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Task Specialization, Immigration, and Wages †

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Large inflows of less educated immigrants may reduce wages paid to comparably-educated, native-born workers. However, if less educated foreign- and native-born workers specialize in different production tasks, because of different abilities, immigration will cause natives to reallocate their task supply, thereby reducing downward wage pressure. Using occupational task-intensity data from the O*NET *dataset and individual US census data, we demonstrate that foreign-born workers specialize in occupations intensive in manual-physical labor skills while natives pursue jobs more intensive in communication-language tasks. This mechanism can explain why economic analyses find only modest wage consequences of immigration for less educated native-born workers.* (*JEL* J24, J31, J61)

Immigration has significantly affected the US labor market during the last few decades, particularly increasing the supply of workers with low levels of formal schooling. Economists continue to debate the wage effects of these large inflows on native-born workers. If workers' skills are differentiated solely by their level of educational attainment, and if the production technology and productivity of each type of labor are given, then a large inflow of immigrants with limited schooling should alter the relative scarcity of education groups, increase wages paid to highly educated natives, and reduce wages paid to less educated ones. George J. Borjas (2003) and Borjas and Lawrence F. Katz (2007) adopt this intuitive approach and use US national-level data to argue that immigration reduced real wages paid to native-born workers without a high school degree by 4 to 5 percent between 1980 and 2000. Area studies by David Card (2001, 2007), Card and Ethan G. Lewis (2007), and Lewis (2005), in contrast, employ city- and state-level data, and find almost no effect of immigration on the wages of less educated native workers.

Gianmarco I. P. Ottaviano and Peri (2006, 2008) emphasize that the effects of immigration depend upon whether native- and foreign-born workers with similar

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observable characteristics are imperfect substitutes in production. They argue that immigrants and natives of comparable educational attainment and experience possess unique skills that lead them to specialize in different occupations, which mitigates natives' wage losses from immigration.[1] Also, Patricia Cortes (2008), analyzing US cities, finds a significant effect of low-skilled immigration on prices of local nontraded goods, and on wages of previous immigrants, and much smaller effects on wages of low-skilled natives. This implies that low-skilled immigrants and natives are imperfect substitutes.

We advance this literature by developing a theory and performing empirical analysis to demonstrate *how* native- and foreign-born workers are imperfect substitutes in production. We focus on workers with little educational attainment and argue that less educated native and immigrant workers specialize in different production tasks. Immigrants are likely to have imperfect language (or, equivalently, "communication") skills, but they possess physical (or "manual") skills similar to those of native-born workers. Thus, they have a comparative advantage in occupations requiring manual labor tasks, while less educated native-born workers will have an advantage in jobs demanding communication skills. Immigration encourages workers to specialize. Less educated natives respond to immigration by leaving physically demanding occupations for language-intensive ones. Importantly, language-intensive tasks tend to earn a comparatively higher return, and those returns are further enhanced by the increased aggregate supply of complementary manually intensive tasks. Therefore, productivity gains from specialization, coupled with the high compensation paid to communication skills, imply that foreign-born workers do not have a large, adverse effect on the wages paid to less educated natives.

We begin, in Section I, by describing a simple model of comparative advantage and incomplete specialization by workers. Workers' skill endowments imply that immigration reduces the compensation paid for manual tasks and increases the compensation paid for communication tasks. The complementary nature of the two skills, and the reallocation of native workers toward communication tasks, favors 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.

Section II describes the decennial data for the 50 US states (plus the District of Columbia) from 1960 to 2000 and the construction of the variables that we use to test our model. Census occupation codes allow us to merge occupational characteristics with individual-level data from the Integrated Public Use Microdata Series (IPUMS) census microdata (Steven Ruggles et al. 2005). To measure the manual and communication skill intensity of occupations, we use the US Department of Labor's *O*NET* dataset on job task requirements. This dataset measures the importance of several physical (dexterity, coordination, and strength) and language (oral and written comprehension and expression) abilities within each census occupation code.

[1] Marco Manacorda, Alan Manning, and Jonathan Wadsworth (2007), and Francesco D'Amuri, Ottaviano, and Peri (2008) argue for similar imperfect substitutability between native and immigrant workers in the UK and Germany, respectively. Other important contributions to the literature on immigration and wages include Joseph G. Altonji and Card (1991); Borjas (1994, 1995, 1999, 2003); Borjas, Richard B. Freeman, and Katz (1997); Kristin F. Butcher and Card (1991); Card (1990); Rachel M. Friedberg and Jennifer Hunt (1995); Friedberg (2001); and James P. Smith and Barry Edmonston (1997).

Data values are based on experts' recent assessments and reflect the current use of skills across occupations.[2]

The empirical analysis in Section III strongly supports key implications of our theory. States with large inflows of less educated immigrants, relative to those with small flows, also experienced a greater shift in skill supply among less educated native-born workers toward communication tasks and away from manual ones; a greater decrease in the total supply of communication relative to manual skills; and a greater increase in the compensation paid to communication relative to manual skills. These results are upheld by two-stage least squares (2SLS) 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 at the state level. The first follows a strategy similar to Card (2001), Card and John E. DiNardo (2000), and Cortes (2008) 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 and to a border dummy.

Section III also performs a host of robustness checks to ensure that the results are not spuriously driven. We control for possible shifts in the demand for skills, analyze how labor flows affect previous immigrant groups and assess how the effects of immigration vary across demographic groups. The results of these checks again support the implications of our model.

Given the positive wage effect of specializing in language-intensive occupations, native-born workers can protect their wages and mitigate losses due to immigration by reallocating their tasks. In Section IV, we use our model and the empirical estimates to simulate the effects of immigration on average wages paid to native-born employees with a high school degree or less. Combining the task complementarity and the increasing specialization among native-born workers in response to immigrants (estimated in Section III), the simulations imply that the wage impact of immigration on less-educated natives is very small for the United States overall. While less-educated natives in states receiving a disproportionately large number of less-educated immigrants (relative to highly-educated ones) still experience wage losses, the effects are usually small and, in some states, they are even positive. The wage effects for natives and immigrants also allow us to calculate the elasticity of substitution between immigrants and natives implied by our simulated model. We obtain values between 20 and 47, with an average of 33. These figures are very

[2] Our analysis ignores changes in the task content of occupations over time. Thus, we might underestimate the effect of immigration on task performance of natives by capturing only the part due to reallocation across occupations. In Peri and Chad Sparber (2008c), we use *Dictionary of Occupational Titles* (*DOT*) and *O*NET* measures of skill intensity. The *DOT* identifies the intensity of skill use in occupations measured in 1977 and 1991, and, therefore, accounts for changes over time. Unfortunately, that dataset contains only two measures of manual skills (eye, hand, and foot coordination, and finger dexterity) and an imperfect measure of communication abilities (the performance of direction, control, and planning activities) that encompass many tasks in addition to language skills. Despite the differences between datasets and skill intensity measures, we found remarkably similar and robust results. We refer the reader to Peri and Sparber (2008c) for a more detailed description of analysis and results using *DOT* variables.

similar to the elasticity estimated directly by Ottaviano and Peri (2008), regressing relative immigrant-native wages on relative hours worked at the national level. Altogether, our findings agree in spirit with those of Card (2001), Card and Lewis (2007), Card (2007), and Cortes (2008), while adding a new dimension and more microfoundations to the structural framework introduced by Borjas (2003) and refined by Ottaviano and Peri (2008).

I. Theoretical Model

We propose a simple general equilibrium model of comparative advantages in task performance to illustrate the effects of immigration on specialization and wages.[3] We briefly describe the model here, and provide more detailed derivations and results in the Appendix. We will test the key qualitative implications of the model in Section III, and use the production structure and empirically-estimated elasticities to simulate the effects of immigration on wages paid to less-educated native-born workers in Section IV.

A. *Production*

Consider an open economy (e.g., a US state) that combines two nontradeable intermediate services, Y_H and Y_L, in a *CES* production function to produce a final tradeable consumption good, Y, according to equation (1).

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

The parameter $\sigma \in (0, \infty)$ measures the elasticity of substitution between Y_H and Y_L. The coefficients β and $(1-\beta)$ capture the relative productivity of these intermediate services in the production of good Y. This final consumption good is also the numeraire, so that all prices and wages are expressed in real terms. We assume that 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 two intermediate services are produced by different workers. Low education workers (with total labor supply equal to L) produce Y_L, and high education workers (H) produce Y_H. The symmetric *CES* production function (1) combining the services of more and less educated workers (i.e., those with and without college experience) is widely used in economics.[4] Some immigration papers, in contrast, separate workers into four education groups: high school dropouts, high school degree holders, those

[3] Gene M. Grossman and Esteban Rossi-Hansberg (2008) develop an interesting theory of offshoring that builds upon a process of international task division. David H. Autor and David Dorn (2007) use a model of differentiated task performance to analyze the evolution of wages in the 1980s and 1990s related to computer adoption. Those models have features similar to ours.

[4] For instance, the literature on cross-country income differences (Daron Acemoglu and Fabrizio Zilibotti 2001; Francesco Caselli and Wilbur John Coleman, II 2006), technological change (Acemoglu 1998, 2002), and labor economics (Katz and Kevin M. Murphy 1992; Card and Thomas Lemieux 2001) all use a production function similar to (1).

with some college experience, and college graduates. However, Ottaviano and Peri (2008) argue that workers with no degree and workers with a high school diploma were close substitutes between 1960 and 2000, as were workers with some college education and those with a college degree. A recent paper by Claudia Goldin and Katz (2007) also argues that "high school graduates and dropouts are close substitutes today." Most of the literature (including Katz and Murphy 1992; Joshua D. Angrist 1995; George E. Johnson 1997; Goldin and Katz 2007; Ottaviano and Peri 2008) does find a significant degree of imperfect substitutability between workers with a high school diploma or less and those with some college education or more. Thus, we advocate a two-group *CES* model distinguishing between workers with a high school degree or less and workers with some college education or more.

We add to the framework above by assuming that less-educated workers must perform both manual and communication tasks in order to produce Y_L. Manual tasks require the use of physical skills such as dexterity, body coordination, or strength. Communication tasks, such as directing, training, and organizing people, require mostly language skills. Let less-educated workers supply M units of manual-task inputs and C units of communication-task inputs in the aggregate.[5] 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 C.

$$(2) \qquad Y_L = \left[\beta_L\, M^{\frac{\theta_L - 1}{\theta_L}} + (1-\beta_L)\, C^{\frac{\theta_L - 1}{\theta_L}}\right]^{\frac{\theta_L}{\theta_L - 1}}.$$

Since this paper focuses on the market for less-educated workers, we make the simplifying assumption that highly-educated workers only perform one "analytical" (or equivalently, "cognitive") task in the production of Y_H.[6] Alternatively, one can assume that highly-educated workers provide both analytical and communication tasks (and very few physical tasks), that those two tasks are highly substitutable, and/or that their relative supply and returns are not affected much by the presence of less educated immigrants.[7] By standardizing the units of these tasks, we can assume that Y_H is produced according to a linear technology equal to the total supply of highly-educated working hours. That is, $Y_H = H$.

Competitive labor markets and perfect competition among producers of Y_L and Y_H yield the relative task demand function in equation (3), where w_M and w_C denote the compensation (price) paid for one unit of manual and communication task, respectively.

$$(3) \qquad \frac{C}{M} = \left(\frac{1-\beta_L}{\beta_L}\right)^{\theta_L}\left(\frac{w_C}{w_M}\right)^{-\theta_L}.$$

[5] We will use capital letters to denote aggregate values, and lower case letters to denote per capita figures, throughout the text.

[6] For a more careful analysis of task specialization between natives and immigrants among highly educated workers, see Peri and Sparber (2008b).

[7] We provide empirical evidence in Section II and in Table W7, in the Web Appendix, that shows the independence between the task supply among highly-educated workers and the inflow of less-educated immigrants.

B. *Relative Supply of Tasks: Natives and Immigrants*

Since each highly-educated worker is identical from a productive point of view, the wage paid to these workers equals the marginal productivity of Y_H in (1). That is, $w_H = P_H$. In contrast, less educated workers are heterogeneous and may differ from each other in their relative task productivity. We consider two types of workers: less-educated "domestic" native-born workers (D), and less-educated "foreign-born" immigrant workers (F). We let L_j (for $j = D$ or F) represent the total labor supply of these groups.

Each less-educated worker chooses an occupation and fully allocates one unit of time in order to provide μ_j units of manual tasks, ζ_j units of communication tasks, or some division between the two. Native and immigrant workers differ in that the first has a comparative advantage in communication tasks. Mathematically, this implies $(\zeta_D/\mu_D) > (\zeta_F/\mu_F)$.

Let l_j be the share of a worker's labor endowment (time) spent performing manual tasks in her occupation, implying that $1 - l_j$ is the time spent performing communication tasks. A worker's supply of manual task units is $m_j = (l_j)^{\delta}\mu_j$, while her supply of communication task units is $c_j = (1 - l_j)^{\delta}\zeta_j$. The parameter $\delta \in (0,1)$ captures the decreasing returns from performing a single task, which implies that no one will fully specialize.

Each worker takes the unit compensation paid to tasks (w_M and w_C) as given, and chooses an occupation allocating her time between manual and communication tasks to maximize labor income. Labor income is given in equations (4) and (5) for less-educated native and immigrant workers, respectively.

$$w_D = (l_D)^{\delta}\,\mu_D w_M + (1 - l_D)^{\delta}\,\zeta_D w_C. \tag{4}$$

$$w_F = (1 - d)[(l_F)^{\delta}\,\mu_F w_M + (1 - l_F)^{\delta}\,\zeta_F w_C]. \tag{5}$$

These equations sum the income from performing manual and interactive tasks. The productivity in each task is specific to the type of worker (F or D). Notice that in (5) we allow wages of immigrants to be a fraction $(1 - d) \in [0,1]$ of their marginal productivity, allowing for some form of discrimination or reduced bargaining power relative to natives. This feature does not affect the relative (or absolute) supply of tasks by immigrants. It only implies that immigrants may earn lower wages than natives do within a given occupation, which is a feature that we allow in the estimation and is supported by the data.

By maximizing wages with respect to l_j, we can identify the equilibrium relative supply of communication versus manual tasks for natives and immigrants. Equation (6), which depends positively on relative task compensation and on the worker's relative efficiency in performing tasks (ζ_j/μ_j), describes the relative task supply for natives $(j = D)$ and immigrants $(j = F)$. Equivalently, equation (7) expresses this relationship in terms of the relative time spent performing these tasks.

$$\frac{c_j}{m_j} = \left(\frac{w_C}{w_M}\right)^{\frac{\delta}{1-\delta}} \left(\frac{\zeta_j}{\mu_j}\right)^{\frac{1}{1-\delta}}. \tag{6}$$

$$\frac{l_j}{1-l_j} = \left(\frac{\zeta_j w_C}{\mu_j w_M}\right)^{\frac{1}{\delta-1}}. \tag{7}$$

Since each occupation is identified by a unique allocation of time between manual and communication tasks, when a worker chooses an occupation to maximize her wage income, she also reveals her relative efficiency (ζ_j/μ_j) in task performance. Equations (6) and (7) can therefore be interpreted as describing the occupation choice for a worker of type j, establishing a unique and invertible relationship between an individual's relative abilities and her occupation.[8] The existence of a continuum of occupations (for values of l_j between zero and one) allows workers to respond continuously to a marginal increase in the relative compensation of communication tasks (w_C/w_M) by marginally increasing c_j/m_j. That is, by moving to an occupation requiring less time devoted to manual tasks, l_j.

In this simplified model, there is no differentiation of abilities within citizenship groups. All native workers are endowed with task efficiency (ζ_D, μ_D), whereas all foreign-born workers have efficiency (ζ_F, μ_F). This implies that each native supplies (c_D, m_D) task units and each immigrant supplies (c_F, m_F), so that members from each group will choose a common occupation. Each group will choose a new occupation, however, if the relative compensation of tasks changes. Hence, in our notation, j represents the worker type as well as her occupation, since the latter fully reveals the former.[9] The aggregate task supply for native and foreign workers will equal the product of individual task supply and total labor supply ($M_j = L_j m_j$ and $C_j = L_j c_j$). This implies that if we substitute c_j/m_j with C_j/M_j (by multiplying numerator and denominator by L_j), expression (6) also describes the relative supply of tasks for natives and immigrants.

Equation (8) represents the aggregate relative supply of tasks in the economy obtained by summing the skills provided by each group.

$$\frac{C}{M} = \frac{C_F + C_D}{M_F + M_D} = \varphi(f)\,\frac{C_F}{M_F} + (1-\varphi(f))\,\frac{C_D}{M_D}. \tag{8}$$

The term $\varphi(f) = (M_F/(M_F + M_D)) \in (0,1)$ is the share of manual tasks supplied by foreign-born workers, and is a simple monotonically increasing transformation of the foreign-born share of less-educated workers,[10] $f = L_F/(L_F + L_D)$. Hence, the aggregate relative supply of tasks in the economy is a weighted average of each group's relative supply, and the weights are closely related to the share of each group in employment. Substituting (6) for natives and immigrants in (8), and equating

[8] In our empirical implementation, for example, a relative task supply $c_j/m_j = 0.16$ corresponds to the occupation "assembler of electrical equipment." A relative task supply of 3.12 corresponds to the occupation "financial service salesperson."

[9] In a model with heterogeneous abilities (as in Peri and Sparber 2008c), as well as in the empirical implementation, workers with different ζ_j/μ_j choose different occupations within each group. In that case, the index j can be thought of as indexing the worker's relative effectiveness as well as her occupation.

[10] Specifically: $\varphi'(f) > 0$; $\varphi(0) = 0$ and $\varphi(1) = 1$.

relative supply with relative demand (expressed by (3)), one can solve for the equilibrium relative compensation of tasks:

$$\frac{w_C^*}{w_M^*} = \left(\frac{1-\beta_L}{\beta_L}\right)^{\frac{(1-\delta)\theta_L}{(1-\delta)\theta_L+\delta}} \left[\frac{\zeta}{\mu}\left(\underset{-}{f}, \underset{+}{\frac{\zeta_F}{\mu_F}}\right)\right]^{\frac{-1}{(1-\delta)\theta_L+\delta}}. \tag{9}$$

The function $\frac{\zeta}{\mu}\left(f, \frac{\zeta_F}{\mu_F}\right)$ is a weighted average of the relative skill endowments among natives and immigrants, and it represents an aggregate measure of communication relative to manual ability in the economy. More specifically, $\frac{\zeta}{\mu}\left(f, \frac{\zeta_F}{\mu_F}\right) = [\varphi(f)\ (\zeta_F/\mu_F)^{1/(1-\delta)} + (1-\varphi(f))\ (\zeta_D/\mu_D)^{1/(1-\delta)}]^{(1-\delta)}$. For a given value of the relative skills of natives (ζ_D/μ_D), the term $\frac{\zeta}{\mu}\left(f, \frac{\zeta_F}{\mu_F}\right)$ depends negatively on f and positively on ζ_F/μ_F, as indicated by the signs in equation (9). This is intuitive. Due to the assumption that $\zeta_F/\mu_F < \zeta_D/\mu_D$, a larger fraction of immigrants decreases the average relative communication skills of the workforce. Similarly, a decrease in the relative communication ability of immigrants (ζ_F/μ_F) for a given share of employment would decrease the average relative communication ability of the workforce.

By substituting the equilibrium wage into the aggregate relative supply for domestic workers, we find their equilibrium relative provision of tasks (equation (10)). The weighted average of C_D^*/M_D^* and C_F^*/M_F^*, according to equation (8), identifies the equilibrium aggregate relative provision of tasks in equation (11).

$$\frac{C_D^*}{M_D^*} = \left(\frac{1-\beta_L}{\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \left(\frac{\zeta_D}{\mu_D}\right)^{\frac{1}{(1-\delta)}} \left[\frac{\zeta}{\mu}\left(\underset{-}{f}, \underset{+}{\frac{\zeta_F}{\mu_F}}\right)\right]^{\frac{-1}{(1-\delta)\theta_L+\delta}\frac{\delta}{1-\delta}}. \tag{10}$$

$$\frac{C^*}{M^*} = \left(\frac{1-\beta_L}{\beta_L}\right)^{\frac{\delta\theta_L}{(1-\delta)\theta_L+\delta}} \left[\frac{\zeta}{\mu}\left(\underset{-}{f}, \underset{+}{\frac{\zeta_F}{\mu_F}}\right)\right]^{\frac{\theta_L}{(1-\delta)\,\theta_L+\delta}}. \tag{11}$$

If we assume that workers also spend their entire wage income to consume Y in each period (there is no capital in the model, so we assume no saving and investment), the equilibrium compensation values w_H, w_M, and w_C fully determine the income, task supply, and consumption of each agent. Hence, the model is a simple general equilibrium static representation of an economy.

C. *Model Predictions and Empirical Specifications*

It is simple and intuitive to perform some comparative static analyses using the equilibrium expressions (9), (10), and (11). In particular, since the average relative ability $\frac{\zeta}{\mu}\left(f, \frac{\zeta_F}{\mu_F}\right)$ depends negatively on the share of immigrants in the population (f), an increase in that share has three effects. First, the return to communication relative to manual tasks increases (equation (9)), which, in turn, implies an increase in the relative supply of communication tasks by natives (equation (10)), while the aggregate relative supply of communication tasks decreases (equation (11)). Similarly,

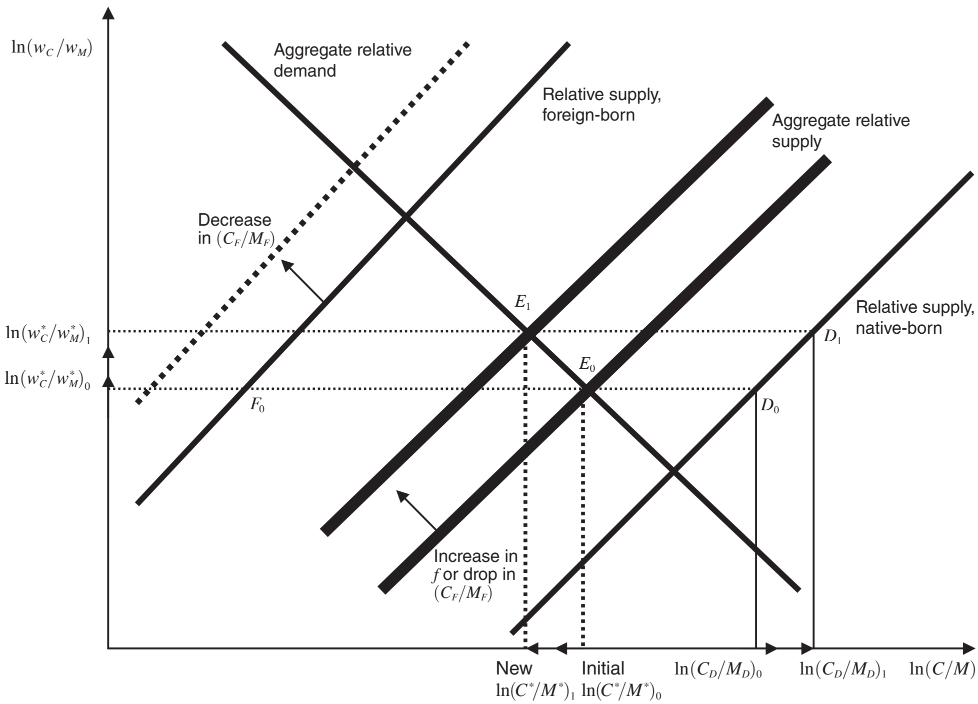


Figure 1. Relative Communication/Manual Task Supply and Demand

since $\frac{\zeta}{\mu}\left(f, \frac{\zeta_F}{\mu_F}\right)$ depends positively on ζ_F/μ_F, a decrease in that variable produces an increase in the relative return to communication versus manual tasks, an increase in the native relative supply of communication versus manual tasks, and a decrease in the overall relative supply of communication versus manual tasks. Empirically, between 1960 and 2000, the United States experienced an increase in f and an inflow of immigrants with lower ζ_F/μ_F relative to natives.

Figure 1 displays the equilibrium in an economy with native- and foreign-born workers, illustrating the effects of an increase in the share of immigrants and/or a decrease in their relative ζ_F/μ_F abilities using relative supply and demand curves. The downward sloping demand curve represents relative marginal task productivity as expressed by equation (3). Comparative advantage dictates that the relative task supply curve for immigrants is to the left of that for domestic workers. Aggregate relative supply (represented by the thickest line in the panel) is a weighted average of the two. The distance of the average supply curve from those of immigrants and domestic workers is proportional to $\varphi(f)$ and $1 - \varphi(f)$, respectively.

The initial equilibrium relative task compensation $\left(\ln(w_C^*/w_M^*)\right)$ and provision $\left(\ln(C^*/M^*)\right)$ is denoted by E_0. The points D_0 and F_0 along the native and immigrant skill-supply curves identify each group's respective initial relative supply of tasks. Either an increase in the foreign-born share of employment or a decrease in ζ_F/μ_F

will shift aggregate supply to the left (the latter also shifts the supply curve for immigrants). This implies a new equilibrium, E_1. The aggregate level of communication versus manual tasks decreases, thus increasing their relative compensation. Natives respond rationally by providing *more* communication versus manual tasks (a move along their relative skill-supply curve to D_1). Hence, a larger share of immigrants among less-educated workers (possibly reinforced by a decrease in their relative communication abilities) pushes less-educated native workers to further exploit their comparative advantage. The economy experiences an increase in the relative compensation of communication versus manual tasks, an increase in natives' relative supply of these tasks, and a decrease in the relative supply of communication versus manual tasks in the aggregate.

In Section III, we empirically test these three predictions by using decennial (year t) US state (s) data for the period 1960–2000. In particular, by log-linearizing the two key equilibrium conditions, (10) and (11), we obtain the two linear empirical specifications expressed below.

$$\ln\left(\frac{C_D}{M_D}\right)_{st} = \gamma f_{st} + \alpha_s^D + \tau_t^D + \varepsilon_{st}^D. \tag{12}$$

$$\ln\left(\frac{C}{M}\right)_{st} = \gamma_{TOT}\, f_{st} + \alpha_s^{TOT} + \tau_t^{TOT} + \varepsilon_{st}^{TOT}. \tag{13}$$

We also invert and log-linearize the relative demand function (3) to obtain a third linear relation given by:

$$\ln\left(\frac{w_C}{w_M}\right)_{st} = -\frac{1}{\theta_L}\ln\left(\frac{C}{M}\right)_{st} + \alpha_s^w + \tau_t^w + \varepsilon_{st}^w. \tag{14}$$

Each regression includes a noncorrelated zero-mean disturbance term (ε_{st}^D, ε_{st}^{TOT}, and ε_{st}^w). Time fixed effects (τ_t^D, τ_t^{TOT}, and τ_t^w) account for common time-varying technological parameters. The first two capture the term $\left(\delta\theta_L/((1-\delta)\theta_L+\delta)\right) \times \ln\left((1-\beta_L)/\beta_L\right)$ from equations (10) and (11), while τ_t^w controls for $\ln\left((1-\beta_L)/\beta_L\right)$ from the relative labor demand equation. The state fixed effects in each expression (denoted α_s^D, α_s^{TOT}, and α_s^w) account for variation due to unobserved characteristics of the population, including the term $\left(1/(1-\delta)\right) \times \ln(\zeta_D/\mu_D)$ from (10).

The remaining terms in these log-linearized expressions represent our theoretical model's central implications. In equation (12), $\gamma \equiv -\left(1/((1-\delta)\theta_L + \delta)\right)\left(\delta/(1-\delta)\right) \times (\partial \ln(\zeta/\mu)/\partial f)$. The model's equation (10) predicts $\gamma > 0$ because a state's foreign-born share of less-educated employment (f_{st}) causes native workers to increase their relative supply of communication tasks. In equation (13), $\gamma_{TOT} \equiv \left(\theta_L/((1-\delta)\theta_L+\delta)\right) \times (\partial \ln(\zeta/\mu)/\partial f)$ is derived from (11), which predicts $\gamma_{TOT} < 0$ since immigration causes the overall relative supply of these tasks to fall. Finally, we use equation (14) to estimate the elasticity of substitution, θ_L, which is predicted to be positive. This specification rearranges the relative demand function for skills (3) so that

$\ln(C/M)_{st}$ represents the explanatory variable. Since $\ln(C/M)_{st}$ is endogenous, we use the results from our regression of (13) and adopt the exogenous shifter of the share of immigrants, f_{st}, as an instrument in estimation of (14).

Sections IIIA, IIIB, and IIIC estimate (12), (13), and (14), respectively. Before showing the results, however, we describe the data and discuss the measures of task supply and task compensation in Section II.

II. Data: Task Variables and Instruments

This section briefly describes how we construct measures of task supply in order to test the main implications of the model.[11] The IPUMS dataset by Ruggles et al. (2005) provides individual-level data on personal characteristics, employment, wages, immigration status, and occupation. We consider data from the decennial census for the period 1960–2000. We include US-born and foreign-born (immigrant) workers who were between 18 and 65 years of age. We calculate the potential experience of workers assuming that those without a degree started working at age 17, and those with a diploma started working at age 19. Whenever we construct aggregate or average variables, we weight each individual by his/her personal census weight, multiplied by the number of hours he/she worked in a year.

Since the immigrant share of employment varies greatly across US states, we interpret states as labor markets and adopt them as the econometric unit of analysis. One critique of this approach is that states are open economies, so the effects of immigration in one state could spill into others through the migration of natives. Most of the literature,[12] however, finds little to no evidence that, in the long run, natives respond to immigration through interstate migration or by exiting employment.[13] Instead, we provide a new explanation for the observed small wage and employment response to immigration. Native-born workers partly protect themselves from competition with immigrants by specializing in language-intensive occupations.

A. *Task Variables*

Construction and National Trends.—In light of our theoretical model, because of the correspondence expressed in (6), we can interpret j not only as representing different individual types, but also as identifying different occupations. Our quantitative analysis requires measures of the effective supply of manual (m_j) and communicative (c_j) tasks in each occupation. We assume that our task-intensity variables, described below, exactly capture this effective task-supply.[14]

[11] A more detailed account of the data, and of the task variable construction, can be found in Sections I–III of the Web Appendix.

[12] E.g., Card (2001, 2007), Card and Lewis (2007), Cortes (2008), Lewis (2005), and Ottaviano and Peri (2007).

[13] We confirm those results with our own analysis of the effect of immigrants on natives' employment reported in Section V of the Web Appendix.

[14] Table W1 in the Web Appendix provides c_j and m_j values for all occupations j.

By merging occupation-specific task values with individuals across census years, we are able to obtain these task supply measures for natives and immigrants by education level, in each state, over time. The US Department of Labor's *O*NET* abilities survey provides information on the characteristics of occupations. This dataset assigns numerical values to describe the importance of 52 distinct employee abilities (which we refer to as "tasks" or "skills") required by each occupation.[15] We merge these occupation-specific values to individuals in the 2000 census. We then rescale each skill variable so that it equals the percentile score in 2000 (between zero and one), representing the relative importance of that skill among all workers in 2000. For instance, an occupation with a score of 0.02 for a specific skill indicates that only 2 percent of workers in the United States in 2000 were supplying that skill less intensely. We then assign these *O*NET* percentile scores to individuals from 1960 to 2000 using the IPUMS variable *occ1990*, which provides an occupational crosswalk over time.[16]

Table A1 in the Appendix lists each of the 52 *O*NET* variables and organizes them into categories that we use to construct our manual and communication skill supply indices. In our "basic" definition of manual skills, we average only the variables capturing an occupation's "movement and strength" requirements.[17] Similarly, our basic definition of communication skills includes only measures of oral and written expression and comprehension.

The basic skill definitions described above manifest most closely the notion of communication and manual skills, and we prefer them. However, as a robustness check, some of our specifications employ an "extended" definition of manual skills, adding "sensory and perception" abilities (i.e., those using the five senses) to the physical skill group (see Table A1 for details). In the Web Appendix, we also show results that use an "extended" definition of communication skills in which we introduce "cognitive and analytical" and "vocal" abilities to that skill group (see Table A1). The simplicity of our two-skill dichotomy forces us to make a few judgment calls when trying to fit all the *O*NET* variables into one of the two categories, especially when using extended definitions. The robustness of our empirical results to the use of our extended definitions, however, lends support to our framework, which summarizes occupations with just two skill measures.

To produce the United States- or state-level variables, we calculate the aggregate supply of manual skills for less-educated immigrants (M_F), natives (M_D), or both groups of workers (M) by summing the values of m_j across individuals (weighted by hours worked). We follow an analogous procedure for aggregate communication skills (creating C_F, C_D, and C).

We now briefly describe how different occupations rank in their use of physical versus language skills according to the *O*NET* task variables, and we present some national trends. Table 1 shows the skill intensity for occupations maintaining the highest, lowest, and average c/m values among occupations with more than 25,000

[15] Classified using the standard occupation classification (SOC).

[16] See Barry R. Chiswick and Paul W. Miller (2007) or Sparber (2009) for alternative uses of *O*NET* data.

[17] Those skills can be further divided, as shown in Table A1, into "limb, hand, and finger dexterity;" "body coordination and flexibility;" and "strength."

Table 1—Occupations, Relative Task Intensity, and Changes in the Foreign-Born Share of Less-Educated Employment

Occupation	Communication intensity index	Manual intensity index	C/M percentile	Change in foreign-born share of less-educated employment 1970–2000 (percentage points)
Four occupations with highest communication/manual values				
Financial managers	0.83	0.23	0.999	+5.7
Managers of properties and real estate	0.74	0.21	0.997	+1.8
Editors and reporters	0.87	0.27	0.991	+12.2
Operations and systems researchers and analysts	0.64	0.20	0.990	+4.1
Five occupations with average communication/manual values				
Cashiers	0.38	0.73	0.562	+12.0
Cooks, variously defined	0.32	0.67	0.530	+19.9
Hairdressers and cosmetologists	0.30	0.62	0.498	+17.0
Repairers of industrial electrical equipment	0.36	0.77	0.490	+9.5
Kitchen workers	0.28	0.62	0.489	+2.8
Four occupations with lowest communication/manual values				
Vehicle washers and equipment cleaners	0.04	0.72	0.021	+20.6
Furniture and wood finishers	0.01	0.72	0.021	+13.4
Roofers and slaters	0.01	0.64	0.020	+26.4
Drywall installers	0.00	0.72	0.006	+24.2

Notes: Authors' calculations based on *O*NET* task definitions and censuses (1970–2000). The occupations included are those with more than 25,000 employees in each year. Only less-educated wage-earning employees between 18 and 65 years old and not living in group quarters are considered. The basic manual index is constructed averaging 19 measures that capture the intensity of several physical abilities. The basic communication task index is constructed averaging four measures that capture oral and written expression and comprehension. Both are standardized to be between zero and one. The details of their construction are reported in the main text and in the Web Appendix.

less-educated workers in each year. As we might expect, values of c/m are highest among managers, analysts, and clerks while construction workers and cleaners score among the lowest. Cooks, hair-dressers, and cashiers score near the average. Table 1 also reports the change in the foreign-born share of workers with a high school degree or less between 1970 and 2000. In accordance with our theory, the foreign-born share increased, on average, by only 6 percentage points in occupations with high communication versus manual task content, by about 12 percentage points in occupations with average communication-manual content, and by an average of 21 percentage points in those with low c/m values. As we only include less-educated workers in the immigration figures shown in Table 1, the educational distribution of immigrants cannot explain this large difference.

A similar message is conveyed in Figure 2, which reports the national trend (1970–2006) in the relative provision of communication versus manual tasks (C/M) for less-educated natives, recent immigrants (those who have been in the United States ten years or less), and long-term immigrants (those residing in the United

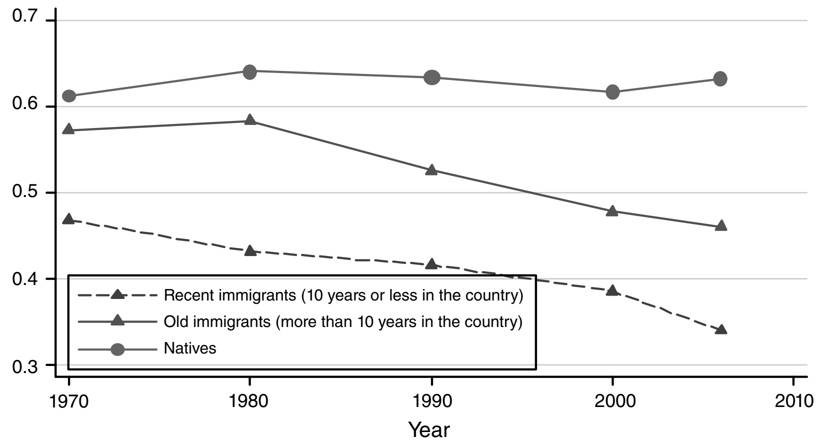


Figure 2. Communication/Manual Intensity of Natives, Recent Immigrants, and Long-Term Immigrants US (1970–2000)
(*Workers with a high school degree or less education*)

Notes: The relative C/M supply for the US economy is constructed by aggregating individuals' supply of communication and manual skills, weighted by their hours worked. Natives are individuals with US citizenship at birth. Recent immigrants are noncitizens or naturalized citizens who resided in the United States for ten years or less. Long-term immigrants are noncitizens or naturalized citizens who resided in the United States for more than ten years.
Source: Ruggles et al. (2005).

States more than ten years).[18] The graph highlights three stylized facts. First, the level of C/M provided by native workers with a high school degree or less has been higher than that of both recent and long-term immigrants with similar educational attainment. Second, relative skill values are always lowest among new immigrants. Third, cross-group disparities have been growing over time. Less-educated native workers have increased (if only slightly) their C/M supply between 1970 and 2006, while values have decreased among foreign-born workers. Altogether, the trends in Figure 2 do not suggest a common response of natives and immigrants to modified relative demand for skills but rather show increasing specialization of the two groups consistent with the idea that immigration represented an exogenous change in relative skill supply. The increase in the relative specialization in manual tasks of immigrants, combined with substantial growth of the immigrant share of less-educated workers,[19] implies that immigration represented a significant negative contribution to the overall value of C/M for the United States. If our theory is correct, this should have important ramifications for native-born task supply and wage earnings, which we analyze at the state level.

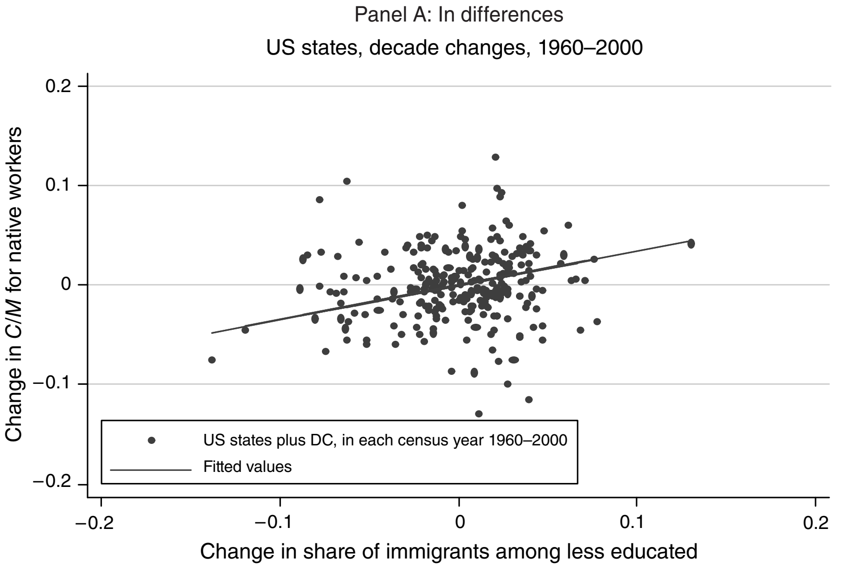
[18] Since the variable "year of immigration" is not available in 1960, we cannot extend this figure back to that year. We provide 2006 American Community Survey (ACS) data for comparison, though it is not part of the empirical analysis.
[19] See Figure W1 in the Web Appendix.

State-Level Quantities and Prices.—The empirical analysis of Section III assumes that states represent labor markets and can be used to test the implications of our theory in Section I. To perform the analysis, we must construct state-level skill data for less educated native workers (C_D/M_D) and immigrant workers (C_F/M_F) in each census year between 1960 and 2000. Importantly, we first clean this data of demographic effects since personal characteristics (such as age, education, gender, or race) affect individual (and state-level) task supply and may correlate with immigration. Failing to account for this could generate a spurious correlation between the presence of immigrants and the task supply of natives. Using a first-stage regression (separately for each census year, *O*NET* variable, and native-immigrant group), we obtain an individual's skill cleaned of demographic effects.[20] Averaging the cleaned *O*NET* variables belonging to each skill type, we compute an individual's total manual and communication task supply. We then create state-level averages for native workers $\left((c_D)_{st} \text{ and } (m_D)_{st}\right)$, and their ratio ($c_D/m_D = C_D/M_D$), for each state s and year t by weighting each individual by his or her personal weight (and hours worked). Using these data, panel A of Figure 3 plots the constructed relative task supply (C_D/M_D) for native workers (in differences from the overall 1960–2000 state average) against the immigrant share of less-educated workers for a state and year (also differenced from the overall state average). Panel B graphs the relative task supply and the immigrant share, in levels, for 2000. Both figures show a strong and significantly positive relationship between the two variables. States where the foreign-born presence grew rapidly between 1960 and 2000 were also those in which natives (after controlling for demographic characteristics) shifted their supply more toward communication tasks and away from manual ones. In 2000, there was a strong, positive correlation between the level of relative task supply among natives and the share of immigrants. These correlations constitute preliminary evidence supporting the prediction of our model that an inflow of less-educated immigrants pushes less-educated natives to supply more communication skills relative to manual ones.

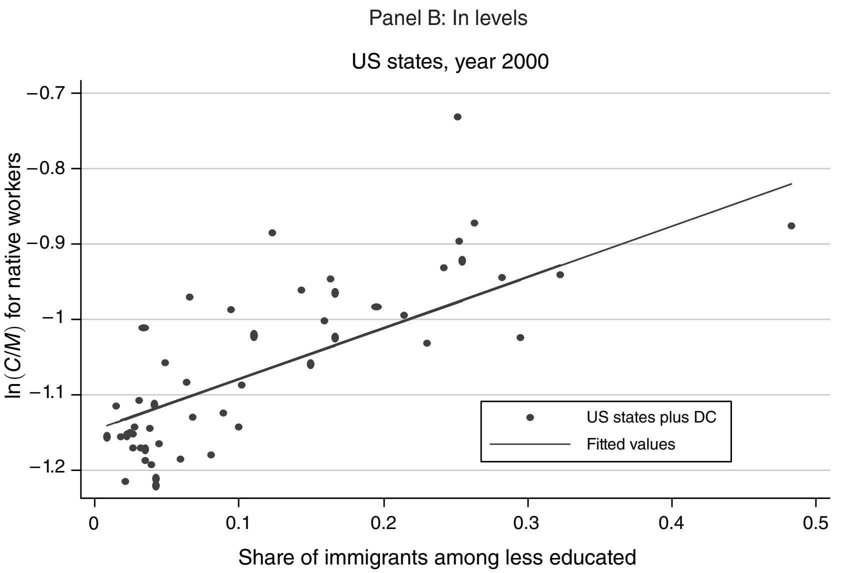
The second set of variables needed for our empirical analysis is the unit compensation of communication and manual skills, w_M and w_C, for each state and year. As we did for the skill data, we need to clean for the effect of individual characteristics. Moreover, in the case of wage compensation, we do not observe the unit wage paid to manual or communication tasks, but we only observe the wage paid to workers in each occupation. Hence, we use a two steps procedure for each state and year.[21] We first regress separately by year, the logarithm of individual real weekly wages on individual characteristics for workers with a high school degree or less. These regressions also include occupation by state dummies whose coefficients represent our estimates for the average "cleaned" log-wage, $\ln(\tilde{w}_{jst})$, for occupation j, state s, and census year t. In the second step, we transform $\ln(\tilde{w}_{jst})$ into levels and regress $\tilde{w}_{jst}$ on the occupation-specific measures of manual (m_j) and communication (c_j) skills (obtained from *O*NET*). We allow the coefficients on the skill variables to vary across states. By separately estimating the second-stage regression in equation (15)

[20] The first-stage cleaning procedure is described in detail in Section II of the Web Appendix.

[21] Again, Section II of the Web Appendix describes the details of the procedure.



Notes: The construction of C/M is described in detail in Section IIA. Fitted lines are from a weighted least squares regression (weights equal to less educated employment in the state). Slope $= 0.34$, Standard error $= 0.04$.



Notes: The construction of C/M is described in detail in Section IIA. Fitted lines are from a weighted least squares regression (weights equal to less educated employment in the state). Slope $= 0.67$, Standard error $= 0.10$.

Figure 3. Share of Immigrants and the Relative C/M Supply of Less-Educated Natives

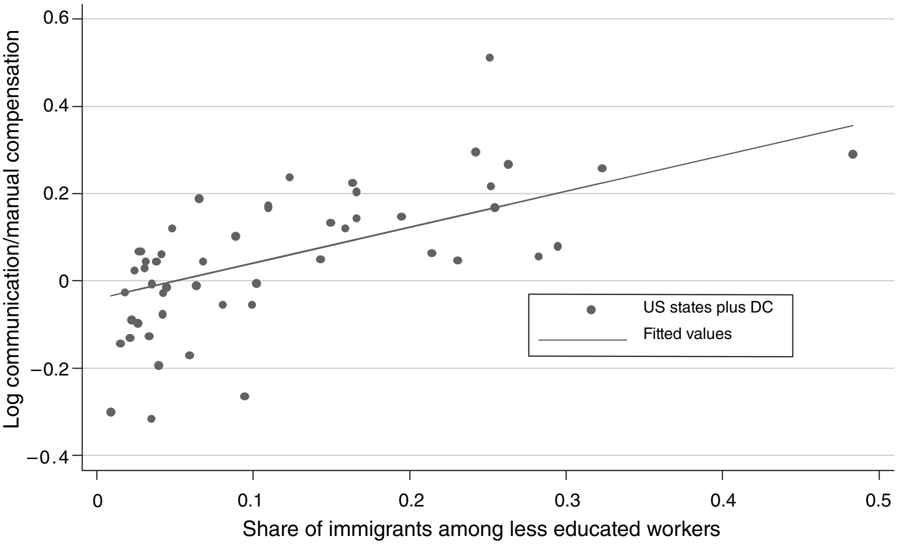


Figure 4. Less Educated Immigrant Share and the Compensation of Communication Relative to Manual Skills across US States, 2000

Notes: The relative compensation of communication and manual skills is constructed by first running an individual wage regression to clean for individual characteristics and then estimating the compensation of skills to vary across states using the average cleaned occupation wages. A detailed description of the procedure is in Section IIA of the text. The fitted line is from a weighted least square regression (weights equal to employment of less educated in the state). Slope = 0.82, Standard error = 0.13.

for each census year, we can identify the state and year-specific compensation, $(w_M)_{st}$ and $(w_C)_{st}$, received for supplying one unit of manual and communication tasks.

$$\tilde{w}_{jst} = (w_M)_{st}\, m_j + (w_C)_{st}\, c_j + \varepsilon_{jst}. \tag{15}$$

Interpreting m_j and c_j as the effective supply of manual tasks in occupation j (as expressed in the theoretical model), equation (15) implements the relationships in (4) and (5) to infer the values of w_M and w_C in a market (state) from the occupational wages. The fact that we controlled for nativity in the first-stage regression implies that we allow wages to differ between natives and immigrants by proportional factors (such as the discrimination effect in equation (5)). In order to obtain estimated coefficients $\widehat{w_M}_{st}$ and $\widehat{w_C}_{st}$ that could be interpreted as the weekly compensation of a unit of skill (and therefore always assuming positive values), we do not include a constant in (15).[22]

[22] Table A2 in the Table Appendix shows some estimates and statistics from implementing regression (15). We report, for each year, the average estimates (at the national level) of $\widehat{w_M}_{st}$ and $\widehat{w_C}_{st}$, the R^2 values, and the number of occupation-state observations used. The table shows that the average compensation to communication tasks was larger than the compensation to manual tasks in each year except for 1980, and since 1980 the premium for communication tasks has increased. It also shows that the model in (15) explains a significant share (30 to 40 percent in each of the years considered) of the cross-occupation variance in wages.

Using the constructed relative task compensation, Figure 4 shows preliminary evidence for another key prediction of our model. The horizontal axis again displays the immigrant share of less-educated foreign-born workers in 2000, and the vertical axis records the constructed relative compensation of communication versus manual tasks ($\hat{w}_C/\hat{w}_M$) by US state. Consistent with our model, states with a larger immigrant share also have higher ($\hat{w}_C/\hat{w}_M$) values (this is what drives natives to alter their skill supply). While Section IIIC will more formally establish the relationship between immigration and relative task compensation, this preliminary evidence emphasizes that a correlation (in levels) existed in 2000.

B. *Instrumental Variables*

Our basic empirical specifications in equations (12), (13), and (14) provide a simplified examination of the theoretical model's predictions. To establish whether correlation between the foreign-born employment share and native-born (or aggregate) skill use (and compensation) is causal, we need to ensure that the cross-state variation of less-educated immigrants is driven mostly by supply shifts. One concern is that unobserved technology and demand factors, which may differ across states, might have simultaneously affected the productivity of (demand for) communicative tasks and attracted immigrants. To establish causality, we use two sets of instruments that build on the fact that documented and undocumented Mexican immigration has represented a large share of the increase in the less-educated foreign-born population, beginning in the 1970s. This aggregate inflow was largely independent of state-specific demand shocks and can be exploited as an exogenous supply shift since it differed across states.

Our first instrument for the share of immigrants among less-educated workers is the share of "imputed" Mexicans among all workers. We impute the number of Mexican immigrants in a state based upon their distribution in 1960 and subsequent national growth rates of Mexican immigrants. This methodology[23] produces powerful instruments as new immigrants, especially those with little education, tend to move to the same areas in which previous immigrants from their source country live.[24] Also, unlike previous waves of immigration, a large proportion of immigrants between 1960 and 2000 came from Mexico. Together, these facts allow us to use the location preferences of Mexicans as factors affecting the supply of foreign-born workers across states and time that are uncorrelated with state-specific changes in demand (productivity).

Our second set of instruments similarly relies upon the exogenous increase in Mexican immigration, but is based on geography. We use the distance of each state's population center of gravity to its closest section of the Mexican border interacted with four census year dummies (1970–2000). This captures the fact that distance

[23] Card (2001) first used this methodology. Cortes (2008), Lewis (2005), Ottaviano and Peri (2007), and Albert Saiz (2008) followed a similar approach.

[24] This is due to information networks between immigrants and their country of origin, as well as to the immigration policy of the United States. The analysis in Krishna Patel and Francis Vella (2007) also shows evidence of strong "network" effects affecting the supply of immigrants. New immigrants are more likely to settle and work in occupations and areas with a large presence of co-nationals.

from the border had a larger effect in predicting the inflow of less educated workers in decades with larger Mexican immigration. Second, we use a Mexican border dummy interacted with decade indicators to capture the fact that border states had larger inflows of Mexican workers due to undocumented border crossings. Essentially, the use of the geographic instruments is equivalent to a difference-in-difference approach in which the identifying variation stems from differences in the inflow of Mexicans between states close to, and far from, the border in the post-1980 period (when Mexican migration rose dramatically) relative to previous decades.

III. Empirical Results

This section uses the empirical specifications in (12), (13), and (14) to formally test the relationships identified by the theoretical model. Section A assesses the correlation between the foreign-born share of less-educated workers and the relative supply of tasks by native workers across states. Section B tests the effect of immigration on the aggregate supply of relative tasks across states. Section C quantifies the effects of immigration on the relative compensation of manual and communication tasks.

A. *Immigration and the Relative Task Supply of Natives*

We begin by estimating equation (12) using least squares, weighting each observation by employment in the cell (thus, accounting for the large variation in labor market size across states), and clustering standard errors by state. This provides a direct test of our theoretical model by determining if γ is positive. We also ascertain whether immigration has a stronger relationship with the average native-born supply of manual (m_D) or communication (c_D) tasks by separately estimating equations (16) and (17).[25]

$$\ln(c_D)_{st} = \alpha_s^C + \tau_t^C + \gamma^C f_{st} + \varepsilon_{st}^C. \tag{16}$$

$$\ln(m_D)_{st} = \alpha_s^M + \tau_t^M + \gamma^M f_{st} + \varepsilon_{st}^M. \tag{17}$$

Columns 1 and 2 of Table 2 present the WLS estimates of γ, γ^C, and γ^M for different definitions of the task variables. Column 1 uses the basic definitions of language and manual ability involving the average of 4 and 19 *O*NET* variables, respectively. Column 2 uses the basic definition for language ability and the extended definition for manual ability (average of 37 *O*NET* variables).[26] Each specification uses the full sample of 255 observations (a decennial panel of 50 states plus the District of Columbia from 1960–2000). Three important results emerge. First, the estimates of γ strongly uphold our theory as the coefficients are between 0.31 and 0.34 and are always significantly positive at the 1 percent confidence level. The estimates in

[25] Recall that $m_D = M_D/L_D$ and $c_D = C_D/L_D$.

[26] Table W2 in the Web Appendix shows the WLS estimates using more restrictive and more inclusive definitions of manual and communication abilities. The results are very similar to those reported here.

Table 2—Foreign-Born Workers and the Native Supply of Tasks
(*Workers with a high school degree or less*)

Explanatory variable: foreign-born share of workers with a high school degree or less							
		(1)	(2)	(3)	(4)	(5)	(6)
Communication definition		Basic	Basic	Basic	Basic	Basic	Basic
Manual definition		Basic	Extended	Basic	Extended	Basic	Extended
Method of estimation		WLS		2SLS using imputed Mexican share, geographic variables as instruments		2SLS using imputed Mexican share, geographic variables as instruments	
Additional controls		State and year fixed effects		State and year fixed effects		State and year fixed effects, computer use, sector-driven C/M	
Dependent variables							
$\ln(C_D/M_D)$	γ	0.34***	0.31***	0.37***	0.33***	0.51**	0.44***
		(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
$\ln(c_D)$	γ^C	0.31***	0.31***	0.33***	0.33***	0.43***	0.43***
		(0.03)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
$\ln(m_D)$	γ^M	−0.03	0.00	−0.04***	0.00	−0.08***	−0.01
		(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
First stage							
Joint F-test of the instruments (p-value)		NA	NA	18.9	18.9	6.9	6.9
				(0.00)	(0.00)	(0.00)	(0.00)
Test of over-identifying restrictions		NA	NA	12.5	13.2	10.2	10.4
Probability ($\chi^2 >$ test) under the null of instrument exogeneity		NA	NA	0.14	0.11	0.25	0.24
Observations		255	255	255	255	255	255

Notes: Each cell contains estimates from a separate regression. The dependent variable in each is indicated in the first column. To construct the average manual m_D and communication c_D skill supply by native workers in a state-year, we first run individual regressions to control for individual age, experience, gender, and race. The state average (hours-weighted) of this "cleaned" supply represents the values c_D and m_D after controlling for individual demographic characteristics, and C_D/M_D is their ratio. The explanatory variable is the immigrant share of less-educated labor hours worked in the state and year. The units of observation in each regression are US states in a census year (decennial panel of 50 states plus Washington, DC from 1960–2000). All regressions include state and year fixed effects. The method of estimation in specifications (1)–(2) is weighted least squares. Regressions use employment as an analytic weight for each observation, and the standard errors are heteroskedasticity-robust and clustered by state. Specifications (3)–(6) use 2SLS using the imputed share of Mexicans (constructed as described in the main text), the distance between the center of gravity of the state and the Mexican border (interacted with decade dummies), and an indicator for states on the Mexican border (also interacted with decade dummies) as instruments. Specifications (5) and (6) include the percentage of workers using a computer at work and the sector-driven communication versus manual task-demand as controls.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

column 1 suggest that a 1 percentage-point increase in the foreign-born share of less-educated workers is associated with a 0.34 percent increase in the relative supply of communication versus manual tasks among natives. Second, this relative increase is primarily achieved through a rise in the supply of language skills, rather than a fall in natives' supply of physical labor. The estimate of γ^C in column 1 implies that a

1 percentage-point increase in the foreign-born share is associated with a significant 0.31 percent rise in natives' supply of communication tasks, whereas the estimates of γ^M imply that the native supply of manual tasks would only decline by 0.03 percent, a value not significantly different from 0. Third, the estimates are precise and robust to the different skill definitions used. The basic definition is the one producing the strongest and most significant results, while the definition that includes abilities not strictly related to physical skills produces a smaller value of γ.

In order to argue that our estimates of γ represent the native-born task supply *response* to immigration, the regressions in columns 3 and 4 of Table 2 perform the two-stage least squares counterparts of columns 1 and 2 by employing the instrumental variables introduced in Section IIB. The coefficients γ, γ^C, and γ^M of columns 3 and 4 are estimated by 2SLS using the imputed share of Mexicans and the geographic variables together as instruments, and, alternatively, the basic-basic and the basic-extended definitions for communication and manual skills, respectively[27]. The estimates of γ are still positive and very significant, and not very far from their WLS counterparts. They now range between 0.33 and 0.37. The *F*-tests reveal that the instruments strongly explain the endogenous variable (f_{st}), and they pass the test for over-identifying restrictions.[28] According to our preferred estimates (of column 3), natives respond to increases in immigration by significantly raising their communication task supply by 0.33 percent for each 1 percentage-point increase in the foreign-born share of less-educated workers. At the same time, they decrease the supply of manual tasks by 0.04 percent for each percentage-point increase in the foreign-born share. Note that the magnitude of the communication task response is much bigger than that of the manual response for all specifications. The similarity of the coefficients in columns 1 to 4, and the fact that the point estimates are slightly larger in the 2SLS regressions, strengthens our conviction that the immigration shock was largely an exogenous shift in the relative supply of skills at the state level to which native workers responded.

Finally state-specific technology and sector-driven changes in task demand could confound the baseline results. The regressions in columns 5 and 6 of Table 2 augment specifications (3) and (4) by controlling for these factors. In particular, they include a variable measuring the share of workers who use a computer at work (to control for the diffusion of information technology across states) and an index of relative task demand based on the state's initial industrial composition and the measured task demand by industries nationwide.[29] While the technological control variables usually have a significant coefficient with the expected sign (not reported) the inclusion of these variables leaves the estimates of γ extremely significant and

[27] Table W3 in the Web Appendix reports the estimates of the same specifications as (3) and (4) using different subsets of instruments. The results are very similar to those reported here.

[28] The value reported in the second to last row is the χ^2 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. We have eight degrees of freedom, one endogenous variable, and nine instruments (four distance-decade interactions, four border-decade interactions, and the imputed share of Mexican workers). 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. See Jeffrey M. Wooldridge (2002).

[29] The construction of both variables is described in detail in Section IV of the Web Appendix.

slightly increased.[30] Including those controls, the native task specialization response to immigration is between 0.44 percent and 0.51 percent for a 1 percentage-point rise in the share of foreign-born labor. Also, as in the other specifications, the positive impact on the supply of interactive skills (0.43) is larger and more significant than the negative effect on physical ones (between -0.08 and 0.00).

Altogether, the results of this section provide robust evidence for the increasing task-specialization of less-educated natives as a consequence of the immigration of less-educated workers. The relative supply of communication versus manual skills among natives increased by roughly 0.40 percent for each one percentage-point increase in the foreign-born share of less-educated workers.

B. *Immigration and Total Task Supply*

The regression specification in (13) provides a test of the equilibrium condition in (11) which argues for a negative relationship between immigration and the aggregate relative supply of communication versus manual tasks in a state. If true, the parameter γ_{TOT} will be negative. (This is the mechanism that alters the relative compensation of tasks and induces the change in the relative supply among natives as shown above.) However, we can also test whether immigration affects the average amount of communication (c) and manual (m) tasks supplied in equilibrium by running two separate regressions with $\ln(c)_{st}$ and $\ln(m)_{st}$ as dependent variables. Analogous to the specifications in (16) and (17), we call these coefficients γ_{TOT}^{C} and γ_{TOT}^{M}. We obtain $(C/M)_{st}$ by aggregating the supply of physical and language skills, using the cleaned individual supply of tasks among natives and immigrants.[31]

The upper part of Table 3 (panel A) shows the estimates of γ_{TOT}, γ_{TOT}^{C}, and γ_{TOT}^{M}. Manual and communication tasks are measured using two sets of *O*NET* variables, with the basic-basic definitions represented in columns 1 and 3 and the basic-extended definition used in columns 2 and 4.[32] Both the WLS (columns 1 and 2) and 2SLS (columns 3 and 4) regressions exhibit negative and significant estimates of γ_{TOT} with similar point estimates ranging between -0.11 and -0.18. This confirms the prediction of our model. The point estimates of our preferred specification (column 3), in which the basic skill definitions are applied and all instruments are used, implies that a 1 percentage point rise in the foreign-born share increases the average supply of manual tasks in the state by 0.05 percent (γ_{TOT}^{M}), and decreases the average supply of communication tasks by 0.10 percent (γ_{TOT}^{C}). Both coefficients are significant, and they lend support to the idea that the inflow of new immigrants decreases the overall relative supply of communication tasks in a state.

[30] The estimated coefficient on the technological variables and alternative specifications are reported in Table W4 of the Web Appendix.

[31] As described above, we perform separate first-stage regressions for foreign-born and native workers to calculate skill supplies cleaned of demographic effects.

[32] Table W5 in the Web Appendix shows the estimated coefficients for all combinations of basic and extended definitions of manual and communication abilities.

Table 3—Foreign-Born Workers, Aggregate Supply of Tasks and Communication-Manual Wage Elasticity
(*Workers with a high school degree or less*)

	(1)	(2)	(3)	(4)
Panel A: Explanatory variable: foreign-born share of workers with a high school degree or less				
Communication definition	Basic	Basic	Basic	Basic
Manual definition	Basic	Extended	Basic	Extended
Method of estimation	WLS		2SLS using imputed Mexican share, geographic variables as instruments	
Additional controls	State and year fixed effects		State and year fixed effects	
Dependent variables:				
Ln(*C/M*) γ_{TOT}	−0.18***	−0.13***	−0.15***	−0.11***
	(0.04)	(0.03)	(0.04)	(0.03)
Ln(*c*) γ^{C}_{TOT}	−0.12***	−0.12***	−0.10***	−0.09***
	(0.03)	(0.03)	(0.03)	(0.03)
Ln(*m*) γ^{M}_{TOT}	0.06***	0.01	0.05***	0.02
	(0.02)	(0.02)	(0.02)	(0.02)
First stage				
Joint *F*-test of the instruments	NA	NA	18.9	18.9
(*p*-value)			(0.00)	(0.00)
Panel B: Explanatory variable: Ln(C/M); dependent variable: Ln(w_C/w_M)				
Estimated relative wage elasticity:	−0.75**	−0.70	−1.58***	−1.36**
$-1/\theta_L$	(0.37)	(0.39)	(0.26)	(0.32)
Implied elasticity of substitution	1.33	1.42	0.63	0.73
First stage				
Joint *F*-test of the instruments	NA	NA	11.4	11.4
(*p*-values)			(0.00)	(0.00)
Observations	255	255	255	255

Notes: Each cell contains estimates from separate regressions. In panel A, the dependent variable is indicated in the first column and the explanatory variable is the foreign-born share of workers with a high school degree or less. The average manual and communication skill supply by native and immigrant workers in a state-year are cleaned in a first-stage regression. They are then combined using hours worked by natives and immigrants as a weight to produce total skill supply at the state-year level. The explanatory variable is the foreign-born share of less-educated labor. Panel B implements the estimation of coefficient $-1/\theta_L$ from equation (14) in the main text. The dependent variable is the relative compensation to communication versus manual tasks. The explanatory variable is the aggregate communication relative to manual skill supply. In all regressions, the units of observation are US states in a census year (decennial panel of 50 states plus Washington DC from 1960–2000). All regressions include state and year fixed effects. Regressions use employment as an analytic weight for each observation, and the standard errors are heteroskedasticity-robust and clustered by state. Specifications (1) and (2) are estimated using least squares. Specifications (3)–(4) are estimated with 2SLS, using the imputed share of Mexicans (constructed as described in the main text), the distance between the center of gravity of the state and the Mexican border (interacted with decade dummies), and an indicator for states on the Mexican border (also interacted with decade dummies) as instruments.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

C. *Immigration and Relative Task Compensation*

The regression specification in equation (14) tests the last important prediction of our model (obtained from the relative demand for skills), which argues that by decreasing the relative supply of communication skills in a state, immigration increases their relative rate of return. The lower part of Table 3 (panel B) estimates the relative compensation response to a state's changing task composition. In particular, exogenous shifts in the overall relative supply of physical versus language skills across states identify the coefficient $1/\theta_L$, where θ_L represents the elasticity of substitution between the tasks. Since exogenous immigration changes will affect the aggregate relative supply of skills (as shown in Section IIIB), we employ the exogenous determinants of the foreign-born share of workers as instruments in the 2SLS specifications. We acquire estimates for compensation paid to communication ($\widehat{w_{M}}_{st}$) and manual ($\widehat{w_{C}}_{st}$) tasks by state and year according to the methodology in Section IIA and then substitute those values into equation (14) to estimate $-1/\theta_L$. Table 3 panel B reports the estimates of $-1/\theta_L$ as well as their implied elasticity of substitution measured using the basic-basic (columns 1 and 3) and basic-extended (columns 2 and 4) task variable definitions.[33] We estimate (14) first by weighted least squares (columns 1 and 2) and then with the imputed Mexicans and geographic variables as instruments (columns 3 and 4). The instruments are relatively powerful in predicting the explanatory variable ($\ln(C/M)$), with an F-statistic above 10. The WLS estimates of $-1/\theta_L$ are between -0.7 and -0.75 while the 2SLS estimates range between -1.36 and -1.58. Both the 2SLS estimates are statistically significant at the 1 percent level. These estimates imply that the share of foreign-born workers significantly increases the relative compensation paid to communication versus manual tasks, thus validating a key mechanism in our model. The results suggest that the elasticity of substitution ranges between 0.63 (2SLS estimates) and 1.42 (WLS estimates). Hence, manual and communication tasks have a significant degree of complementarity. These figures are comparable to commonly estimated values for the elasticity of substitution between labor and capital (usually near 1), or between workers of different education levels (σ, which falls between 1.5 and 2).[34]

D. *Specification Checks and Extensions*

Our model's prediction for the wages of less-educated native workers employs two implicit simplifying assumptions. First, we assume that highly-educated natives are imperfect substitutes with all less-educated workers, and that their relative task supply is not affected by the presence of less-educated immigrants. Second, we assume that long-term immigrants are similar to new immigrants and different from native workers in that, relative to natives, they also have a comparative advantage in manual tasks. This allows us to group new and long-term immigrants together in our empirical analysis. In this section, we test the validity of these two assumptions. Moreover, we assume a homogenous response among US-born workers with a high school education or less. Our approach, however, allows us to identify the effect of immigration on the task specialization of specific demographic groups of less educated native workers. If γ varies across these groups, then the wage implications of immigration on those groups will vary as well. We also explore this possibility.

[33] Estimates using different sets of instruments are reported in Table W6 of the Web Appendix.
[34] See Katz and Murphy (1992) or Angrist (1995).

Impact on Highly-Educated Natives and Long-Term Immigrants.—Highly-educated workers (those with some college education) are not close substitutes for less-educated workers. Instead, they perform different production tasks (mostly analytical and cognitive) that are not affected by less-educated immigrants, and supply far fewer manual tasks than less-educated workers do. The average value of the manual supply index for workers with some college education is half of the average among those with a high school education or less, while the highly-educated supply of communication tasks is double that of less-educated workers. We also tested whether the average supply (by state and year) of tasks measured *among highly-educated natives* is affected by the *immigrant share of less educated workers* in the state and year.[35] While the standard errors are large, the regressions clearly indicate that there is no effect of less-educated immigration on the relative supply of communication and analytical tasks among highly-educated natives. The regressions also indicate that immigration does not affect the already small supply of manual tasks among highly-educated natives.

As for long-term immigrants, Figure 2 shows that they still supplied more manual versus communication tasks than natives throughout the 1970–2000 period. This similarity between new and long-term immigrants may be the reason that many authors find a larger effect of immigration on the wages of previous immigrants than on natives (see Card 2001; Ottaviano and Peri 2008; Cortes 2008). In the context of our model, the substitutability of skills among these groups implies that foreign-born workers will experience only a small (if any) reallocation of task supply in response to an inflow of new immigrants. They therefore experience more wage competition with new entrants. Column 1 of Table 4 compares estimates of γ, γ^C, and γ^M from regressions similar to (12), (16), and (17) where the dependent variable measures the task supply of less-educated workers, bifurcated between long-term immigrants (Group 1) and US natives (Group 2). The method of estimation is 2SLS using imputed Mexicans and geographic variables as instruments for the immigrant share of less educated workers.[36] The point-estimates show that long-term immigrants had a weaker tendency to respond to immigration by moving away from manual tasks and into communication tasks, relative to natives. Moreover the magnitude of the response is small for long-term immigrants ($\gamma = 0.24$ relative to 0.36 for natives), and the large standard errors imply that the estimates of γ for long-term immigrants are not significant at standard levels of confidence. Thus, the empirics concur with the predictions of our model. Though long-term immigrants are becoming more like natives in their skill use, their response to immigration is smaller and less significant, making them especially vulnerable to wage competition with new immigrants.

Impact across Demographic Groups.—The remaining columns of Table 4 compare estimates of γ, γ^C, and γ^M for groups of less-educated US natives, bifurcated by race (column 1), gender (column 2), age (column 3), and education (column 4). For each comparison, Group 1 represents those earning lower wages (blacks,

[35] The full set of estimates is reported in Table W7 in the Web Appendix.

[36] The full set of estimates using WLS and 2SLS methods of estimation with different sets of instruments is reported in Table W8 of the Web Appendix.

Table 4—Impact of Foreign-Born Workers on the Supply of Tasks among Different Demographic Groups
(*Controlling for individual characteristics in the construction of aggregate skills*)

Explanatory variable: foreign-born share among workers with a high school degree or less
Dependent variables: relative communication/manual skills for the group, basic definition

		Only US native workers are included in specifications (2) to (5)				
		(1)	(2)	(3)	(4)	(5)
Group 1		Long-term immigrants	Blacks	Women	Young (18–40)	High school dropout
Group 2		Natives	Nonblacks	Men	Old (41–65)	High school degree
Dependent variables						
Group 1, $\ln(C_1/M_1)$	γ	0.24	0.63**	0.11**	0.34***	0.34***
		(0.28)	(0.11)	(0.05)	(0.13)	(0.07)
Group 1, $\ln(c_1)$	γ^C	0.13	0.50**	0.10**	0.25**	0.28**
		(0.18)	(0.09)	(0.03)	(0.10)	(0.05)
Group 1, $\ln(m_1)$	γ^M	−0.11	−0.13**	−0.01	−0.09**	−0.06*
		(0.10)	(0.03)	(0.03)	(0.04)	(0.03)
Group 2, $\ln(C_2/M_2)$	γ	0.37**	0.20**	0.26**	0.11	0.20
		(0.05)	(0.10)	(0.11)	(0.08)	(0.14)
Group 2, $\ln(c_2)$	γ^C	0.33**	0.15*	0.20*	0.09	0.15
		(0.05)	(0.08)	(0.10)	(0.07)	(0.10)
Group 2, $\ln(m_2)$	γ^M	−0.04*	−0.05	−0.06**	−0.02	0.05
		(0.02)	(0.03)	(0.02)	(0.02)	(0.04)
Observations		255	255	255	255	255

Notes: Each cell contains estimates from separate regressions. The dependent variable is calculated for specific demographic groups. Column 1 shows the estimates for immigrants and natives. Columns 2–5 include native workers only in each group. In each comparison, Group 1 earns lower wages than Group 2 does. The average manual m_i and communication c_i skill supply for each group i in a state-year are calculated by averaging individual supply using personal weight times hours worked as weights. The units of observation in each regression are US states in a census year (decennial panel of 50 states plus Washington, DC from 1960–2000) for a total of 255 observations. All regressions include state and year fixed effects. The method of estimation is 2SLS using imputed Mexican and geographic IV. Regressions use employment in the cell as an analytic weight for each observation, and the standard errors are heteroskedasticity-robust and clustered by state.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

women, younger workers, and workers without a high school diploma). Except for women, individuals in Group 1 were also more specialized in manual than communication tasks, and more vulnerable to job competition with immigrants. The first three rows report the 2SLS estimates of γ, γ^C, and γ^M (using all instruments) for Group 1, and the remaining rows report the same coefficients for Group 2. Each of the eight native-born groups in Table 4 responds to immigration by shifting their specialization from manual tasks to communication tasks. The shift was significant in six cases, and the increase in supply of communication skills was more significant and larger than the decrease in supply of physical tasks for all eight groups. Interestingly, for each comparison, the native group that was more at risk to competition with immigrants (due to a larger reliance upon manual task performance) also exhibited a greater skill response. Men increased their relative skill supply by

0.26 percent for every percentage point increase in the foreign-born share, while women only increased theirs by 0.11 percent. Young workers and those without a high school diploma also significantly shifted their relative supply ($\gamma = 0.34$), while older workers, and those with a diploma, did not. This is not surprising since young workers have greater occupational mobility (older workers have very low rates of occupational change), and workers with extremely low educational attainment are potentially more threatened by immigrants. Most strikingly, black workers responded to immigration by changing their relative task specialization three times more than nonblack workers did ($\gamma = 0.63$ versus $\gamma = 0.20$). Blacks were much more specialized in manual tasks in comparison to nonblacks in 1960, and were more susceptible to competition with immigrants. The strong response among blacks in moving toward more language-intensive occupations should, at least in part, have shielded them from large negative wage effects.[37]

IV. Simulated Effects of Immigration on Real Wages, 1990–2000

Our empirical analysis suggests that to understand the wage implications of immigration, simulations must account for the adjustment in native-born task supply. Hence, we can use our model, production parameters (particularly σ), the estimated task complementarity (θ_L), and the effect of immigration on native-born task supply (γ) to simulate the full impact of immigration on the average wage of natives across US states.

We focus on the effect of immigration on wages paid to less-educated natives.[38] To do this, we must consider two channels. First, we need to obtain values for the percentage change in compensation to manual ($\Delta w_M/w_M$) and communication ($\Delta w_C/w_C$) tasks, and then weight those changes by the initial (pre-immigration) average task supply of natives (m_D and c_D).[39] Second, we need to account for the change in the effective supply of natives' manual and communication tasks due to immigration (Δm_D and Δc_D). The wage impact of this reallocation of tasks equals $(\Delta m_D)\, w_M + (\Delta c_D)\, w_C$. Altogether, equation (18) expresses the net effects of total immigration on average wages paid to native-born workers with little educational attainment, highlighting the contribution from these two channels.

$$(18) \qquad \frac{\Delta w_D}{w_D} = \underbrace{\frac{\Delta w_M}{w_M}\,\frac{w_M}{w_D}\,m_D + \frac{\Delta w_C}{w_C}\,\frac{w_C}{w_D}\,c_D}_{\textit{First Channel}} + \underbrace{(\Delta m_D)\,\frac{w_M}{w_D} + (\Delta c_D)\,\frac{w_C}{w_D}}_{\textit{Second Channel}}.$$

[37] We believe that the impact of immigration on subgroups of American workers, and blacks in particular, is worthy of further analysis. Borjas, Jeffrey Grogger, and Gordon H. Hanson (2006) present an alternative analysis of the effect of immigrants on black workers.

[38] The Appendix also shows the formula to obtain the effect of immigration on wages of highly educated workers.

[39] Equations (23) and (24) in the Appendix report the derived expressions for $\Delta w_M/w_M$ and $\Delta w_C/w_C$. The expressions are affected by inflows of both high and low education labor.

Table 5—The Simulated Effects of Immigration on Task Compensation and Average Native Wage, 1990–2000

	Percentage change of highly-educated due to immigration (1)	Percentage change of less-educated due to immigration (2)	Percentage change in wage of less-educated, assuming perfect native-immigrant substitution (3)	Percentage change in wage of less-educated due to task complementarities and specialization (4)	Overall percentage change of average wage paid to less-educated natives (3) + (4) (5)
Arizona	8	29	−8.2	2.5	−5.7
California	12	24	−4.5	2.3	−2.2
Nevada	16	34	−5.8	2.2	−3.6
New Jersey	13	10	1.6	1.3	2.9
New York	10	13	−0.7	1.6	0.9
Texas	8	22	−4.8	1.8	−3.0
United States	6	9	−1.2	0.9	−0.3

Notes: The variables and parameters used in the simulations reported above are described in the text. In particular, we assumed $\sigma = 1.75$ and $\theta_L = 1$. The six states chosen are those with the highest foreign-born employment shares among less-educated workers in 2000. The parameters used to estimate the change in supply of each task among native workers in response to immigration are the parameters in column 4 of Table 2, namely $\gamma^M = 0.33$ and $\gamma^C = -0.00$.

Importantly, there are two reasons why this model predicts a mitigated wage effect (that may even be positive) when compared to models that assume perfect substitution between natives and immigrants within education groups. First, while the impact on manual compensation ($\Delta w_M / w_M$) due to the increased supply of manual skills from immigrants is negative, it is weighted by the manual task supply of the natives, which is smaller than the manual supply of the average individual because the average includes foreign-born workers. Similarly, the positive (or less negative) impact on language compensation ($\Delta w_C / w_C$) is weighted by the language task supply of natives, which is larger than the average. Hence, the negative contribution from that term (labeled as "First Channel" in equation (18)) is smaller for less-educated natives than it is for the average less-educated worker. Second, the reallocation of tasks implies that $\Delta m_D < 0$ and $\Delta c_D > 0$, so that if the communication task supply response is larger than that of manual tasks, and if $w_M / w_D < w_C / w_D$ (both conditions are theoretically and empirically true), then the term labeled "Second Channel" in expression (18) would positively contribute to the average wage paid to domestic, less-educated workers. Hence, equation (18) reports the wage consequences of immigration on less-educated native workers, after accounting for task complementarity and for the reallocation of tasks by natives. That formula, combined with those in the Appendix (and plugging in the estimated parameters), allows us to simulate the effect of immigration on average wages paid to less-educated natives, once we feed in the percentage change in the supply of more- and less-educated workers due to immigration.

Table 5 reports such simulated effects of immigrant flows between 1990 and 2000 at the national level (last row) and for the six states with the highest immigrant share of less-educated labor in 2000 (listed alphabetically). The first two columns report the increase in foreign-born employment (as a percentage of 1990 total group employment) among workers with some college education ($\Delta H_F/H$), and those with a high school degree or less ($\Delta L_F/L$), respectively. While immigration of less-educated workers was larger than for more educated workers, flows were fairly balanced at the US level as the employment of more educated immigrant workers increased by 6 percent, while the employment of less educated immigrant workers increased by 9 percent.

Columns 3–5 simulate the wage consequences of immigration for less-educated native-born workers. In the simulations, we use a value of $\sigma = 1.75$, which is in the middle of the range of estimates usually found in the literature ($1.5 - 2.0$),[40] and we set $\theta_L = 1$, a value close to the average of our estimates in panel B of Table 4. Since the inflow of more educated immigrants was usually smaller than the inflow of less educated ones, the simulated wage effect on workers with a high school education or less is usually negative. However, in order to emphasize the new insight of this paper, column (3) reports the effect on average wages before accounting for any shift in domestic task supply or for differences in the relative supply of tasks. That is, these figures are useful for identifying the counter-factual wage effects identified by models that assume perfect substitutability between native and foreign-born workers of similar educational attainment.[41] Column 5, by comparison, reports the wage effects for less-educated natives accounting for the complementarity and reallocation of tasks following immigration, according to equation (18).[42] Column 4 provides the difference between these values. Thus, this column illustrates the difference between the wage effects estimated in our model of comparative advantage versus a traditional model of homogeneous less-educated labor.

By specializing in language skill-intensive occupations, less-educated natives reduce wage losses due to immigration. At the national level, specialization causes a reduction in this loss of almost 1 percentage point, from −1.2 percent to an ultimate loss of just −0.3 percent. In states with large immigrant flows (such as California, Arizona, and Nevada), task reallocation reduces the wage loss by around 2.4 percentage points. In New York, specialization changes the effect of immigration on less-educated natives from negative to positive values. Let us reemphasize, again, that the wage effects presented in column 5 of Table 5 are the results of simulations. Their differences reflect the implementation of formula (18), using the same parameter estimates (θ_L and γ) on different inflows of more- and less-educated immigrants by state.

It is also interesting to note that the figures in column 3 of Table 5 represent the wage consequence for *any* less-educated worker who possesses skills that are perfectly substitutable with immigrants and who fails to respond to new labor flows

[40] See Katz and Murphy (1992), Johnson (1997), and Goldin and Katz (2007).

[41] Note that before accounting for the specialization adjustment, immigration would have caused a wage loss in the United States of 1.2 percent for less-educated workers. As emphasized repeatedly in Ottaviano and Peri (2008), this relatively moderate consequence is due to the roughly balanced flow of immigrants across education groups (after merging the highly substitutable workers with no degree and those with a high school diploma together).

[42] We compute the values of Δc_D and Δm_D by multiplying the change in the foreign-born share of each state between 1990 and 2000 by the average response of communication and manual task supply to immigration found in column 4 of Table 2 (respectively +0.33 and −0.00). The resulting values are elasticities that, when multiplied by the initial average values of task supply, equal Δc_D and Δm_D.

by changing occupations. Thus, column 3 also illustrates the change in wages paid to previously established immigrant workers.[43] By extension, column 4 can then be interpreted as the percentage change in the relative wage between less-educated natives and foreign-born workers. If we divide those values by the percentage change in relative hours worked (L_F/L_D), we can obtain the inverse elasticity of substitution between immigrant and native workers implied by our model. This provides a useful benchmark to compare with direct measures of this elasticity, such as those recently provided by Ottaviano and Peri (2008). The resulting inverse elasticity of substitution between natives and immigrants obtained with this method ranges between 0.021 and 0.051 with an average of 0.03, thus implying an elasticity between 20 and 47, with an average of 33. These values are similar to those estimated by Ottaviano and Peri (2008). In particular, their preferred specifications (pooling men and women) report values between 0.024 and 0.047 (significant at the 1 percent level). Hence, the mechanism illustrated in this paper can explain most of their estimated imperfect substitutability. On the surface, an average inverse elasticity of 0.03 looks small. Given that relative supply has changed by as much as 60–90 percent, however, our estimates suggest a 2–3 percent change in the relative native-immigrant wage that favors natives. This relative effect is large enough to significantly reduce the potential wage loss among natives, and it implies that less-educated foreign-born workers are the ones who experience most of the negative wage consequences of new immigration.

V. Conclusions

The effects of immigration on the 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 different 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 in order to shield themselves from competition with immigrant labor. This paper provides a simple theoretical framework, and new 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 communication- 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 communication skills rises, thereby rewarding natives who progressively move to language-intensive jobs.

Our empirical analysis used *O*NET* data to measure the task content of occupations in the United States between 1960 and 2000. We find strong evidence supporting the implications of our theoretical model. On average, less educated immigrants supplied more manual tasks, relative to communication tasks, than

[43] This is because previous immigrants are similar to new immigrants in their task specialization and did not significantly change their task supply in response to immigration.

did natives. In states with large immigrant inflows, native workers shifted to occupations more intensive in language skills and less intensive in physical skills. At the same time, immigrants more than compensated for the change in skill supply among natives, ensuring an overall increase in manual task supply and driving communication task-intensive occupations to earn higher wages in those states. As a consequence, immigration-induced wage losses among less-educated native workers are significantly smaller than the losses predicted by models in which less-educated native and foreign-born labor is perfectly substitutable. In particular, we estimate that immigration only reduced average real wages paid to less-educated US-born workers by 0.3 percent between 1990 and 2000. Without task specialization that loss would have been 1.2 percent.

Appendix: Derivation of $\frac{\Delta w_H}{w_H}$, $\frac{\Delta w_M}{w_M}$, $\frac{\Delta w_C}{w_C}$, and $\frac{\Delta Y_L}{Y_L}$

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, C, and H to obtain their marginal products.

$$w_M = (\beta_L \beta) Y^{\frac{1}{\sigma}} Y_L^{\left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right)} M^{-\frac{1}{\theta_L}}. \tag{19}$$

$$w_C = (1 - \beta_L) \beta Y^{\frac{1}{\sigma}} Y_L^{\left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right)} C^{-\frac{1}{\theta_L}}. \tag{20}$$

$$w_H = P_H = (1 - \beta) Y^{\frac{1}{\sigma}} Y_H^{-\frac{1}{\sigma}}. \tag{21}$$

Highly-educated workers earn the unit price of the intermediate good they produce. The logarithmic differential of (21) directly measures the change in wages paid to highly-educated workers (w_H) in response to immigration (among both high- and low-education workers), and can be expressed as in equation (22), where $\kappa_H = (w_H H/Y)$ is the income share paid to highly-educated labor, and $(1 - \kappa_H)$ is the share paid to less-educated labor.

$$\frac{\Delta w_H}{w_H} = \frac{\Delta P_H}{P_H} = -\frac{1}{\sigma} \frac{\Delta H}{H} + \frac{1}{\sigma}\left(\kappa_H \frac{\Delta H}{H} + (1 - \kappa_H) \frac{\Delta Y_L}{Y_L}\right). \tag{22}$$

Wages paid to less-educated workers are divided into their task components. The first-order effect of immigration is equal to the percentage change in the intermediate good price P_L. Values for $(\Delta w_M / w_M)$ and $(\Delta w_C / w_C)$ in equations (23) and (24) are obtainable from logarithmic differentials of (19) and (20).

$$\frac{\Delta w_M}{w_M} = \frac{1}{\sigma}\left(\kappa_H \frac{\Delta H}{H} + (1 - \kappa_H) \frac{\Delta Y_L}{Y_L}\right) + \left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right) \frac{\Delta Y_L}{Y_L} - \frac{1}{\theta_L} \frac{\Delta M}{M}. \tag{23}$$

$$\frac{\Delta w_C}{w_C} = \frac{1}{\sigma}\left(\kappa_H \frac{\Delta H}{H} + (1 - \kappa_H) \frac{\Delta Y_L}{Y_L}\right) + \left(\frac{1}{\theta_L} - \frac{1}{\sigma}\right) \frac{\Delta Y_L}{Y_L} - \frac{1}{\theta_L} \frac{\Delta C}{C}. \tag{24}$$

Using equations (23) and (24), we can express the wage effect for less-educated workers at constant specialization by substituting for $\Delta w_M/w_M$ and $\Delta w_C/w_C$, and simplifying to obtain equation (25).[44]

$$(25)\qquad \frac{\Delta w_L}{w_L} = \frac{\Delta w_M}{w_M}\frac{w_M}{w_L}m + \frac{\Delta w_C}{w_C}\frac{w_C}{w_L}c = \kappa_M\frac{\Delta w_M}{w_M} + (1-\kappa_M)\frac{\Delta w_C}{w_C}.$$

Note that (25) represents the average manual and communication wage effects weighted by their respective initial supplies. The total effect of immigration on the average, native-born, less-educated worker, accounting for (25) as well as for the effect of changing specialization, is given by equation (18) in the main text.

To derive $\Delta Y_L/Y_L$, first note that, since Y_L is produced under perfect competition using services of less educated workers, we know the total income generated in sector Y_L will be distributed to less-educated workers as in equation (26).

$$(26)\qquad P_L Y_L = w_L L = w_M M + w_C C.$$

This allows us to relate changes in the production of Y_L to small changes in inputs M and C as in equation (30). The formal proof hinges only on constant returns to scale to M and C in (2). First, rewrite equation (30) by dividing by $P_L Y_L$. Then, take the total differential with respect to M and C to find equation (27).

$$(27)\qquad \frac{dY_L}{Y_L} = \frac{d\left(\frac{w_M}{P_L}\frac{M}{Y_L} + \frac{w_C}{P_L}\frac{C}{Y_L}\right)}{dM}dM + \frac{d\left(\frac{w_M}{P_L}\frac{M}{Y_L} + \frac{w_C}{P_L}\frac{C}{Y_L}\right)}{dC}dC.$$

From the definition of wages, we know that $w_M/P_L = dY_L/dM$ and $w_C/P_L = dY_L/dC$. Distributing the differentiation with respect to M and C, we can rewrite (27) as in (28).

$$(28)\qquad \frac{dY_L}{Y_L} = \frac{w_M M}{P_L Y_L}\frac{dM}{M} + \frac{w_C C}{P_L Y_L}\frac{dC}{C} + \left[\frac{d\left(\frac{dY_L}{dM}\right)}{dM}\frac{M}{Y_L} + \frac{d\left(\frac{dY_L}{dC}\right)}{dM}\frac{C}{Y_L}\right]dM$$
$$+\left[\frac{d\left(\frac{dY_L}{dM}\right)}{dC}\frac{M}{Y_L} + \frac{d\left(\frac{dY_L}{dC}\right)}{dC}\frac{C}{Y_L}\right]dC.$$

Due to constant returns to scale of M and C in Y_L, the expression $(dY_L/dM) \times (M/Y_L) + (dY_L/dC) \times (C/Y_L)$ equals one (Euler Condition). Constant returns also imply that the second derivatives (with respect to M or C), multiplied by the shares M/Y_L and C/Y_L, sum to zero. Hence, the two terms in brackets equal zero so that (27) reduces to (29).

$$(29)\qquad \frac{dY_L}{Y_L} = \frac{w_M M}{P_L Y_L}\frac{dM}{M} + \frac{w_C C}{P_L Y_L}\frac{dC}{C}.$$

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

Finally, we label the term $w_M M/P_L Y_L = w_M M/w_L L$ as κ_M, and $w_C C/P_L Y_L = w_C C/w_L L$ as $(1 - \kappa_M)$. We then use Δ, rather than d, to indicate a small (rather than an infinitesimal) change to obtain equation (30)

$$(30) \qquad \frac{\Delta Y_L}{Y_L} = \frac{w_M \Delta M + w_C \Delta C}{P_L Y_L} = \kappa_M \frac{\Delta M}{M} + (1 - \kappa_M) \frac{\Delta C}{C}.$$

Appendix Table A1— Skill Types, Sub-Types, and Variables from *O*NET*

Type of skill	Definition	Skill sub-type	*O*NET* variables
Manual (or physical) skills	Basic definition: movement and strength	Limb, hand, and finger dexterity	Arm-hand steadiness; manual dexterity; finger dexterity; control precision; multilimb coordination; response orientation; rate control; reaction time; wrist-finger speed; speed of limb movement
		Body coordination and flexibility	Extent flexibility; dynamic flexibility; gross body coordination; gross body equilibrium
		Strength	Static strength; explosive strength; dynamic strength; trunk strength; stamina
	Extended definition: movement and strength plus sensory-perception skills	General perception	Perceptual speed; spatial orientation; visualization; selective attention; time sharing
		Visual perception	Near vision; far vision; visual color discrimination; night vision; peripheral vision; depth perception; glare sensitivity
		Hearing perception	Hearing sensitivity; auditory attention; sound localization
Communication (or language) skills	Basic definition: oral and written	Oral	Oral comprehension; oral expression
		Written	Written comprehension; written expression
	Extended definition: oral and written plus cognitive, analytical, and vocal skills	Cognitive and analytical	Fluency of ideas; originality; problem sensitivity; category flexibility; mathematical reasoning; number facility; deductive reasoning; inductive reasoning; information ordering; memorization; speed of closure; flexibility of closure
		Vocal	Speech recognition; speech clarity

Note: *O*NET* variables are from the *O*NET* abilities survey available at http://www.onetcenter.org/.

Table A2—Summary Statistics for the Estimated State-Specific Compensation of Manual and Communication Tasks, Basic Definitions of Skills

Year	Average W_M	Average W_C	R^2	Observations
1960	519	566	0.41	7738
1970	603	704	0.43	10591
1980	664	617	0.31	15880
1990	547	557	0.38	15607
2000	543	576	0.32	15142

Notes: The compensation paid to manual and communication tasks is in 2000 US dollars and corresponds to weekly returns. The R^2 are from Regression (15) when estimated with a constant term.

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