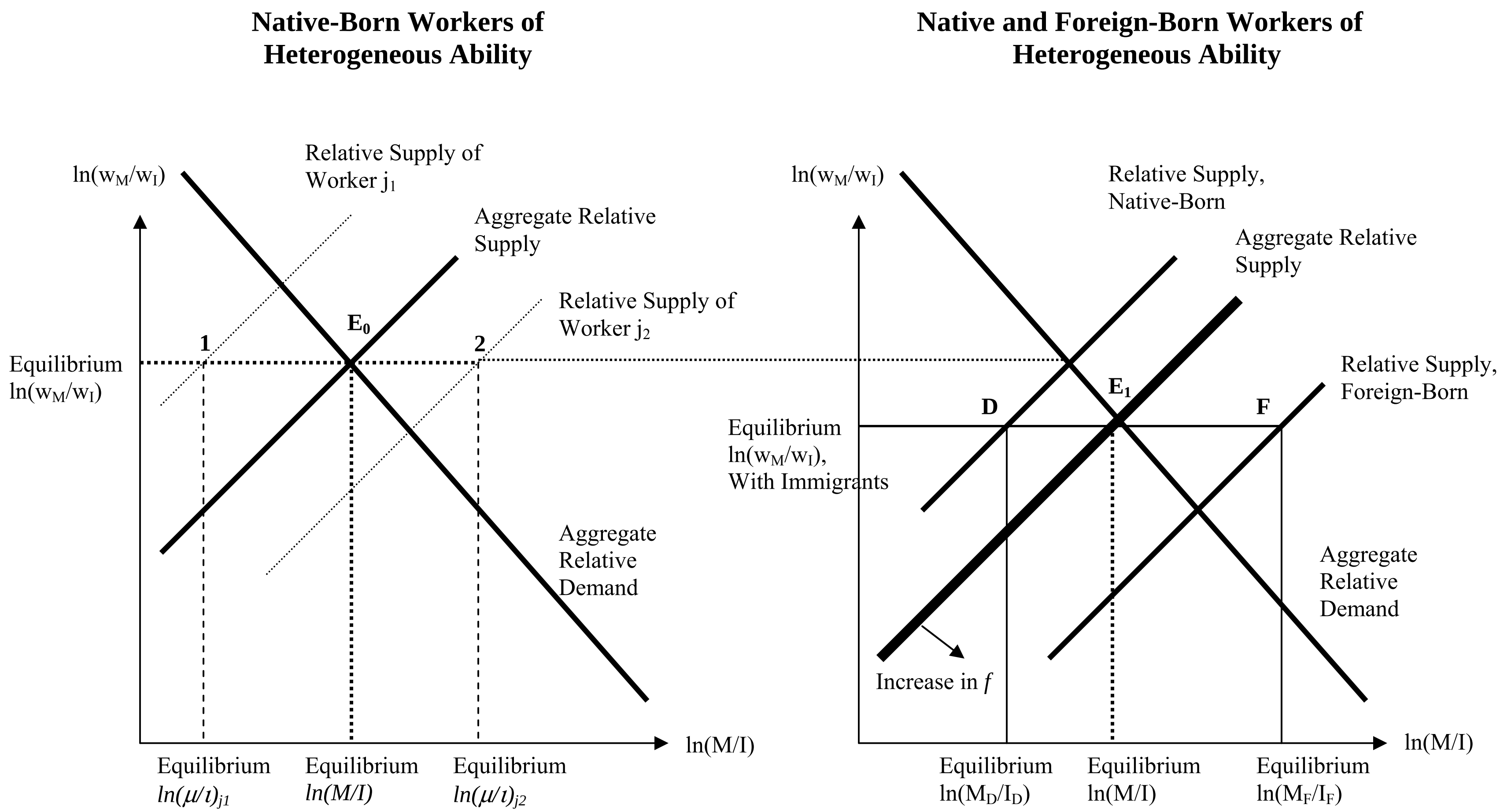
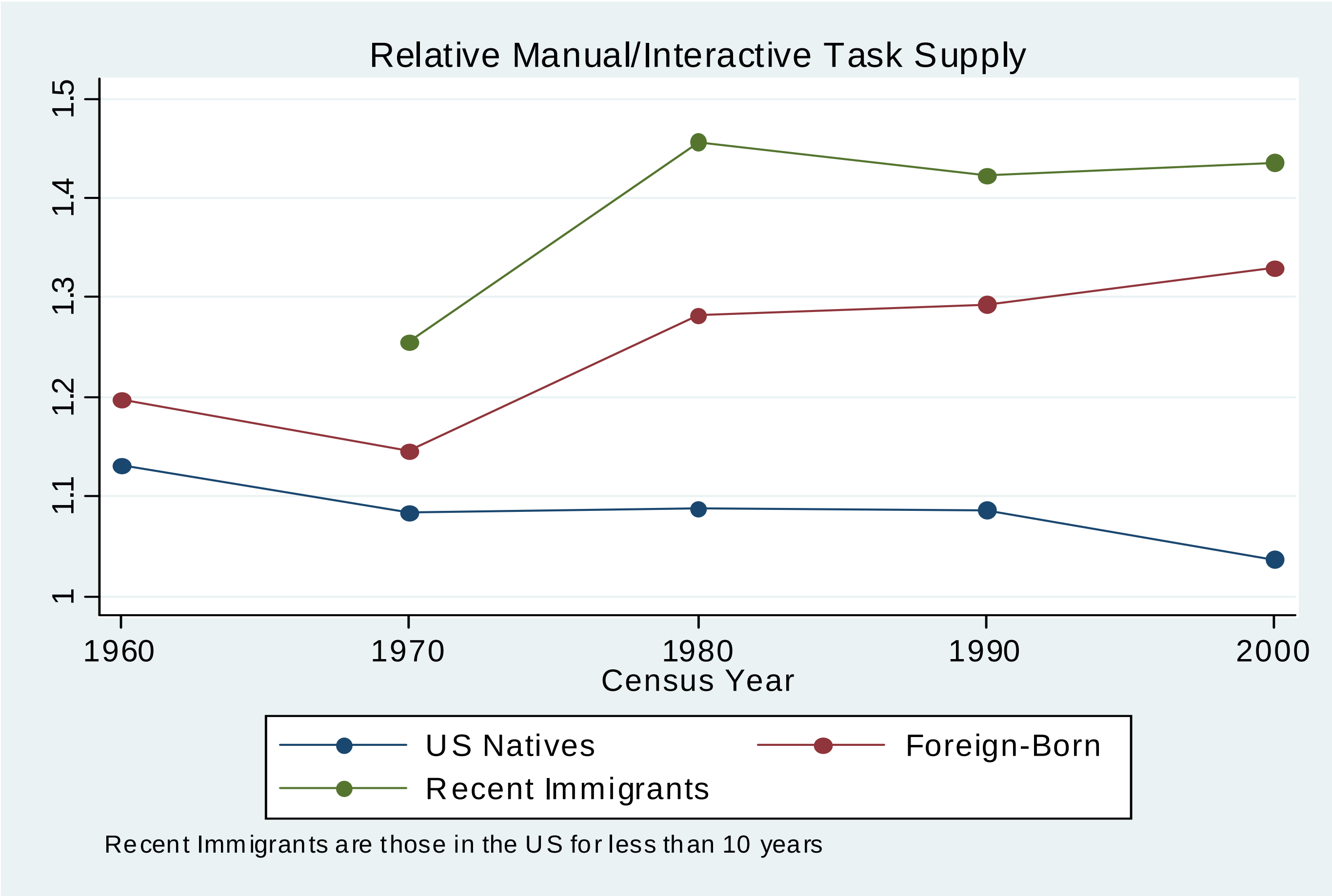
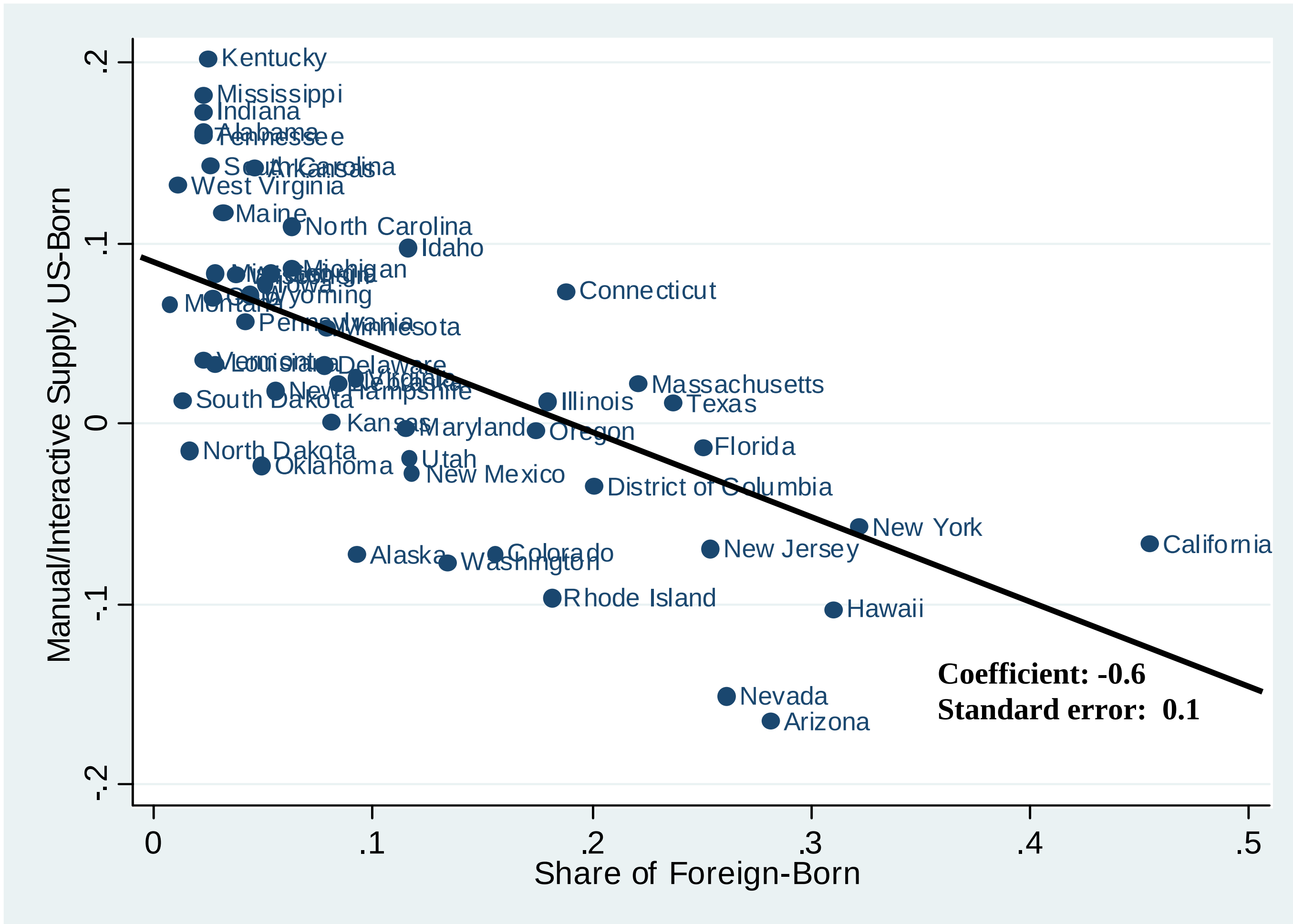


Figure 2
Relative Supply of Manual/Interactive Tasks in the US
Native, Foreign-Born, and Recent Immigrants with a High School Degree or Less, 1960-2000



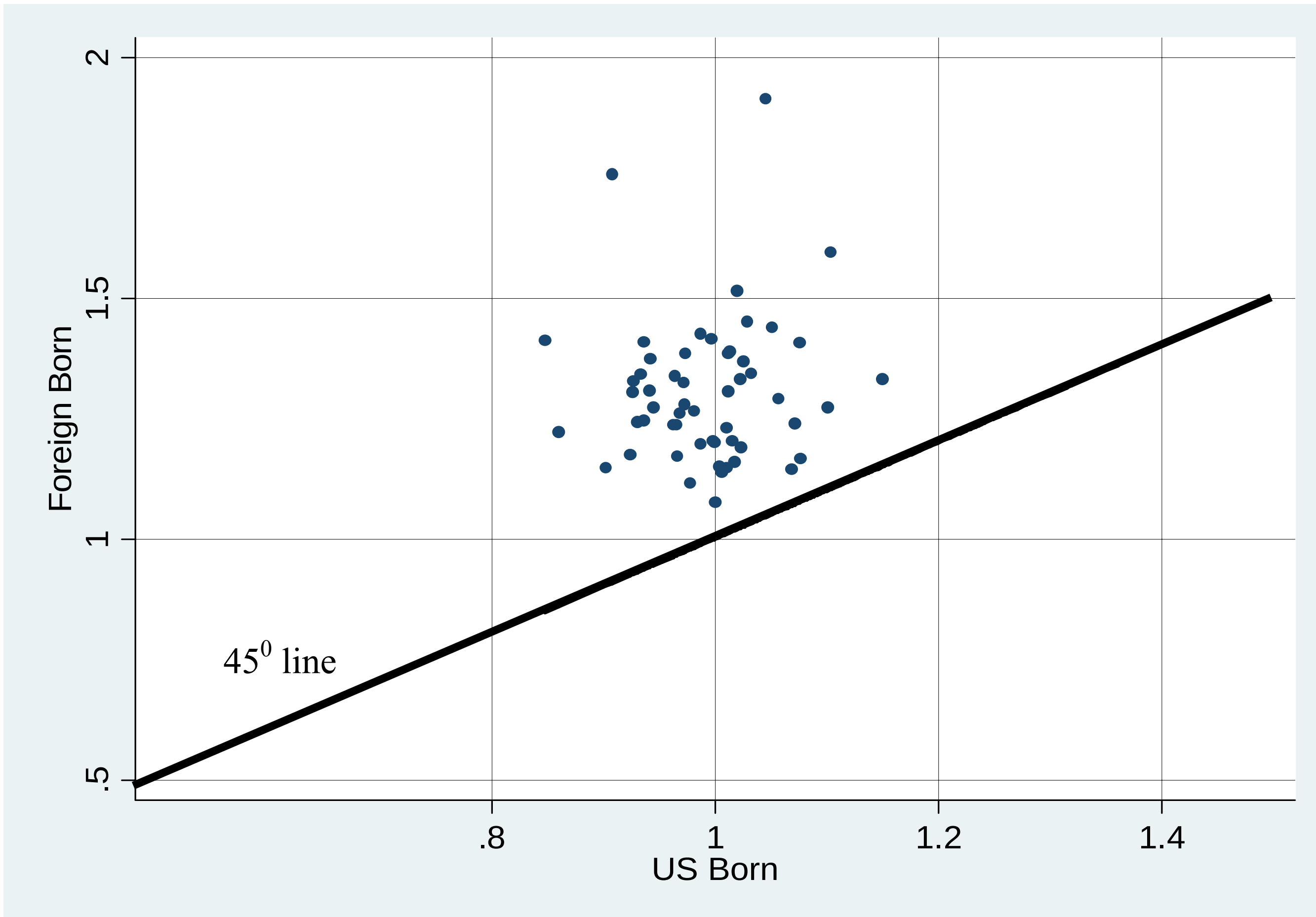
Note: The relative supply of tasks for native, foreign-born, and recent immigrants reported above are obtained by aggregating the values of EHF and DCP over individuals of the relevant group, weighted by their Census weight, and calculating their ratio. The construction of the indices EHF and DCP is described in the main text. The indices used in the figures are those obtained using the 1977 DOT definition of task intensity for 1960, 1970 and 1980, and the 1991 DOT definitions for year 1990 and 2000.

Figure 3
Share of Foreign-Born Workers and the Relative Supply of Manual/Interactive Tasks by Native-Born Workers, High School Degree or Less, US States, 2000



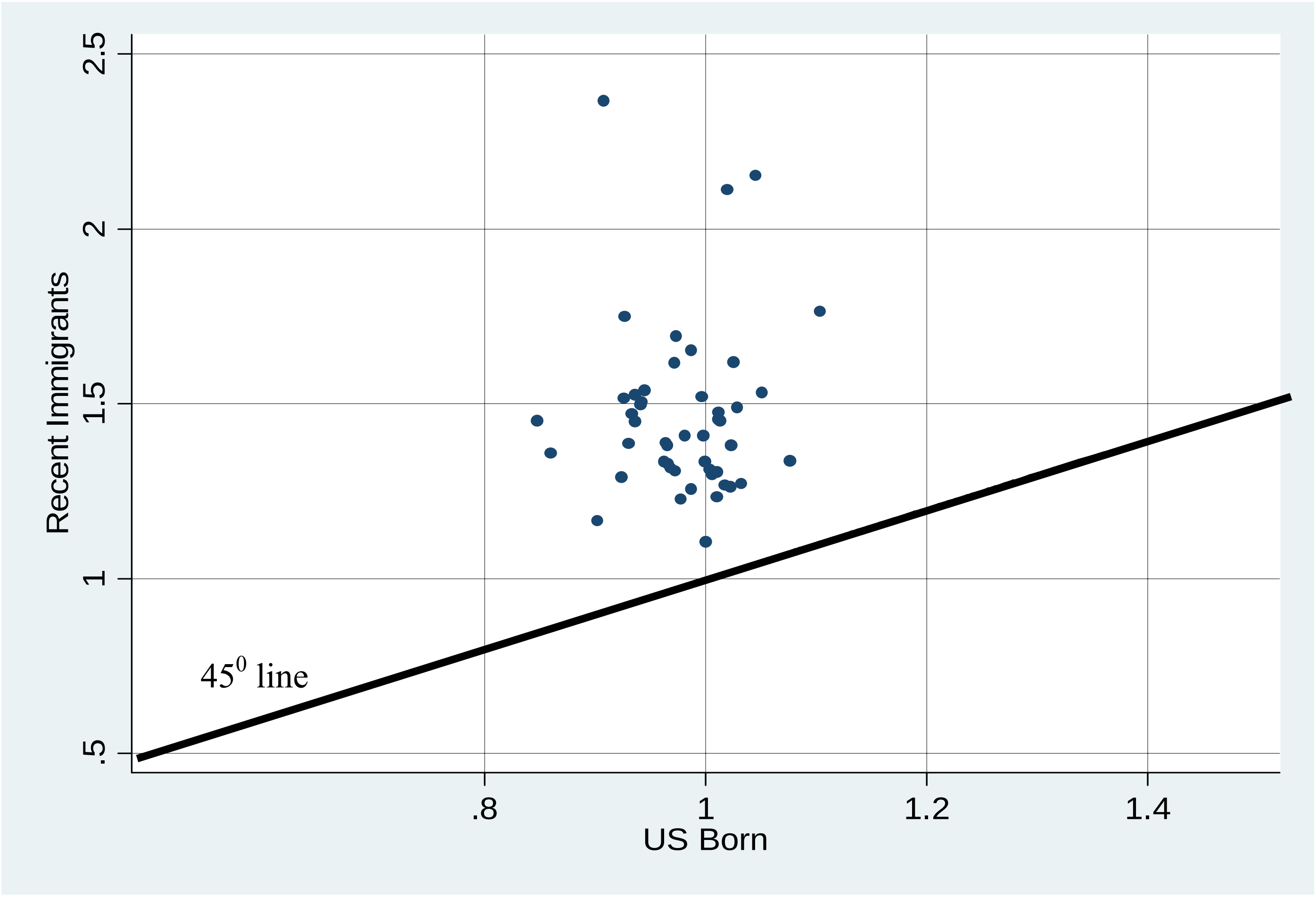
Note: The vertical axis reports the relative skill supply (M_D/I_D) of native workers in 2000. The construction of the indices EHF and DCP is described in the main text. The horizontal axis reports the foreign-born share of workers with a high school diploma or less in 2000.

Figure 4
Relative Supply of Manual/Interactive Tasks
Foreign-Born versus Natives with a High School Degree or Less, 1960-2000



Note: The vertical axis reports the relative skill supply (M_F/I_F) of immigrants. The horizontal axis reports the relative skill supply (M_D/I_D) of natives. Points represent US states in Census years. Only observations in which the share of immigrant workers with a high school degree or less was at least 10% are included.

Figure 5
Relative Supply of Manual/Interactive Tasks
Recent Immigrants versus Natives with a High School Degree or Less, 1960-2000



Note: The vertical axis reports the relative skill supply (M_F/I_F) of immigrants who have been in the US for ten years or less. The horizontal axis reports the relative skill supply (M_D/I_D) of natives. Points represent US states in Census years. Only observations in which the share of immigrant workers with a high school degree or less was at least 10% are included.