Gifts of the Immigrants, Woes of the Natives: Lessons from the Age of Mass Migration

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January 25, 2019

ONLINE APPENDIX F

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F. Theoretical Framework

F.1 Overview

In what follows, I present a simple model to explain the three key findings of Section 6 in the paper, namely that immigration

1. Increases natives' employment, without generating negative effects even for workers in highly exposed occupations

2. Boosts economic activity, capital utilization, and productivity

3. Increases (reduces) the fraction of natives employed in high (low) occupations, and promotes natives' occupational upgrading

I build on a model of biased technical change (Acemoglu, 2002), where a final good is produced combining two intermediate inputs. One of the two intermediate inputs is produced using only non-production (proxy for high skilled) workers, while the other uses both laborers (proxy for low skilled workers) and capital.[1] Capital is, in turn, endogenously supplied by a continuum of manufacturing establishments, each producing a different variety. In this standard set-up, I formally show under what conditions an immigration shock in the unskilled sector can benefit high skilled natives without harming workers in the more exposed sector. As in the more general model of Acemoglu (2002), the key intuition is that, by increasing the supply of unskilled labor, immigration can induce an endogenous response from the production side (i.e., the entry of new plants), which can partly (or even completely) accommodate the inflow of immigrants.

Next, I present two extensions of the model. First, I assume that immigrants and native laborers are imperfect substitutes, and show that the degree of capital adjustment needed to absorb the immigration shock is lower than in the baseline version of the model. This is intuitive: on the one hand, the negative (competition) effect induced by immigration is lower, since immigrants are only imperfect substitutes for unskilled natives; on the other, the complementarity between the skills of natives and those of immigrants makes firms' investment even more profitable than before. Second, I endogeneize natives' sectoral choice, assuming that natives can work in both the skilled and the unskilled sector, while immigrants are barred from non-production occupations. Following the inflow of immigrants, natives reallocate their labor away from the unskilled (and more exposed) sector and towards more skilled occupations. In this case, immigration is absorbed by two distinct channels: first,

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[1]See Goldin and Katz (2009) for the relationship between production and non-production workers and education or skills in the early twentieth century.

through an increase in firms' investment, as before; second, via occupational mobility of natives who tend to take up jobs where they have a comparative advantage relative to immigrants.[2]

F.2 Set-Up

F.2.1 Demand Side

I consider a general equilibrium model with two types of workers, skilled and unskilled, who have the same utility function over consumption of the final good

$$U\left(C\left(t\right)\right) = \int_0^\infty \exp\left(-\rho t\right) \frac{C^{1-\theta}\left(t\right)}{1-\theta} dt$$

where ρ is the discount rate and θ is the intertemporal elasticity of substitution (or, equivalently, the coefficient of relative risk aversion). To ease notation, whenever possible, I drop the time index. The budget constraint is given by

$$C + I + Z \leq Y$$

where I and Z denote respectively investment and expenditures to enter the manufacturing sector and produce capital supplies (introduced below).[3]

F.2.2 Supply Side

The final good (Y) is produced combining two intermediate inputs, Y_H and Y_L, according to a CES production function

$$Y = [Y_H^\gamma + Y_L^\gamma]^{\frac{1}{\gamma}} \tag{F1}$$

where $\gamma \leq 1$ governs the elasticity of substitution between the two intermediate goods.[4] The price of the final good is normalized to 1, and both Y_H and Y_L are produced by a large number of perfectly competitive firms. Since I am interested in evaluating the effects of a change in the supply of unskilled labor (induced by an immigration shock), to simplify the analysis, I assume that Y_H is produced using only high skilled workers, while both unskilled

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[2] Peri and Sparber (2009) is the first paper that formally shows empirically and theoretically this mechanism. However, the forces highlighted in my model are rather different from those originally proposed in Peri and Sparber (2009).

[3] I assume that the standard no Ponzi condition holds, so that the lifetime budget constraint is satisfied.

[4] The elasticity of substitution betwen Y_H and Y_L is given by $\varepsilon = \frac{1}{1-\gamma}$. When $\gamma = 1$, i.e. $\varepsilon \to \infty$, the two intermediate goods are perfect substitutes; when $\gamma \to 0$, i.e. $\varepsilon \to 1$, Y is produced according to a Cobb-Douglas; when $\gamma \to -\infty$, i.e. $\varepsilon \to 0$, Y_H and Y_L are perfect complements.

labor and capital are used in the production of Y_L:[5]

$$Y_H = H$$

and

$$Y_L = KL^\beta \tag{F2}$$

Capital is, in turn, the aggregate of inputs (that I refer to as machines) supplied by a continuum of manufacturing plants, each producing a different variety, $k_L(v)$

$$K = \frac{1}{1-\beta} \int_0^{N_L} k_L^{1-\beta}(v)\, dv$$

where N_L is the number of manufacturing plants (and thus of varieties).

F.2.3 Production of Machines

As in Acemoglu (2002), machines are assumed to fully depreciate after use, and are supplied by monopolists at price $p_L^k(v)$ for all $v \in [0, N_L]$. Once a specific machine is invented, the monopolist has full property rights over that variety, and can produce it at marginal cost $\lambda \equiv 1 - \beta$. Finally, I assume that one unit of the final good used in the development of machines directed towards Y_L generates η_L new varieties of L-complementary machines. That is,

$$\frac{dN_L(t)}{dt} = \eta_L Z(t) \tag{F3}$$

F.3 Equilibrium

An equilibrium is defined as a set of prices of machines, p_L^k, that maximizes monopolists' profits, demand for machines, x_L, that maximizes profits of producers of intermediate good Y_L, factor and product prices, w_L, w_H, p_L, and p_H, such that markets clear, and number of machine varieties, N_L, that satisfies the free entry condition.

First, because of perfect competition, prices of Y_H and Y_L, p_H and p_L, are equal to their marginal products:

$$p_H = Y_H^{\gamma-1} [Y_H^\gamma + Y_L^\gamma]^{\frac{1}{\gamma}-1} \tag{F4}$$

and

$$p_L = Y_L^{\gamma-1} [Y_H^\gamma + Y_L^\gamma]^{\frac{1}{\gamma}-1} \tag{F5}$$

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[5]I assume that the labor markets are competitive and clear at every instant. For now, I also assume that skill supplies are given, but below I endogeneize native workers' occupational choice (see Section F.5.2).

The price ratio is thus[6]

$$p \equiv \frac{p_H}{p_L} = \left(\frac{H}{Y_L}\right)^{\gamma - 1} \tag{F7}$$

Since $Y_H = H$, it follows directly that

$$w_H = p_H \tag{F8}$$

Next, from the maximization problem of producers of good Y_L, it is possible to derive the demand for machines:

$$k_L(v) = \left(\frac{p_L}{p_L^k(v)}\right)^{\frac{1}{\beta}} L \; \forall v \tag{F9}$$

The profit maximization of monopolists, in turn, implies that the price of each variety is given by

$$p_L^k(v) = 1 \; \forall v \tag{F10}$$

so that

$$k_L(v) = p_L^{\frac{1}{\beta}} L \; \forall v \tag{F11}$$

Using $(F11)$ and $(F10)$, monopolists' profits are then

$$\pi_L = \beta p_L^{\frac{1}{\beta}} L \tag{F12}$$

implying that the net present discounted value of profits for a monopolist is

$$V_L = \frac{\beta p_L^{\frac{1}{\beta}} L}{r} \tag{F13}$$

where r is the interest rate. Even though, in principle, the interest rate can be time-varying, I focus on a balanced growth path (BGP), where r is constant and equal to $(\theta g + \rho)$, where g is the steady state growth rate of output (see below).

Replacing $(F11)$ in $(F2)$, we get

$$Y_L = \frac{N_L L}{1 - \beta} p_L^{\frac{1 - \beta}{\beta}} \tag{F14}$$

Using $(F14)$, and solving the maximization problem of intermediate producers in sector L,

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[6]It should be noted that normalizing the price of the final good to 1 is equivalent to write

$$\left[p_H^{\frac{\gamma}{\gamma - 1}} + p_L^{\frac{\gamma}{\gamma - 1}}\right]^{\frac{\gamma - 1}{\gamma}} = 1 \tag{F6}$$

one can derive the unskilled wage, given by

$$w_L = \frac{N_L}{1 - \beta} p_L^{\frac{1}{\beta}} \tag{F15}$$

Finally, the free entry condition in the machine-producing market implies that

$$V_L \eta_L = 1$$

Or,

$$\eta_L \beta p_L^{\frac{1}{\beta}} L = r$$

The previous expression pins down the price of Y_L as a function of r, η_L, β, and L:[7]

$$p_L = \left(\frac{r}{\eta_L \beta L} \right)^{\beta} \tag{F16}$$

In online appendix G, I show that, using $(F16)$ in $(F14)$ and combining the resulting expression with $(F5)$ and $(F6)$, it is possible to derive an equation that characterizes the relationship between the equilibrium number of plants, N_L, and the supply of both high and low skilled workers (H and L):

$$N_L = \frac{H(1-\beta) L^{\frac{\beta\gamma}{1-\gamma}}}{\psi^{(1-\beta)} \left[\psi^{\frac{\beta\gamma}{1-\gamma}} - L^{\frac{\beta\gamma}{1-\gamma}} \right]^{\frac{1}{\gamma}}} \tag{F17}$$

where $\psi \equiv \frac{r}{\eta_L \beta}$.

The last step to fully characterize the steady state equilibrium of the economy is to determine the BGP growth rate, g. As noted above, along the BGP, $r = \theta g + \rho$. Using the free entry condition into the monopolist sector, it can be shown that (see also Acemoglu, 2002)[8]

$$g = \frac{1}{\theta} [\beta \eta_L L - \rho] \tag{F18}$$

Before turning to the comparative statics exercise of the next section, where I study the effects of immigration on the economy, let me highlight three important results, which will be used extensively below. Direct inspection of $(F16)$ and of $(F17)$ shows that

$$\frac{\partial p_L}{\partial L} < 0 \tag{F19}$$

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[7] Note that, once we have p_L, it is immediate to get p_H from $(F6)$: $p_H = \left(1 - \left(\frac{L}{\psi} \right)^{\frac{\gamma\beta}{1-\gamma}} \right)^{\frac{\gamma-1}{\gamma}}$.

[8] Note that, from the No Ponzi condition it directly follows that $\rho > g(1 - \theta)$.

$$\frac{\partial N_L}{\partial H} > 0 \ \forall \gamma \tag{F20}$$

and, most importantly,

$$\gamma > 0 \implies \frac{\partial N_L}{\partial L} > 0 \tag{F21}$$

The three results, $(F19)$, $(F20)$, and $(F21)$, are standard in the biased technical change literature (Acemoglu, 1998, 2002). However, especially $(F21)$ will be very important when studying the effects of immigration in the next section, so it is worth briefly discussing the intuition behind it. Specifically, incentives to enter the manufacturing sector depend on two forces - a price and a market size effect. When the former dominates, an increase in the supply of a given factor reduces incentives to introduce technologies complementary to that factor. When the latter prevails, instead, higher supplies of a factor will make it more profitable to develop technologies biased towards that factor. As stated in $(F21)$ (see the proof in online appendix G), if $\gamma > 0$, i.e. when the degree of complementarity between high and low skilled workers is not too high, the market size effect will be stronger, and an increase in the supply of unskilled labor will induce capital accumulation in the unskilled sector, by increasing the number of plants producing technologies that are unskill-biased.

F.4 Evaluating the Effects of Immigration

In this section, I study how an exogenous increase in immigration affects the economy. To mirror the empirical setting considered in my paper, I assume that immigrants can only be employed in the unskilled sector, and do not have access to high skilled jobs, either because of skill mismatch or because of discrimination. For the moment, I assume that unskilled natives and immigrants are perfect substitutes, and that natives' labor supply in each sector is fixed. Below, I relax both these assumptions. Before turning to the analysis, note the followings. First, it is trivial to see that an increase in N_L mechanically favors capital accumulation. Second, from $(F15)$ it is immediate to verify that the unskilled wage is increasing in N_L and decreasing in L. Third, from $(F6)$, it follows directly that an increase in p_L will lower p_H, so that higher (lower) p_L will depress (increase) the high skilled wage.

Now, assume that the economy experiences an exogenous inflow of immigrants, which increases L. What happens to capital, wages, and the skill premium?

Capital Accumulation. First, from $(F21)$, we know that if

$$\gamma > 0 \tag{F22}$$

N_L is increasing in L. Hence, the first result is that, if $(F22)$ holds, immigration favors

capital accumulation in the unskilled sector.[9]

High Skilled Wages. Second, it is immediate to see from $(F16)$ that higher immigration will reduce the price of Y_L, p_L, and, in turn raise p_H and w_H (see $(F6)$). Thus, immigration has a positive and unambiguous effect on high skilled wages.

Unskilled Wages. Turning to the impact of immigration on wages of unskilled workers, there are two countervailing forces. First, immigration has a negative effect on unskilled wages - the standard *substitution effect* that takes place as the economy moves along the (downward sloping) demand curve. Second, if $\gamma > 0$, there is a *directed technology effect* (Acemoglu, 1998): the increase in skill supplies (induced by immigration) increases incentives to open new plants and develop skill-complementary technologies, in turn exerting positive pressure on w_L. Remember that

$$w_L = \frac{\psi N_L}{L(1-\beta)} \tag{F23}$$

Then, from the previous expression, it is immediate to see how the two channels (the substitution effect and the capital response) just described affect the unskilled wage. Online appendix G provides an expression showing for which parameter values the directed technology effect prevails over the substitution effect. In line with Acemoglu (2002), this happens when γ is sufficiently large.[10] The main take-away from this discussion is that, when technology is allowed to be directed and as long as $\gamma > 0$, the standard (substitution) negative effect of immigration on earnings of unskilled natives will be partly (or even completely) offset by the endogenous technology response.

Skill Premium. Finally, I evaluate the effects of immigration on the skill premium, $\omega \equiv \frac{w_H}{w_L}$. Using the equilibrium conditions derived above, the skill premium can be written as

$$\omega = \left(\frac{1-\beta}{\psi}\right) \frac{\left(1-\left(\frac{L}{\psi}\right)^{\frac{\gamma\beta}{1-\gamma}}\right)^{\frac{\gamma-1}{\gamma}}}{N_L(L)} L \tag{F24}$$

where I am emphasizing the fact that, in equilibrium, N_L is a function of L (see $(F17)$). From $(F24)$, it is clear that an increase in L (induced by immigration) has two separate effects on the skill premium. First, higher L reduces w_L because of substitution and increases w_H because of complementarity (at least as long as $\gamma < 1$). Second, there is an indirect effect, operating through changes in N_L. Whenever $\gamma > 0$, the latter will tend to offset (and, if γ is sufficiently high even reverse) the positive effect of immigration on the skill

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[9]This result follows directly from the fact that, in equilibrium, $K = \frac{N_L}{1-\beta}\psi$.

[10]In particular, a sufficient (but not a necessary) condition for the total effect of immigration on the unskilled wage to be positive is that $\gamma > \frac{1}{1+\beta}$. This condition can be equivalently expressed in terms of the derived elasticity of substitution, $\sigma \equiv \left(\frac{1}{1-\gamma} - 1\right)\beta + 1$, as $\sigma > 2$ (Acemoglu, 2002).

premium. In online appendix G, I explicitly derive expressions for each of the two forces, and provide a sufficient condition (in terms of γ and β) under which immigration reduces the skill premium.[11]

To summarize, when technology is endogenous and ($F22$) holds, an exogenous shock to immigration:

1. Increases capital accumulation in the unskilled sector

2. Raises the high skilled wage

3. Has ambiguous effects on both the unskilled wage and the skill premium. If the degree of substitutability between factors (i.e. γ) is sufficiently high, immigration can even be beneficial to unskilled natives.

Of course, one should not conclude that immigration is necessarily beneficial to *all* natives. In fact, the previous analysis makes it clear that, for immigration to benefit (or at least not to harm) natives in the more exposed sector, specific conditions - in particular, scope for capital accumulation and technological upgrading - must be satisfied.

F.5 Extensions

Thus far, I have neglected two potentially important mechanisms that, in addition to the capital response highlighted above, can help natives in more exposed occupations to cope with a sudden increase in immigration. First, I assumed that immigrants and unskilled natives are perfect substitutes in production; second, I fixed natives' labor supply in each sector. Yet, a large body of the literature has documented that neither condition is likely to hold in practice (Card, 2005; Peri and Sparber, 2009; Ottaviano and Peri, 2012; Foged and Peri, 2016). For this reason, and to more thoroughly analyze the channels through which immigration affects natives' labor market outcomes, I now relax each of the two assumptions.

F.5.1 Imperfect Substitutability Between Immigrants and Natives

I start by relaxing the assumption that immigrants and unskilled natives are perfect substitutes. In particular, I specify the total supply of unskilled labor as

$$L = [I^{\alpha} + U^{\alpha}]^{\frac{1}{\alpha}} \tag{F25}$$

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[11] As in Acemoglu (2002), a sufficient condition for ω to fall with L is that $\gamma > \frac{1}{1+\beta}$.

where I and U refer, respectively, to immigrants and unskilled natives, and $\alpha \leq 1$ governs the elasticity of substitution between the two. When $\alpha \to 1$, we are in the limit case of perfect substitutability considered above. Since immigrants and unskilled natives are likely to display at least some degree of substitutability, I assume that $\alpha > 0$, but do not restrict this parameter any further.

When $\alpha \in (0,1)$, an increase in immigration will raise the unskilled labor aggregate in $(F25)$ more than one for one. To see this, note that

$$\frac{\partial L}{\partial I} = \left[1 + \left(\frac{U}{I}\right)^{\alpha}\right]^{\frac{1-\alpha}{\alpha}} \tag{F26}$$

As long as $\alpha \in (0,1)$, the term inside the square brackets is strictly greater than 1, and elevating this to $\left(\frac{1-\alpha}{\alpha}\right)$ will never yield a number below 1 (in the limit case of $\alpha = 1$, the increase in I will imply a one for one increase in L). It follows that

$$\frac{\partial L}{\partial I} \geq \frac{\partial L}{\partial L} = 1 \tag{F27}$$

with a strict inequality whenever $\alpha \in (0,1)$. The result in $(F27)$ is going to be important for some of the comparative static exercises below.

From now onwards, let us consider only the (empirically relevant) case in which $0 < \alpha < 1$. As before, I now study the effects of an exogenous increase in immigration on capital, wages, and on the skill premium.

Capital Accumulation. Remember from above that as long as $\gamma > 0$, $\frac{\partial N_L}{\partial L} > 0$. Hence, $(F27)$ immediately implies that

$$\frac{\partial N_L}{\partial I} > \frac{\partial N_L}{\partial L} > 0 \tag{F28}$$

In words, once we allow for immigrants and unskilled natives to be imperfect substitutes (i.e. $\alpha \in (0,1)$), if $\gamma > 0$, not only immigration has a positive effect on the number of plants producing machines complementary to unskilled workers, but also, this effect is going to be larger than in the baseline case of perfect substitutability.

High Skilled Wages. Since

$$w_H = \left(1 - \left(\frac{L}{\psi}\right)^{\frac{\gamma\beta}{1-\gamma}}\right)^{\frac{\gamma-1}{\gamma}}$$

it follows that $\frac{\partial w_H}{\partial L} > 0$. From $(F27)$ we know that $\frac{\partial L}{\partial I} > \frac{\partial L}{\partial L}$, and so

$$\frac{\partial w_H}{\partial I} = \frac{\partial w_H}{\partial L}\frac{\partial L}{\partial I} > \frac{\partial w_H}{\partial L}\frac{\partial L}{\partial L} > 0 \tag{F29}$$

That is, as for capital accumulation, also the high skilled wage increases more in response to immigration when immigrants are imperfect (and not perfect) substitutes for unskilled natives.

Unskilled (Natives) Wages. Differently from above, we now have to distinguish between wages of unskilled natives and those of immigrants. In particular, it can be shown that, in equilibrium,[12]

$$w_U = \frac{\psi N_L}{(1-\beta)}\frac{L^{-\alpha}}{U^{1-\alpha}} \tag{F30}$$

As in Section F.4, it is immediate to see how the two channels (the substitution effect and the capital response) affect the wage of unskilled natives: on the one hand, higher immigration increases competition for unskilled natives, thereby lowering their marginal product; on the other, when $\gamma > 0$, immigration favors the entry of establishments producing unskilled-complementary technologies, in turn exerting positive pressure on unskilled wages. By comparing $(F30)$ to $(F23)$, it is clear that, because of imperfect substitutability between immigrants and natives (i.e. $\alpha < 1$), the (negative) substitution effect is now smaller than in the baseline model presented above.

In online appendix G, I provide a sufficient condition for the directed technology effect to prevail over the substitution effect, and show that the range of values of γ for which immigration raises the wage of unskilled natives is larger than in the case of perfect substitutability between immigrants and natives.[13] More formally, defining $\tilde{\gamma}$ (resp. $\tilde{\gamma}'$) the threshold value of γ above which immigration increases earnings of unskilled natives when $\alpha = 1$ (resp. $\alpha < 1$), online appendix G shows that

$$\tilde{\gamma} > \tilde{\gamma}' \ \forall \alpha \in (0,1) \tag{F31}$$

This result is intuitive: when immigrants and natives are imperfect substitutes, the direct

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[12]To see this, note that

$$\begin{aligned} w_U &= \frac{\partial (p_L Y_L)}{\partial U} = \frac{\partial (p_L Y_L)}{\partial L}\frac{\partial L}{\partial U} \\ &= w_L \left(\frac{L}{U}\right)^{1-\alpha} \end{aligned}$$

[13]In particular, a sufficient condition for the wage of unskilled natives to increase with immigration is that $\gamma > \frac{\alpha}{\alpha+\beta}$.

negative (competition) effect of immigration on natives' wages is counterbalanced by two distinct forces. First, as before, capital accumulation and the development of (unskilled) biased technologies. Second, complementarity between the skills of immigrants and natives and the resulting gains from diversity (e.g. Peri and Sparber, 2009; Foged and Peri, 2016, among others).

Skill Premium. The skill premium can be now expressed as

$$\omega = \frac{w_H}{w_U} = \left(\frac{1-\beta}{\psi}\right) \frac{\left(1 - \left(\frac{L}{\psi}\right)^{\frac{\gamma\beta}{1-\gamma}}\right)^{-\frac{1-\gamma}{\gamma}}}{N_L(L)} L^\alpha U^{1-\alpha} \tag{F32}$$

As before, it is possible to show that the direct effect of immigration on the skill premium is positive. This result is intuitive, and follows directly from the assumption that immigrants are closer substitutes for unskilled than for high skilled natives. Also, similar to Section F.4, the indirect effect of immigration mediated by capital deepening tends to lower the skill premium. The total effect of immigration is, as usual, given by

$$\left(\frac{\partial\omega}{\partial I}\right)^{TOT} = \left[\frac{\partial\omega}{\partial L} + \frac{\partial\omega}{\partial N_L}\frac{\partial N_L}{\partial L}\right]\frac{\partial L}{\partial I}$$

and, as already noted above, is ambiguous. In online appendix G, I derive an explicit condition that shows under which parameter values the skill premium falls with immigration.[14] As for the unskilled wage, also in this case, introducing the assumption of imperfect substitutability between immigrants and natives ($\alpha < 1$) increases the range of values of γ for which immigration can reduce income inequality, relative to the scenario of perfect substitution ($\alpha = 1$).

To conclude, assuming (consistent with the empirical evidence) that immigrants and unskilled natives are imperfect substitutes in the production of Y_L lowers the degree of capital adjustment needed for the economy to absorb an immigration shock . Even in this case, however, whether or not there is room for major technological change is probably a key condition for immigration to benefit native workers, without harming even those in more exposed jobs.

F.5.2 Endogeneizing Natives' Occupational Choice

In this sub-section I formalize the idea that, in response to immigration, natives might re-allocate their labor away from occupations more exposed to immigrants' competition and

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[14]Specifically, if $\gamma > \frac{\alpha}{\alpha+\beta}$, immigration will reduce income inequality among natives.

take up more skilled jobs. As argued in Peri and Sparber (2009) among others, such labor reallocation can take place because natives and immigrants differ in terms of skills, language proficiency, and education. As a result, natives may be induced to specialize in occupations where they have a comparative advantage relative to immigrants.

The structure of the model is as before, but I now assume that there are two types of domestic labor: first, native whites; second, African Americans and previously arrived immigrants. Native whites can be employed in both sectors, whereas African Americans and immigrants can only work in the unskilled sector, due to skill mismatch and discrimination. To simplify the analysis, I assume, as in the baseline model, that native whites working in the unskilled sector are perfect substitutes for immigrants and African Americans.[15]

Wages are allowed to differ across sectors, but all workers are paid the same within each sector. I denote native whites working in the high and low skilled sectors respectively with H and U, and, without loss of generality I normalize $H + U = 1$. The assumption of perfect substitutability between unskilled natives and immigrants implies that $L = U + I$, where I refers to immigrants and African Americans. It is straightforward to verify that native whites choose the sector paying the higher wage, and so, for them to work in both sectors, wages must be equalized, i.e.

$$\omega \equiv \frac{w_H}{w_L} = 1 \tag{F33}$$

Suppose that, before the immigration shock, $(F33)$ holds so that native whites are employed in both sectors. Combining $(F33)$ with $(F24)$, we get

$$1 = \left(\frac{1-\beta}{\psi} \right) \frac{\left(1 - \left(\frac{L}{\psi} \right)^{\frac{\gamma\beta}{1-\gamma}} \right)^{\frac{\gamma-1}{\gamma}}}{N_L} L \tag{F34}$$

Replacing $(F17)$ in $(F34)$, it is possible to determine the equilibrium number of native whites working as laborers (before the immigration shock), which is given by[16]

$$U = \frac{\psi^{\frac{\gamma\beta}{\gamma(1+\beta)-1}}}{(1+I)^{\frac{1-\gamma}{\gamma(1+\beta)-1}}} - I \tag{F35}$$

Having determined U from $(F35)$, and noting that $H = 1 - U$, all other equations follow as in the baseline model of Section F.3, with the only difference that, now, skill supplies (of native whites) are endogenously determined according to $(F34)$.

In what follows, I investigate how an immigration shock affects capital, wages, and the

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[15]Relaxing this assumption does not alter any of the results below.
[16]See online appendix G.

distribution of native workers across the two sectors. Two cases can arise. First, even after the immigration shock, wages are equalized across sectors, and native whites continue to work in both sectors.[17] Second, after the immigration shock ($F34$) no longer holds, and all native whites move to the high skilled sector. To keep the analysis close to my empirical results, I focus on the second scenario, and show that, in this framework, after the immigration shock: i) all native whites work in the high skilled sector and earn a higher wage (relative to the pre-migration equilibrium); ii) the number of manufacturing plants in the new equilibrium is higher; iii) it is possible even for wages of African Americans and previously arrived immigrants not to fall (or, to experience only a small decline).

Sector and Wages of Native Whites. First, by assumption, the new equilibrium entails $H = 1$, $U = 0$, and $\omega > 1$. Second, when the immigration shock is sufficiently large relative to the initial (native) labor force in the unskilled sector, it is possible for the high skilled wage to be higher after the immigration shock (relative to its pre-immigration level). Remembering that

$$w_H = \left(1 - \left(\frac{L}{\psi}\right)^{\frac{\gamma\beta}{1-\gamma}}\right)^{-\frac{1-\gamma}{\gamma}}$$

and denoting with the subscript 1 (resp. 0) the equilibrium variables after (resp. before) the immigration shock, the condition $w_{1,H} > w_{0,H}$ can be written as

$$\left(1 - \left(\frac{I_0 + U_0}{\psi}\right)^{\frac{\gamma\beta}{1-\gamma}}\right)^{\frac{1-\gamma}{\gamma}} > \left(1 - \left(\frac{I_1}{\psi}\right)^{\frac{\gamma\beta}{1-\gamma}}\right)^{\frac{1-\gamma}{\gamma}}$$

Or, after a few rearrangements,[18]

$$I_1 - I_0 > U_0 \tag{F36}$$

That is, for natives' wage to increase, the immigration shock must be sufficiently *large* (relative to the fraction of native whites initially working in the unskilled sector).[19]

Unskilled Wages. Next, using ($F23$), the new and the old equilibrium wages in the

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[17]It is easy to check that, even in this case, the fraction of natives in the unskilled sector falls when γ is sufficiently high.

[18]Using ($F35$), ($F36$) can be equivalently written as

$$I_1 > \left(\frac{\psi^{\gamma\beta}}{(1+I_0)^{1-\gamma}}\right)^{\frac{1}{\gamma(1+\beta)-1}}$$

[19]The intuition for this result is discussed below.

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unskilled sector are given by

$$w_{1,L} = \frac{\psi N_{1,L}}{I_1 \left(1 - \beta\right)} \tag{F37}$$

and

$$w_{0,L} = \frac{\psi N_{0,L}}{\left(I_0 + U_0\right)\left(1 - \beta\right)} \tag{F38}$$

where $N_{0,L}$ and $N_{1,L}$ are the pre and post immigration number of manufacturing plants (determined below). For wages in the unskilled sector to be equal before and after the immigration shock, it must be that

$$\frac{N_{1,L}}{I_1 - I_0} = \frac{N_{0,L}}{U_0} \tag{F39}$$

From $(F36)$, it is clear that for both the high skilled wage to rise and the unskilled wage not to fall, the number of manufacturing plants must be higher in the post-immigration equilibrium, i.e. $N_{1,L} > N_{0,L}$. Moreover, the endogenous capital response needed to absorb the immigration shock is increasing in the term $\frac{I_1 - I_0}{U_0}$.

Capital Accumulation. The latter observation already anticipated that, in the new equilibrium, the number of manufacturing plants must be higher than before the immigration shock. Using $(F17)$, we know that

$$N_L = \frac{\left(1 - U\right)\left(1 - \beta\right)\left(I + U\right)^{\frac{\beta\gamma}{1-\gamma}}}{\psi^{(1-\beta)} \left[\psi^{\frac{\beta\gamma}{1-\gamma}} - \left(I + U\right)^{\frac{\beta\gamma}{1-\gamma}}\right]^{\frac{1}{\gamma}}}$$

Then,

$$N_{1,L} = \frac{\left(1 - \beta\right) I_1^{\frac{\beta\gamma}{1-\gamma}}}{\psi^{(1-\beta)} \left[\psi^{\frac{\beta\gamma}{1-\gamma}} - I_1^{\frac{\beta\gamma}{1-\gamma}}\right]^{\frac{1}{\gamma}}}$$

and

$$N_{0,L} = \frac{\left(1 - U_0\right)\left(1 - \beta\right)\left(I_0 + U_0\right)^{\frac{\beta\gamma}{1-\gamma}}}{\psi^{(1-\beta)} \left[\psi^{\frac{\beta\gamma}{1-\gamma}} - \left(I_0 + U_0\right)^{\frac{\beta\gamma}{1-\gamma}}\right]^{\frac{1}{\gamma}}}$$

Combining the latter two expressions, $N_{1,L} > N_{0,L}$ whenever

$$\frac{I_1^{\frac{\beta\gamma}{1-\gamma}}}{\left[\psi^{\frac{\beta\gamma}{1-\gamma}} - I_1^{\frac{\beta\gamma}{1-\gamma}}\right]^{\frac{1}{\gamma}}} > \frac{\left(1 - U_0\right)\left(I_0 + U_0\right)^{\frac{\beta\gamma}{1-\gamma}}}{\left[\psi^{\frac{\beta\gamma}{1-\gamma}} - \left(I_0 + U_0\right)^{\frac{\beta\gamma}{1-\gamma}}\right]^{\frac{1}{\gamma}}}$$

Taking logs on both sides and rearranging, we get

$$\frac{\beta\gamma}{1-\gamma}\log\left(\frac{I_1}{I_0+U_0}\right) > \log\left(1-U_0\right) + \frac{1}{\gamma}\log\left(\frac{\Phi_1}{\Phi_0}\right) \tag{F40}$$

where $\Phi_1 \equiv \psi^{\frac{\beta\gamma}{1-\gamma}} - I_1^{\frac{\beta\gamma}{1-\gamma}}$ and $\Phi_0 \equiv \psi^{\frac{\beta\gamma}{1-\gamma}} - (I_0+U_0)^{\frac{\beta\gamma}{1-\gamma}}$. Note that, from $(F36)$,

$$I_1 > I_0 + U_0$$

implying that $\log\left(\frac{I_1}{I_0+U_0}\right) > 0$. Similarly, $\Phi_1 < \Phi_0$, and so $\log\left(\frac{\Phi_1}{\Phi_0}\right) < 0$. Finally, since $U_0 \in (0,1)$, $\log\left(1-U_0\right) < 0$. But then, if $(F36)$ holds, $(F40)$ is always satisfied.

Discussion. The previous analysis showed that, if natives can reallocate their labor across sectors (but immigrants cannot), and if capital endogenously adjusts after the immigration shock, the followings can happen: $i)$ all natives end up working in the high skilled sector; and $ii)$ even workers that are prevented from entering the high skilled sector might experience only limited wage losses. Two mechanisms are responsible for (i) and (ii). First, natives' endogenous occupational choice allows them to move away from the sector most exposed to immigration and, potentially, take advantage of the complementarity between their skills and those of immigrants. Second, and crucially, capital endogenously adjusts to the inflow of immigrants - this is the capital response that was already operating in the previous versions of the model.

When the inflow of immigrants is *sufficiently large*, capital accumulation will not only boost wages in the skilled sector, but also, will partly or completely offset the direct, negative effect of immigration on earnings of workers in the unskilled sector. When analyzing these results from the lenses of a neoclassical framework, the latter observation might seem somewhat counterintuitive: the economy should be better able to cope with immigration when the latter is relatively contained. But, this line of reasoning misses the key point.

Specifically, the neoclassical framework fails to incorporate the endogenous (directed) technological response, which is key for the economy to absorb the immigration shock. By raising the supply of unskilled workers, immigration increases firms' incentives to invest. Capital accumulation, in turn, increases the marginal productivity of both high and low skilled workers, compensating (or reversing) the initial negative effect of immigration on wages.

F.6 Taking Stock

In this note, building on a standard model of biased technical change (Acemoglu, 2002), I presented a tractable framework to study the effects of immigration on natives' labor market outcomes, incorporating three important mechanisms. First, the degree to which firms can expand (or enter the market) and the scope for major capital adjustments. Second, complementarity in the skills, the language proficiency, and in education of immigrants and natives. Third, the potential decision of natives to reallocate their labor away from more exposed occupations, and into sectors where they have a comparative advantage relative to immigrants. I derived conditions under which the model is able to deliver the key findings documented in my paper, namely that immigration can: *i*) increase natives' employment, without harming any specific group; *ii*) promote capital accumulation and boost economic activity; and *iii*) favor natives' occupational mobility, by increasing (lowering) the fraction of natives in high (low) skilled occupations.

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