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WELCOME TO THE MACHINE: FIRMS' REACTION TO LOW-SKILLED IMMIGRATION

by Antonio Accetturo*, Matteo Bugamelli* and Andrea Lamorgese*

Abstract

We assess the impact of low-skilled immigration on capital intensity. We first present a model characterized by frictions in the labor market and firms' asymmetric information on workers' skills and show that firms can react to the immigration-induced reduction of their workforce's skill level by increasing the capital-labor ratio. We test the predictions of the model on a sample of Italian manufacturing firms over the period 1996-2007, finding that increased immigration of low-skilled workers from developing countries, measured at the provincial level and instrumented with pre-existing enclaves of immigrants and network effects, raises capital intensity. In line with the predictions of the theoretical model, the impact of immigration, which is quite robust across empirical specifications, is stronger for larger firms and in skill-intensive sectors.

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Keywords: capital intensity, low-skilled migration, firm heterogeneity.

Contents

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1 Introduction [1]

In the last twenty years the rapid growth of world population, the persistence of wide gaps in income, diverging population trends, and exceptional geo-political changes have led to a huge increase in the number of migrants from the developing and emerging to the advanced economies. These inflows have raised concerns in host economies, ranging from a worsening of labor market conditions for natives to changes in the productive and technological structure, from increased crime rates to deteriorating public finances. The attention paid to this topic by the economic literature has consequently grown fast (Borjas, 1994).

This paper focuses on the impact of low-skilled immigration on capital intensity from both a theoretical and empirical perspective. Through a theoretical model based on workers' skill heterogeneity and imperfect labor markets, we set the stage to study the link between an inflow of low-skilled immigrants and firms' optimal choices in terms of technology and productive factors. The model is a closed-economy version of Helpman et al. (2010), which we generalize to a two-factor (capital and blue-collar workers) production function. The key features are: i) workers are heterogeneous in terms of skills, firms in terms of level of demand; ii) firms have imperfect information on workers' skill and employ workers through a costly process of search and screening; iii) immigrants have, on average, lower abilities and fewer outside options than natives. In this model an increase in the share of immigrants in a firm's labor force reduces, ex ante, its average productivity and wages paid. Facing these changes, firms re-optimize their factor mix and may change their degree of capital intensity in a direction that depends on the parameter values; in particular, there is a range of parameters, which appears to be more likely

[1]Corresponding author: Andrea R. Lamorgese Address: Via Nazionale 91, 00192 Roma, Italy. Email: andrea.lamorgese@bancaditalia.it.We wish to thank Giuseppe Parigi and Roberto Golinelli for providing the data on capital stock, Guglielmo Barone, Carlo Devillanova, Luigi Infante, Giovanni Mastrobuoni, Elisabetta Olivieri, Pierre Picard, Paolo Pinotti, Alfonso Rosolia and two anonymous referees for their comments, as well as seminar participants at Bank of Italy, University of Turi, Catholic University of Milan, NASM - Econometric Society (Boston, 2009), ESPE (Sevilla, 2009), AIEL (Sassari, 2009), CIDEI (Roma, 2009), Urban Economics Association (San Francisco, 2009). The usual disclaimer applies. The views expressed herein are those of the authors and not necessarily those of Bank of Italy.

in Italy, where the greater downward rigidity of wages with respect to productivity makes labor relatively more expensive than capital, thus inducing firms to adopt more capital-intensive technology. As a result, an increase in low-skilled immigration may end up raising the capital-labor ratio.

The theoretical model is then tested on a dataset that combines very detailed data on Italian manufacturing firms with provincial data on immigrants by country of origin. The analysis, covering 1996-2007, includes the recent phase of rapid acceleration of low-skilled immigration. Just to give some numbers, in 2008 there were 3.4 million resident foreigners, about 6 per cent of the total population, against less than half that share in 2003, and just 1 per cent in 1991. The immigrants are mostly from the developing and emerging countries and are relatively young and low-skilled (Bank of Italy, 2009).

In the empirical specification we relate firm-level changes in capital intensity to province-level changes in the immigrant population from 20 emerging and developing countries. We address potential endogeneity biases in immigration flows using an instrument based on the tendency of immigrants to move to pre-existing enclaves, as in Altonji and Card (1991), Saiz (2007), and Card (2007). We control for firm fixed effects and other time-varying firm-level variables that are related to the choice of capital and labor.

We find a positive causal effect of low-skilled immigration on capital intensity, that is quite stable and robust across empirical specifications. In line with the main predictions of the theoretical model, we find that the impact is stronger on firms with higher job turnover, on larger firms, and in sectors where the degree of complementarity across workers is higher.

The empirical literature on the effects of immigration on the host economy is extremely rich but is concerned primarily with the labor market outcomes of natives.[2] This paper relates to a more recent stream of literature aimed at assessing how immigration affects a country's productive structure. The thesis is that an

[2]In such areas as employment, wages and type of occupations (or tasks), Okkerse (2008) provides a survey of the labor market effects of immigration.

exogenous immigration-induced increase in the availability of low-skilled workers may cause a shift toward low-skill tasks and activities. In this strand of literature it is useful to distinguish papers that only look at recomposition within the labor force from those, like ours, that consider more than one input and extend the focus to capital and technology. Among the former, Lewis (2004) and Card and Lewis (2007) show that most of the increase in the relative supply of low-skilled labor induced by low-skilled Mexican immigration to the US has been absorbed by changes in skill intensity within narrowly defined industries; that is, the adjustment has not occurred through a change in sectoral specialization, as the Heckscher-Ohlin model would predict but rather within sectors, either across or within firms. According to Gandal et al. (2004), the high-skilled Russian immigration to Israel had an analogous effect, but of opposite sign, with a shift toward more skill-intensive production. On the basis of a German matched employer-employee dataset, Dustmann and Glitz (2007) suggest that the technological adjustment is due to the within-firm component: factor intensities shift toward relatively more intense use of low-skilled workers.

With a focus on capital and technology, Peri (2009) uses the large variation in the inflow of immigrants across US states and finds that immigration causes an increase in total factor productivity and a decrease in skill intensity. He finds no significant effect on capital intensity, measured by the ratio of capital to output. For US manufacturing plants Lewis (2011) shows that an increase in the share of high-school dropouts relative to high-school graduates induced by immigration in some metropolitan area slows the adoption of automation technologies and decreases the growth of capital-labor and capital-output ratios.

Our paper is quite close to Lewis (2011), but with two significant differences. In the theoretical sphere we have a more general setting, with imperfect labor market and heterogeneous workers, thus generating a more complex set of results. Our empirical exercise has a different focus, since rather than assess the consequences of the increased availability of unskilled workers we estimate the impact on the capital-labor ratio of the ethnic composition of the blue-collar workforce, which in turn affects average skills.

The remainder of the paper is organized as follows. In the next section we present the theoretical model; then we describe the empirical specification (section 3), and the data (section 4). Section 5 presents the results, and section 6 concludes.

2 The theoretical model

In this section we present a theoretical model offering both a conceptual framework within which to analyze the relationship between immigration and capital intensity and theoretical guidance to the empirical analysis. The model is a closed economy version of Helpman et al. (2010), which we generalize to a two-factor production function. It analyzes the impact of immigration on the capital-labor ratio in a labor market characterized by asymmetric information. More specifically, we assume that workers' abilities are heterogeneous but not directly observable by firms. Firms can pay to screen workers and get an imprecise signal on a worker's ex-post match-specific heterogeneous ability and thus improve the composition of their workforce and their productivity. Since immigrants are assumed to be, on average, less skilled than natives, firms facing a larger share of immigrants in their local labor market tend to have lower productivity. From a firm's perspective, this "negative" effect of immigration can be balanced by lower labor costs, as immigrants have fewer outside options and therefore are paid lower wages. Thus immigration, through the effects on productivity and wages, ends up affecting a firm's optimal decision on capital intensity.

2.1 Market demand and technology

Suppose that each firm i faces a fixed demand D_i randomly drawn from a generic continuous distribution $g(D)$. We identify firms by the realization of their demand, and suppress the index i in what follows.

In order to meet demand, a firm produces using capital (K) and production workers (L). Since our focus is on low-skilled immigration from less developed countries, and, according to the Italian Labor Force survey, 90 percent of foreigners in Italian manufacturing are blue-collar workers, we simplify by not considering white-collar workers in the production process.[3]

We combine capital and (blue-collar) labor through a CES constant-return-to-scale production function of the following type:

$$Y = \left[\gamma K^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(L\bar{a}^{\alpha})^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \quad (1)$$

where $\sigma > 1$ is the elasticity of substitution between capital and labor, and γ captures the degree of capital intensity of the production process. Notice that workers are complementary; that is, the average skill of blue-collar workers ($\bar{a}$) affects labor productivity proportionally, and $\alpha > 1$ measures the degree of complementarity.

2.2 Labor market

The labor market part of the model builds on the recent contribution by Helpman et al. (2010). We assume an imperfectly functioning labor market where workers have heterogeneous abilities (a) that are unobservable to the firms, hiring occurs via costly search and screening, and wages are set through bargaining between each worker and each firm. A worker's ability is ex-ante unobservable to the firm, since it is assumed to be relation-specific; in other words, we assume that previous matches between a worker and other firms are uninformative about that worker's productivity in any current or future match. However, firms can pay for a screening technology to get (ex-ante) a signal on a worker's match-specific ability. We assume that the screening cost is fixed, equal to f_S, and the signal is imprecise in the sense that firms can only detect whether a worker's ability is above or below a certain threshold a_c. While the decision to screen is endogenous, in our model the threshold is fixed exogenously, unlike in Helpman et al. (2010). The presence of a fixed screening cost, which a firm compares to the profits gains of screening, implies

[3] In the empirical analysis, we will control for the labor force composition by qualification.

that in equilibrium there are screening and non-screening firms, depending on the realization of demand D.

Unlike Helpman et al. (2010), we introduce two different groups of heterogeneous workers, immigrants and natives, and assume that on average immigrants have lower ability than natives. In line with our focus on low-skilled immigration, immigrants are assumed to have less human capital and language skills, so that they end up being less productive than natives in any given job. Consistently with the information structure described above, firms know that immigrants are less productive on average but do not observe the ability of the single worker, either immigrant or native, that they might be hiring.

A firm is randomly matched with a set of workers whose distribution of abilities mirrors that in the province where the firm is located. In particular, a worker's ability is randomly drawn from one of the following Pareto distributions, depending on whether he is native or immigrant:

$$Pr(A \geq a|natives) = \left(\frac{a_M}{a}\right)^{\varepsilon_N} \tag{2}$$

$$Pr(A \geq a|immigrants) = \left(\frac{a_M}{a}\right)^{\varepsilon_F}, \tag{3}$$

where $\varepsilon_F > \varepsilon_N > 1$ are the shapes of the two distributions and a_M is the scale parameter. Equations (2) and (3) have the classical implications of a Pareto distribution. That is, for any given job the probability of finding a high-ability worker is lower than that of finding a low-ability worker. This holds for both natives and immigrants, but the probability of finding a high-ability worker is lower among immigrants than natives. Expected abilities are as follows:

$$E(a|natives) = \frac{\varepsilon_N \ a_M}{\varepsilon_N - 1} > E(a|immigrants) = \frac{\varepsilon_F \ a_M}{\varepsilon_F - 1} \tag{4}$$

The rich structure of the model in terms of firms and workers' heterogeneity allows us to replicate the evidence that the share of immigrants in total employment is indeed highly heterogeneous across Italian firms, even within the same province, and is usually negatively correlated with firm size and productivity (Bank of Italy, 2009).

2.3 The firm's maximization problem

A firm chooses the level of capital and the number of production workers to maximize profits under the constraint that output (Y) equals demand (D), that is:

$$\begin{aligned} \max_{n,K} \quad & \Pi(D) = \left[\gamma K^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(L(n)\bar{a}^{\alpha})^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} - rK - wL(n) - I_S(f_S) \\ \text{s.t.} \quad & Y = D \end{aligned} \tag{5}$$

where r is the rental cost of capital, I_S is a dummy variable set to one if the firm decides to screen, n is the number of workers the firm is matched to. Notice that n is the actual control variable, since the choice of the number of workers to be matched maps deterministically in the number of (production) workers actually used in the production process (L). A non-screening firm hires as many workers as it chooses to be matched to, i.e., $L(n) = n$, whereas a screening firm hires only those whose ability is above the threshold a_c: by the property of the Pareto distribution, this is equal to $L = \Phi n$, where $\Phi = \eta^{\varepsilon_F}\beta + \eta^{\varepsilon_N}(1-\beta)$ is the share of workers passing the screening test, β the share of immigrants in the local labor force, and $\eta = a_M/a_c < 1$.

The screening decision determines the employment level (L), the share of immigrants (β_{firm}) and the average productivity of the workforce ($\bar{a}$). In a non-screening firm, the share of immigrants is equal that in the local labor market, that is ($\beta_{firm} = \beta$): it hires $n\beta$ migrants and $n(1-\beta)$ natives. In a screening firm, the share of immigrants is, again by the properties of the Pareto distribution, equal to $\beta_{firm} = \beta\eta^{\varepsilon_F}/\Phi$. By the same properties, we can also calculate the average ability of workers in both types of firms.

Summarizing, the optimal choice on n implies that a firm's employment, its share of immigrants and the average ability of its workforce are defined by the following triple (L, $\bar{a}$, β_{firm}):

$$[L, \bar{a}, \beta_{firm}] = \begin{cases} [n, Z_1, \beta] & \text{if no screening} \\ \left[\Phi n, \dfrac{Z_2}{\Phi\eta}, \dfrac{\beta\eta^{\varepsilon_F}}{\Phi}\right] & \text{if screening} \end{cases} \tag{6}$$

where $Z_1 = \beta\dfrac{\varepsilon_F}{\varepsilon_F - 1} + (1-\beta)\dfrac{\varepsilon_N}{\varepsilon_N - 1}$ is the weighted average of the expected abilities in the two distributions of workers that the non-screening firm faces, and $Z_2 = \beta\dfrac{\varepsilon_F}{\varepsilon_F - 1}\eta^{\varepsilon_F} + (1-\beta)\dfrac{\varepsilon_N}{\varepsilon_N - 1}\eta^{\varepsilon_N}$ is the weighted average of the expected abilities of the two truncated distributions of ability, where the truncation is exogenously given at a_c. Finally, it is trivial to show that $Z_2 < \Phi < Z_1$.

Two implications of the model's setting are worth mention. First, within each province, since immigrants have lower expected abilities than natives, screening firms have a workforce with higher average ability and a lower share of immigrants.[4] Secondly, the share of immigrants in a firm's workforce grows with that in the province where the firm is located. This holds for both screening and non-screening firms, i.e.:

$$\frac{\partial\beta_{firm}}{\partial\beta} = \begin{cases} 1 & \text{if no screening} \\ \dfrac{\eta^{\varepsilon_N}\eta^{\varepsilon_F}}{\Phi^2} & \text{if screening.} \end{cases} \tag{7}$$

2.3.1 Wage setting

Wages are influenced by firms' screening decisions and workers' outside options. Bargaining is such that by adjusting employment firms can drive the wage down to a worker's replacement cost. Since the screening technology is not perfect and allows firms only to determine whether a worker's ability is above or below a certain threshold, firms cannot offer a wage schedule conditional on ability but pay the same wage to all those who are above the threshold.

[4]The first part of the statement is shown in lemma 3, point ii). The second one trivially derives by the inspection of (6), considering that $\phi > \eta^{\varepsilon_F}$ by the definition of Φ.

Following a standard Diamond-Mortensen-Pissarides approach (Diamond, 1982; Mortensen and Pissarides, 1994), replacement costs depend on workers' outside options through market tightness. Formally, the replacement cost for a worker of nationality $l = \{N, F\}$ is $b_l = \delta_0 x_l^{\delta_1}$, where $\delta_0 > 0$, $\delta_1 > 0$ are two constants, and x_l is labor market tightness, defined as the probability of being employed conditional on being sampled by a firm.

Under the assumption of risk-neutrality, the supply of workers searching for jobs depends on their expected income elsewhere in the economy, i.e. their outside option ω_l. In equilibrium, workers are indifferent between seeking for employment at a given firm and opting for outside income, only if the latter equals the probability of being sampled and hired (x_l) multiplied by the expected wage: $\omega_l = x_l b_l$. This implies that the replacement cost is equal to $b_l = \delta_0^{1/(1+\delta_1)} \Omega_l$, where $\Omega_l = \omega_l^{\delta_1/(1+\delta_1)}$.

We also suppose that natives' outside option (ω_N) is greater than immigrants' one (ω_F), so that $b_F < b_N$.[5] From a firm's point of view, the search cost is a weighted average of the workers' replacement costs and therefore a function of the outside options, which is equal to

$$b = \delta_0^{\frac{1}{1+\delta_1}} \left[\beta_{firm} \Omega_F + (1 - \beta_{firm}) \Omega_N \right]. \tag{8}$$

By taking logs and deriving by β it is clear that:

$$\frac{\partial \ln b}{\partial \beta} = \frac{\partial \ln b}{\partial \beta_{firm}} \frac{\partial \beta_{firm}}{\partial \beta} = \frac{\Omega_F - \Omega_N}{\beta_{firm} \Omega_F + (1 - \beta_{firm}) \Omega_N} \frac{\partial \beta_{firm}}{\partial \beta} < 0, \tag{9}$$

that is, an increase of the share of immigrants in the local labor force decreases search costs for both screening and non-screening firms.

As in Helpman et al. (2010), we assume that workers have no incentive to directly search for firms in each sector. This implies that in equilibrium, a worker's expected

[5] This is a quite reasonable in the Italian case for at least two reasons. On the one hand, immigration visas are usually issued only if the immigrant is actually working in Italy, thus driving the reservation wage down; on the other hand, the law dictates that a foreigner who remains unemployed cannot renew the annual visa unless he or she finds another job.

wage conditional on being sampled (and hired) is the same across all firms in a sector. Hence using (6)

$$w = \frac{nb}{L} = \begin{cases} b & \text{if no screening} \\ \frac{b}{\Phi} & \text{if screening.} \end{cases} \quad (10)$$

where $\frac{n}{L}$ represents the probability of a sampled worker being hired by a firm; this is equal to one for non-screening firms and to $\frac{1}{\Phi} < 1$ for screening firms. Equation (10) shows that screening firms pay higher wages since they have, on average, workers of higher ability, those that are more costly to replace.

Finally, we also suppose that firms have no incentive to directly search for workers, so that no firm employs only native workers. For this to be the case it must be that:

$$\frac{E(a|natives)}{b_N} = \frac{E(a|immigrants)}{b_F} \quad (11)$$

$$\frac{\frac{\varepsilon_N}{\varepsilon_N - 1}}{b_N} = \frac{\frac{\varepsilon_F}{\varepsilon_F - 1}}{b_F} \Rightarrow \frac{E_F}{E_N} = \frac{\Omega_F}{\Omega_N}, \quad (12)$$

where $E_l = \varepsilon_l/(\varepsilon_l - 1)$ for $l = \{N, F\}$.

2.3.2 Equilibrium factor mix

By maximizing (5) and using (6) and (10), the optimal ratio between capital and production workers is equal to:

$$k^*_{NS} = \frac{K}{n} = \left[\frac{\gamma b_{NS}}{(1-\gamma)r}\right]^{\sigma} \frac{1}{Z_1^{\alpha(\sigma-1)}}. \quad (13)$$

for a non-screening firm and to:

$$k^*_S = \frac{K}{L} = \left[\frac{\gamma b_S}{(1-\gamma)r}\right]^{\sigma} \frac{1}{\left(\frac{Z_2}{\eta}\right)^{\alpha(\sigma-1)} \Phi^{\sigma-\alpha(\sigma-1)}}, \quad (14)$$

for a screening firm. b_{NS} and b_S are the search cost for, respectively, non-screening and screening firms. To show how the equilibrium capital intensity of a profit-maximizing firm depends on the share of migrants in the local labor market (β), we take logs of equations (13) and (14) and differentiate with respect to β. For the non-screening case, the impact of immigration on the capital intensity is equal to:

$$\frac{\partial \ln k_{NS}^*}{\partial \beta} = \frac{\sigma}{b_{NS}} \frac{\partial b_{NS}}{\partial \beta} - \frac{\alpha(\sigma - 1)}{Z_1}(E_F - E_N), \quad (15)$$

while, given screening, it is:

$$\frac{\partial \ln k_S^*}{\partial \beta} = \frac{\sigma}{b_S} \frac{\partial b_S}{\partial \beta} - \alpha(\sigma - 1)\left(\frac{E_F \eta^{\varepsilon_F} - E_N \eta^{\varepsilon_N}}{Z_2} - \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi}\right) - \sigma \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi} \quad (16)$$

We devote the next section to a discussion of the sign of these two partial effects.

2.4 Theoretical predictions

We are now ready to derive our theoretical results. First we show how the equilibrium capital-labor ratio depends on the share of immigrants in the local labor force (Lemma 1). When the effect of immigration on capital intensity is positive, we show that it is larger for screening firms (Lemma 2). Finally, we prove that only firms with large sales (i.e., demand) find it optimal to screen workers, so that in equilibrium there are both screening and non-screening firms (Proposition 1).

Lemma 1

In this economy,

if $\alpha > \sigma/(\sigma - 1)$ (wages are stickier than productivity), migration inflows induce an increase in firms' capital intensity;

if $\alpha < \sigma/(\sigma - 1)$ (productivity stickier than wages), migration inflows induce a decrease in firms' capital intensity;

The proof is in Appendix 2.

The intuition goes as follows. For non-screening firms the inflow of immigrants to a local labor market decreases the search costs (the first term in (15)) and also, by lowering the average ability of workers (the second term in equation (15)), the marginal product of labor. If $\alpha > \sigma/(\sigma-1)$, the decrease in the marginal product of labor is (in modulus) larger than that in search costs, so that firms choose to substitute capital for labor, raising the capital-labor ratio. The opposite occurs when $\alpha < \sigma/(\sigma-1)$. For screening firms, this holds *a fortiori*, since the effect on the second term is stronger due to the stochastic dominance of natives' over the immigrants' distribution of abilities (the third term in equation (16)). Intuitively, screening firms face higher replacement costs, making it convenient to choose a larger capital-labor ratio.

Corollary 1 *If $\alpha > \sigma/(\sigma-1)$, the positive effect of migration on the capital-labor ratio increases with α.*

Proof of corollary 1

This statement immediately follows from (15) and (16), and the proof of Lemma 1.

Lemma 2

If wages are stickier than productivity ($\alpha > \sigma/(\sigma-1)$), and provided that $\alpha < \sigma/[\beta(\sigma-1)]$, screening firms have greater incentive to raise their capital-labor ratio in response to immigration than non-screening firms.

The proof is provided in Appendix 2. The underlying intuition is that, due to the complementarities among workers, screening firms face a stronger decrease of labor productivity but also face stickier wages, as their workers are harder to replace (more skilled workers are rarer due to the Pareto distribution of abilities). These two effects lead to a larger elasticity of the capital-labor ratio to the inflow of immigrants.

Proposition 1 *Only firms with sales larger than a certain threshold, D^*, screen workers.*

The proof is provided in Appendix 2. Intuitively, since screening is a costly activity with a fixed cost, only firms with large enough revenues can afford it. As a result, when $\alpha > \sigma/(\sigma - 1)$, and given Lemma 2 (i.e., the effect of immigration on capital intensity is larger for screening firms), low-skilled immigration flows induce a greater capital deepening among larger firms.

2.5 Comparison with Lewis (2011)

Since our result on capital intensity is the opposite of Lewis (2011), discussion of the relationship between the two papers is needed. Lewis (2011) proposes a model where labor markets are perfectly competitive, unskilled workers are a substitute for capital, and skilled workers are complement to capital. In this setting, an increase in the relative supply of unskilled workers makes them more convenient than capital, which is accordingly substituted for. Our model encompasses Lewis (2011) but is more general: while we retain the assumption that blue-collar workers (Lewis's "unskilled") are a substitute for capital, we allow them to be heterogeneous in their skills or abilities,[6] and the heterogeneity also has a native *vs.* immigrant dimension. Moreover, since production is assumed to be increasing in workers' average ability (i.e., $\alpha > 0$), blue-collar workers are complements to one another so that the presence of very low-skilled workers, as immigrants might be, has a negative effect on productivity.

It is plain to see that if in our model we mute either differences in skills between immigrants and natives or the degree of complementarity among blue-collar workers, we get the negative impact on capital intensity found by Lewis (2011).

As to skill heterogeneity, if we take the following transformation of equation (15):

$$\frac{\partial \ln k^*_{NS}}{\partial \beta} = \sigma \frac{\Omega_F - \Omega_N}{\beta \Omega_F + (1-\beta)\Omega_N} - \frac{\alpha(\sigma-1)}{Z_1}(E_F - E_N) \tag{17}$$

and assume that $E_F = E_N$, the sign of the derivative becomes negative. This is because $\Omega_F < \Omega_N$, due to institutional factors like those described in section 2.3.1 that are independent of abilities.

[6] In other terms, we are estimating the effect of a change in the skill distribution within blue-collar workers, while Lewis estimates the effect of a larger blue-collar share in the overall workforce.

If we instead rewrite equation (15) in the following way:

$$\frac{\partial \ln k^*_{NS}}{\partial \beta} = -[\alpha(\sigma-1)-\sigma]\frac{E_F - E_N}{\beta E_F + (1-\beta)E_N}. \tag{18}$$

it is again straightforward to see that setting $\alpha = 0$, since $E_F < E_N$ a higher share of low-skilled immigrants has a negative impact on the capital-labor ratio.

3 The empirical model

Our theoretical model suggests studying the relationship between a change in capital intensity and an exogenous inflow of low-skilled immigrants. Empirically, then, we estimate the following equation:

$$g^k_{ijt} = \eta_i + \eta_t + \eta_j + \beta_1 \Delta \ln \frac{L^{imm}_{jt-1}}{Pop_{jt-1}} + \beta_2 g^{sh\_blue}_{ijt} + \beta_3 \mathrm{X}_{ijt-1} + \varepsilon_{ijt}, \tag{19}$$

where i indexes firms, j the province where firm i is located, and t is year-time. The dependent variable g^k_{ijt}, i.e. the firm-level rate of increase in the capital-labor ratio, is equal to the difference between the rate of investment in machinery and equipment (g^K_{ijt}) and the rate of growth in the number of blue-collar workers (g^L_{ijt}). The investment rate is computed as the ratio of investment[7] at time t (I_{ijt}) to the installed capital stock at time $t-1$ (K_{ijt-1}). Importantly, we restrict the focus to machinery and equipment and production workers because low-skilled immigrants are mostly production workers and the type of capital that is relevant for such workers is machinery and equipment, whereas ICT is complementary to white-collar workers. Thus the coefficient of interest β_1 captures the correlation between the variation in capital intensity at firm level and the change in the (log) share of low-skilled immigrants in the total population ($\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}}$) in the province.

[7]Following the empirical investment literature non-convexities in the adjustment cost function make investments quite lumpy and volatile over time (Doms and Dunne, 1998). It follows that the distribution of I_{ijt}/K_{ijt-1} (both cross-sectional and within firm) is characterized by some huge numbers and very frequent zeros. We deal with this problem by excluding all observations with an investment-capital ratio larger than one (i.e. all the cases in which a firm more than doubles its production capacity in a given year).

Equation (19) includes a series of controls. First of all, contrary to what is assumed in the theoretical model for the sake of simplicity, in the empirical specification we control for the rate of increase in share of production workers at the firm level ($g_{ijt}^{sh\_blue}$). This is important for two reasons. As Bugamelli et al. (2008) show, during the last decade Italian firms have reacted to the challenges of globalization and the European single currency by increasing the share of white-collar workers used in the production process, but we want the identification of β_1 to be net of this structural change. The inclusion of $g_{ijt}^{sh\_blue}$ among the regressors also serves to control for the effects of low-skilled immigrants inflows on firms workforce composition by skill —the subject of most of the related literature (Lewis, 2004; Gandal et al., 2004; Card and Lewis, 2007; Dustmann and Glitz, 2007; Peri, 2009; Lewis, 2011). In other words, the effect on capital intensity we want to identify must be considered as additional to the effects on skill intensity estimated in those papers.

Firms' investment decisions are influenced by various factors. We control for financing conditions by two variables: the amount of cash flow ($cashfl$) and a self-scription as credit-rationed ($credrat$). Investment decisions are also a function of expected demand, so we add the expected level of demand in the next year ($exdem$) and a measure of the degree of uncertainty surrounding that estimate ($uncert$ Guiso and Parigi, 1999). The type of investment good also influences the investment decision. Reasonably, the cost-benefit assessment of a new machinery or equipment changes if the good, once purchased, can be sold in a second-hand market or leased: we explicitly control for this ($rever$). In one empirical specification we also add the lagged dependent variable to take into account the possible stickiness of productive factors (Bond and Van Reenen, 2007).

The empirical specification contains a full set of fixed effects. Firm-level fixed effects (η_i) control for time-invariant unobservable factors, related for example to entrepreneurs' abilities or preferences, that could affect the choice of the factor mix. Country-level common shocks are captured by year fixed effect (η_t) and time-invariant local characteristics by provincial fixed effects (η_j).[8] Standard errors are always clustered by province.

3.1 Causality

Firm-level controls and fixed effects cannot guarantee that the estimation of β_1 is not biased due to omitted variables or reverse causality. For example, unexpected local demand shocks may simultaneously affect a firm's demand for capital and labor and the immigrants' location decision; obviously, the direction of such an omitted variable bias depends on the effect on capital intensity. Alternatively, a widespread increase in the capital-labor ratio in a certain region is likely to raise the marginal productivity of labor, induce an inflow of migrants, and so generate an upward bias in the estimate of β_1 (reverse causality).

To address these concerns we resort to an IV estimation that exploit the fact that immigrants tend to move to areas where other immigrants of the same nationality are already settled (Altonji and Card, 1991; Saiz, 2007). In other words, we break the link between immigration flows and business cycle at the provincial level by instrumenting the former with the exogenous supply-push factors related to network effects. In formulas, the instrument is built as follows:

$$Instr_{jt} = \Delta \ln \frac{\widehat{L_{jt}^{imm}}}{Pop_{jt}},$$

where $\widehat{L_{jt}^{imm}} = \sum_c \delta_{jc1992} L_{ct}^{imm}$ is the predicted number of immigrants in province j at time t, L_{ct}^{imm} is the total number of immigrants in Italy from country c at time t, $\delta_{jc1992} = L_{jc1992}^{imm}/L_{c1992}^{imm}$ is the share of country c nationals in province j in 1992. To choose country c, we sort the set of all countries of origin in decreasing order of immigrants population in 1992, and let c range over the subset of the top twenty countries, which accounted for nearly 80 per cent of the total immigrants

[8] The provincial fixed effect should be redundant in a regression with fixed effects at the firm level, unless some firms change location over time. In our sample this phenomenon is marginal. If the model is estimated on the subset of firms that do not change location, the results hold true.

Table 1: Descriptive statistics: Stock of immigrants from the top twenty countries of origin

country of origin	# of immigrants	share	cumulative share	# of immigrants in mfg., 2005
Morocco	83292	17.28	17.28	51680
Romania	8250	1.71	18.99	38252
Albania	24886	5.16	24.16	35067
Senegal	24194	5.02	29.17	15208
India	9918	2.06	31.23	12943
Ghana	11303	2.35	33.58	12512
Tunisia	41547	8.62	42.20	9387
Nigeria	5627	1.17	43.36	6891
Serbia and Montenegro	25848	5.36	48.73	6640
Pakistan	6983	1.45	50.18	5849
Philippines	36316	7.53	57.71	5794
China	15776	3.27	60.98	4315
Egypt	18473	3.83	64.82	3783
Sri Lanka	12114	2.51	67.33	2872
Poland	12139	2.52	69.85	2679
Brazil	10953	2.27	72.12	1085
Argentina	9603	1.99	74.11	813
Iran	6821	1.42	75.53	605
Ethiopia	7627	1.58	77.11	193
Somalia	9265	1.92	79.03	90

Notes: "# of immigrants" is the stock of immigrants from each country of origin in 1992 from the data set on Italian residents; the countries of origins are the top twenty by number of immigrants in 1992. The columns "share" and "cumulative share" report the share and the cumulative share of immigrants from the various countries in the total stock of immigrants, again in 1992. In the last column we use 2005 data from the Labor Force Survey on the number of immigrants working in Italian manufacturing industry by country of origin.

population that year (table 1).[9]

Exclusion restrictions require that the instrument not be correlated with unobserved factors that vary with time and province. But since 1992 immigrants were few in number, it is very unlikely that their presence and therefore their distribution by provinces at that time could influence capital intensity later on. Admittedly, our instrument might not be valid if immigration were concentrated just in a few provinces, making it impossible to disentangle local and national flows: fortunately, this is not the case since the provinces numbered 95 in 1992 and the one with the largest immigrant population share (Milan) did not exceed 15 per cent of total im-

[9]The same twenty countries accounted for over 70% of total immigration in 2007.

migration. Moreover, the bulk of immigration has been relatively recent, during a time when the Italian economy has experienced its longest slowdown, and therefore the lowest attractiveness, in the post-war period; in 2008 there were 3.4 million resident foreigners, about 6 per cent of the population, up from less than half that in 2003 and just 1 per cent in 1991.[10]

In view of the foregoing, we are quite confident that our instrument is driven mostly by supply push factors.

4 The data

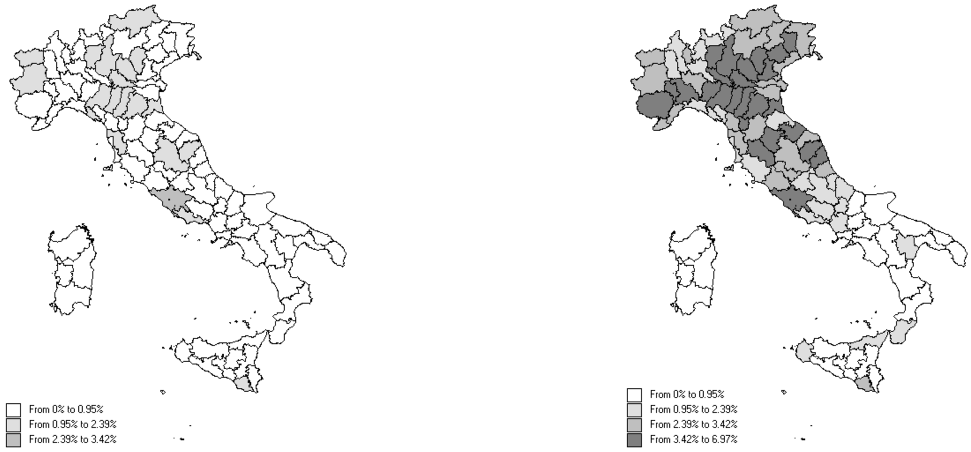
In the empirical analysis we combine data on the stock of foreigners by country of origin and Italian province of residence with a data set of manufacturing firms localized in Italy.

The stock of migrants is taken from the annual permits released by the Italian Ministry of the Interior. As is clear from the data in Table 1, almost half of the foreigners residing in Italy are from central and eastern Europe, mainly Albania and Romania (11.7 and 18.2 per cent, respectively), about a quarter from North Africa, and about a sixth from Asia. Compared with those in other European countries, foreign residents in Italy are younger and less educated. Over the period 2005-07 the median age of those older than 16 was 38, against over 50 in Germany and France. Among those with aged 25-55, about half had at most compulsory schooling and only 14 per cent a university degree (in the EU15 the corresponding averages are 32 and 36 per cent). Using civic register data on provincial population, we can compute our regressor, i.e., $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$. Figure 1 shows its distribution across Italian provinces. Quite evidently, the ratio of immigrants to total population was much higher in central and northern provinces in 1996 (panel a) and, despite more intense immigration flows, also in 2006 (panel b).

Firm-level data comes from the annual Survey on Investment in Manufacturing

[10]According to OECD (2007), Italy ranked third (after the US and the UK) among the main destinations of migration flows in the period 2003-2006.

Figure 1: The distribution of foreign residents by Italian province



panel a: 1996 panel b: 2006

(SIM), conducted by the local branches of the Bank of Italy. The quality of the SIM dataset is guaranteed by the close personal relationship between branch officials of the Bank of Italy's locales and the firms surveyed and by the intensive data revision by statisticians at the Bank of Italy.[11] Out of the full dataset, we use only the subsample of manufacturing firms with at least 50 employees, available continuously since 1984.[12]

The questionnaires, submitted to companies at the beginning of each year for the previous year, collect a wide range of information: year of foundation, nationality of ownership, location, sector of activity, ownership structure, employment (annual average), investment (realized and planned), sales (domestic and export), capacity utilization, indebtedness. Information on employment structure is very detailed.

Especially important for our purposes, the data on investment flows are very detailed: they are separately available for i) land and buildings, ii) machinery and equipment, iii) transportation goods, and iv) ICT. Here, we take investment in

[11] Many papers have used these data. Among others, see Guiso and Parigi (1999) and Iranzo et al. (2008).

[12] Firms with 20-49 employees were not surveyed until 2002, service firms not until 2001.

machinery and equipment at constant prices and deflate its monetary value with the corresponding sectoral investment prices from the national accounts. Since the survey does not give figures on installed capital stock, we rely on the measure constructed by Bontempi et al. (2010) who matched these survey data with the balance sheet figures from the Company Accounts Data Service (CADS). Bontempi et al. (2010) derive the data on capital stocks at constant prices according to the following formula:

$$K_{it} = (1 - \delta_{st})K_{it-1} + I_{it} \tag{20}$$

where I and δ represent, respectively, effective investment at constant prices in machinery and equipment and the sectoral depreciation rate from the national accounts. To obtain the initial values of the capital stocks, Bontempi et al. (2010) exploit the "accounting" initial values K_{i0} obtained from CADS nominal book values, deflated with the sectoral investment deflators.

A measure of investment reversibility ($rever$) is taken from Bianco et al. (2009). This is a firm-level dummy variable equal to one if at time t the firm has purchased or sold investment goods in the second-hand market or leased them.[13]

Firm-level nominal data on cash flow ($cashfl$) are derived from CADS.[14] We then deflate this with sector-level production deflators taken from national accounts and scale it by lagged capital stock. All the other firm-level regressors are from SIM. Average employment, available by qualification (white- vs blue-collar workers), is used to build $g_{ijt}^{sh\_blue}$. The dummy variable $credrat$ is equal to 1 if a firm answers positively to these three questions: (i) at current market terms would you like to borrow more?; (ii) would you be willing pay a higher interest rate in order to borrow more? (iii) have you applied for a loan credit but been turned down? While

[13]Leasing investment is considered reversible because normally the client has the option to return the good: as a consequence, leasing firms usually finance goods that enjoy a large second-hand market. Since this variable is not available in the survey after 2003, for these years Bianco et al. (2009) have attributed the value of one if the firm operated in the second-hand market at least twice in the period 1996-2002.

[14]We subtract dividends from the accounting item "cash flow".

the expected change in sales (at constant prices) is provided directly by the firm (*exdem*), we compute its degree of uncertainty (*uncert*) as the squared difference between the maximum and the minimum values of the expected real change. In some robustness exercises, we also use SIM data on the current level of sales (*sales*) and job turnover (*jobtur*), the latter being computed as the yearly sum of inflows and outflows of workers divided by average employment level for the year.

We limit the empirical analysis to firms located in the Center and North of the country to avoid the potential bias due to the long-standing, structural backwardness of the Southern regions (in per capita GDP, employment rates, relative manufacturing value added, intensity of immigration). We also drop all observations for the year 2004 to exclude the jump in the number of residence permits recorded in 2003 after the enactment of an immigration regularization act (the Bossi-Fini's amnesty) in 2002.[15]

The working sample is an unbalanced panel with more than 5,000 observations (for roughly 1,000 firms) over the period 1996-2007. Descriptive statistics for the pooled sample are in Table 2. Over the period the production function changed significantly, with an average increase in capital and white-collar labor with respect to blue-collar workers (Bugamelli et al. (2008)). This was accompanied by a 15 per cent yearly increase in the share of (mostly) low-skilled immigrants. As expected, average firm size in the dataset we use is quite large, thus making our sample quite representative of medium-large sized Italian firms. Cash flow amounted on average to almost 30 per cent of the installed capital stock. The expected annual increase in sales averages 4 per cent, but with considerable variance across firms and years. The difference between maximum and minimum expected demand averages just above 1 percentage point.

Table 2: Descriptive Statistics: 1996-2007 average

	mean	sd	p50
g_{ijt}^{k}	0.185	0.298	0.156
$g_{ijt}^{sh\_blue}$	-0.010	0.253	-0.005
$\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$	0.152	0.216	0.124
Number of employees	536	1369	193
$cashfl$	0.289	0.375	0.235
$credrat$	0.025	0.158	0
$rever$	0.346	0.475	0
$exdem$	0.037	0.148	0.23
$uncer$	0.012	0.035	0.003
$jobtur$	0.271	0.440	0.181
$sales$	10.810	1.330	10.647

Notes: All variables are averages over the period 1996-2007. g_{ijt}^{k} is the growth rate of the ratio of production capital stock to the number of blue-collar workers at firm level. $g_{ijt}^{sh\_blue}$ is the growth rate of the ratio of blue-collar to white-collar workers at firm level. $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$ is the growth rate of the share of immigrants in total population at province level. $credrat$ is a dummy variable equal to 1 if a firm declared to be credit-rationed. $cashfl$ is the deflated value of a firm's cash flow scaled down by its lagged capital stock. $rever$ is a dummy variable equal to 1 if the investment goods of a firm can be sold on the second-hand market. $exdem$ is the average change in a firm's next-year expected sales. $uncer$ is the difference between maximum and minimum expected changes in sales. $jobtur$ is the sum of inflows and outflows of workers in a year divided by the average employment level that year. Finally, $sales$ is the logarithmic transformation of a firm's current level of sales.

5 Results

First we estimate equation (19) by OLS. In column (1) of Table 3 we start from a simple specification that includes only the changes in the share of immigrants and of blue-collar workers.[16] In the specification, while an increase in the share of blue-collar workers is accompanied by a one-to-one decrease in the (production)capital-(unskilled)labor ratio,[17] immigration has no significant effect on capital intensity. Columns (2) and (3) augment the baseline specification in two directions. In column (2) we control for the financing status of the firm and the reversibility of its

[15] In 2003 more than 700,000 foreigners were legalized and so entered in civic registers, artificially inflating the 2002-03 increase in the foreign population share.

[16] Excluding the blue-collar share leaves all estimates basically unchanged.

[17] This result is consistent with Lewis (2011)

Table 3: Capital intensity and immigration: base regression

Dependent variable: g_{ijt}^{k}						
	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$	0.002	0.001	0.009	0.209**	0.212**	0.287**
	(0.012)	(0.012)	(0.017)	(0.096)	(0.095)	(0.124)
Lagged dependent var			-0.010			-0.011
			(0.009)			(0.010)
exdem			0.056**			0.063***
			(0.022)			(0.023)
uncer			0.192*			0.168
			(0.109)			(0.115)
$g_{ijt}^{sh\_blue}$	-1.005***	-1.005***	-0.976***	-1.004***	-1.003***	-0.970***
	(0.008)	(0.008)	(0.016)	(0.009)	(0.009)	(0.017)
rever		-0.005	-0.003		-0.005	-0.004
		(0.006)	(0.008)		(0.006)	(0.008)
credrat		-0.005	-0.016		0.002	0.001
		(0.016)	(0.023)		(0.017)	(0.025)
cashfl		0.023***	0.024**		0.021**	0.020*
		(0.008)	(0.011)		(0.008)	(0.012)
Observations	5513	5513	3290	5513	5513	3290
Number of firms	1180	1180	804	1180	1180	804
F first step				76.84	77.61	52.84

Notes: OLS and IV estimates of equation (19). Firm-level and year fixed effects are always included. Standard errors are clustered by province. The dependent variable g_{ijt}^{k} is the growth rate of the ratio of production capital stock to the number of blue-collar workers at firm-level. $g_{ijt}^{sh\_blue}$ is the growth rate of the ratio of the number of blue-collar workers to that of white-collar workers at firm-level. $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$ is the growth rate of the share of the stock of immigrants to total population at province level. *credrat* is a dummy variable equal to 1 if a firm declared to be credit-rationed. *cashfl* is the deflated value of a firm's cash flow scaled down by its lagged capital stock. *rever* is a dummy variable equal to 1 if the investment goods of a firm can be sold on the second-hand market. *exdem* is the average change in the next year's sales expected by a firm in the current year. *uncer* is the difference between the maximum and minimum values of the expected change of sales. *** p<0.01, ** p<0.05, * p<0.1.

investment: while the coefficient of $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$ is still not significantly different from zero, the presence of self-financing (i.e., cash flow) is positively correlated with the rise in the capital-labor ratio. Results on immigrants do not change when we also add control for the expected level and uncertainty of future demand (column 3). Not surprisingly, the level of expected demand is positively correlated with change in capital intensity. The same holds for the degree of demand uncertainty, as firms facing greater uncertainty on demand prefer to contain employment more than investment. In any case, this latter result is statistically not very robust, as we will see.

Columns (4) through (6) show the IV estimates. While the firm-level controls have very similar estimated coefficients, we now find a positive, highly significant and very stable coefficient of $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$. This implies that OLS estimates were biased downward, probably due to measurement error, reverse causality or omitted variables.[18] The F-tests for the excluded instruments from the first stage regressions (reported in the bottom of Table 3) are safely above the standard levels of the weak instruments literature (Bound et al., 1995). The implied effect of immigration on capital intensity is quite large. A one standard deviation increase in the immigrant share of population induces a rise of 4.6 percentage points in the rate of increase in capital intensity. The introduction of controls for demand (column (6)) lowers the number of observations considerably, but without changing the estimate of the immigration variable. For this reason column (5) is our preferred specification.

5.1 Robustness

We test the robustness of our results in four dimensions: with respect to immigrants' specialization, job turnover, regional trends and sectoral trends.

[18]As explained in section 3.1 this may be due to the business cycle effect. Positive local economic conditions (for example, an increase in aggregate demand) are likely to attract foreign workers to an area. But as the theoretical model shows, this should not change the factor mix, since technology and factor prices remain unaffected. IV estimates eliminate these cyclical effects and help identify the causal effects of an exogenous supply of foreign labor.

The first check involves the immigrants' sectors of specialization. So far ($\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$) included among the top twenty countries of origin, nationalities specialized both in industrial activities (such as Romanians and Senegalese) and in service sectors (Filipinos and Poles). This might imply an incorrect identification of the causal impact of immigration in equation (19). For example, as Barone and Mocetti (2011) show, the arrival of Filipinos domestic workers caused an increase in the labor market participation of Italian women, which could ultimately be the main reason why firms choose a different capital-labor ratio.

To deal with this problem, we check whether the effect we find is indeed attributable to immigrants specialized in manufacturing. More precisely, we define as "manufacturing" nationalities the six countries with the largest number of manufacturing workers in the 2005 wave of the Labor Force Survey (last column of Table 1). In practical terms, we split the immigration variable into two complementary components: $\Delta \ln \frac{L_{INDjt}^{imm}}{Pop_{jt}}$ is the growth rate of the share of immigrants specialized in manufacturing (i.e. Morocco, Romania, Albania, Senegal, India and Ghana) and $\Delta \ln \frac{L_{NOINDjt}^{imm}}{Pop_{jt}}$ is that for other immigrants. We compute the instruments accordingly. If the mechanism identified by the theoretical model is correct, we should find a positive and significant coefficient of $\Delta \ln \frac{L_{INDjt}^{imm}}{Pop_{jt}}$, and this is exactly what we observe in the first column of Table 4. A larger share of immigrants not specialized in manufacturing causes a decrease in the capital-labor ratio.

The second test follows naturally from the predictions of the theoretical model. One crucial hypothesis is that the firms that more frequently engage in searching for workers are more likely to hire immigrants after an exogenous inflow of foreign workers. This implies that firms with a higher job turnover are more exposed to a deterioration in average quality induced by immigration, and should therefore be more prone to invest in capital. In column (2) of Table 4 we show the estimates for immigrants share interacted with a measure of job turnover: the fact that interaction has a positive and significant coefficient confirms the prediction.

Lastly we test whether the possible presence of omitted variables due to local or

Table 4: Capital intensity and immigration: robustness

Dependent variable: g^k_{ijt}				
	Immigrant specialization (1)	Turnover (2)	Regional trends (3)	Sectoral trends (4)
$\Delta \ln \frac{L^{imm}_{INDjt}}{Pop_{jt}}$	0.704**			
	(0.308)			
$\Delta \ln \frac{L^{imm}_{NOINDjt}}{Pop_{jt}}$	-0.184*			
	(0.107)			
$\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}}$		0.157	0.179*	0.191**
		(0.095))	(0.106)	(0.096)
$\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}} * jobtur$		0.188**		
		(0.078)		
$g^{sh\_blue}_{ijt}$	-1.002***	-1.003***	-1.004***	-1.005***
	(0.010)	(0.009)	(0.009)	(0.009)
$rever$	-0.008	-0.005	-0.005	-0.004
	(0.007)	(0.006)	(0.006)	(0.006)
$credrat$	0.011	0.002	0.000	-0.003
	(0.021)	(0.017)	(0.017)	(0.017)
$cashfl$	0.018*	0.021**	0.021**	0.020**
	(0.010)	(0.008)	(0.008)	(0.008)
$jobtur$		-0.025		
		(0.019)		
Observations	5513	5513	5513	5513
Number of firms	1180	1180	1180	1180
F first step	17.29	39.00	62.64	73.74

Notes: IV estimates of equation (19). Firm-level and year fixed effects are always included. Standard errors are clustered by province. The dependent variable g^k_{ijt} is the growth rate of the ratio of production capital stock to the number of blue-collar workers at firm-level. $g^{sh\_blue}_{ijt}$ is the growth rate of the ratio of the number of blue-collar workers to that of white-collar workers at firm-level. $\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}}$ is the growth rate of the share of the stock of immigrants to total population at province level. $\Delta \ln \frac{L^{imm}_{INDjt}}{Pop_{jt}}$ ($\Delta \ln \frac{L^{imm}_{NOINDjt}}{Pop_{jt}}$) is the growth rate of the share of the stock of immigrants specialized in manufacturing (non-manufacturing) in total population stock at province level. Countries whose workers are mostly specialized in manufacturing are Morocco, Romania, Albania, Senegal, India and Ghana. $credrat$ is a dummy variable equal to 1 if a firm declared to be credit-rationed. $cashfl$ is the deflated value of a firm's cash flow scaled down by the its lagged capital stock. $rever$ is a dummy variable equal to 1 if the investment goods of a firm can be sold on the second-hand market. $jobtur$ is a firm's yearly sum of inflows and outflows of workers divided by the average employment level in the year. *** p<0.01, ** p<0.05, * p<0.1.

sectoral trends may bias the estimates. First we add location dummies (NUTS-1 regions, according to the European Union classification) interacted with year dummies (column (3)); then we insert the interaction between sector and year dummies. The results are given in the last two columns of Table 4. The key finding is that the coefficient of $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$ remains remarkably stable at the level estimated in the base regressions of Table 3.

5.2 Heterogeneous effects

The validity of the model's mechanism can be further tested empirically. As Lemma 2 and Proposition 1 show, the impact of immigration on capital intensity can be heterogeneous across sectors and firms. Empirically, we seek such heterogeneous effects along two dimensions: firm size, as proxied by the log of sales ($sales$) and the degree of complementary across workers (α).

The theoretical model shows that firms with greater sales are more likely to screen their workers and, so should increase their capital-labor ratio more sharply in the face of an exogenous flow of immigrants. In column (1) of Table 6 the baseline equation is augmented with the interaction between the immigration variable $\Delta \ln \frac{L_{jt}^{imm}}{Pop_{jt}}$ and the level of sales ($sales$). The positive and statistically significant coefficient of the interaction term shows that large firms do increase their capital intensity more than smaller ones, and thus confirms the predictions of the model.

The model also predicts that the positive effect of migration on capital intensity is stronger, the higher is α. In the model, α represents the return on the average quality of workers. The empirical counterpart of this kind of relationship is not straightforward. To this end we observe that if a firm's production function is characterized by a high return on the workers' average quality, that firm should opt for a larger share of skilled workers. Thus we proxy α with the share of skilled workers at sectoral level using the OECD-STAN database. To ensure exogeneity, we compute this measure on US data, which are available for 1998. Sectoral variables for α are provided in table 5. The median value (0.16) is computed on the distribution of firms.

Table 5: Sectoral values for α

Sector	Skill Intensity	Above the median
Food, beverages and tobacco	0.161	YES
Textiles, leather and footwear	0.118	NO
Wood, paper and paper products	0.092	NO
Printing, publishing and reproduction	0.081	YES
Oil refining, coal and coke	0.245	YES
Chemicals and chemical products	0.386	YES
Rubber and plastics products	0.151	NO
Other non-metallic mineral products	0.139	NO
Basic metals and fabricated metal products	0.138	NO
Machinery, n.e.c.	0.147	YES
Computers, electrical machinery and communication equipment	0.281	YES
Transport equipment	0.260	YES
Manufacturing n.e.c., including furniture	0.155	YES

Notes: Source: OECD STAN

Columns (2) and (3) of Table 6 present the baseline regression separately for sectors with lower and higher skill intensity. Again the results confirm the theoretical predictions: the effect of immigration is positive for more skill-intensive sectors and not different from zero in sectors with a smaller share of skilled workers.

6 Concluding remarks

The massive global migration has raised considerable concern over the impact on host country economies of a large number of unskilled immigrants joining the workforce. In this paper, we have focused on firms and in particular on their choice of the capital-labor ratio. In this regard, our paper is complementary to the empirical literature on the impact of immigration on the level of workers' skill level.

Our empirical specification was guided by a theoretical model whereby under certain conditions, that are very likely to apply to the Italian institutional setup, firms may choose to counteract the drop in productivity due to the arrival of low-skilled immigrants by increasing capital intensity. Empirically the data for a sample of Italian manufacturing firms over the period 1996-2007 fully validate these predictions. The result is robust to a number of alternative specifications, and IV estimation indicates that the relationship is causal.

Table 6: Capital intensity and immigration: heterogeneity

Dependent variable: g^{k}_{ijt}		α	
		<median	>median
	(1)	(2)	(3)
$\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}}$	-0.469*	-0.050	0.306***
	(0.272)	(0.204)	(0.110)
$\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}}$	0.063***		
* *sales*	(0.024)		
$g^{sh\_blue}_{ijt}$	-1.003***	-1.024***	-1.000***
	(0.009)	(0.020)	(0.010)
rever	-0.005	0.002	-0.007
	(0.006)	(0.011)	(0.008)
credrat	0.004	-0.008	0.010
	(0.018)	(0.031)	(0.022)
cashfl	0.020**	0.019	0.022**
	(0.009)	(0.019)	(0.010)
Observations	5513	1622	3891
Number of firms	1180	336	844
F first step	39.18	25.60	53.28

Notes: IV estimates of equation (19). Firm-level and year fixed effects are always included. Standard errors are clustered by province. The dependent variable g^{k}_{ijt} is the growth rate of the ratio of production capital stock to the number of blue-collar workers at firm-level. $g^{sh\_blue}_{ijt}$ is the growth rate of the ratio of the number of blue-collar workers to that of white-collar workers at firm-level. $\Delta \ln \frac{L^{imm}_{jt}}{Pop_{jt}}$ is the growth rate of the share of the stock of immigrants in total population at province level. *credrat* is a dummy variable equal to 1 if a firm declared to be credit-rationed. *cashfl* is the deflated value of a firm's cash flow scaled down by the its lagged capital stock. *rever* is a dummy variable equal to 1 if the investment goods of a firm can be sold on the second-hand market. *sales* is the logarithmic transformation of a firm's current level of sales. *jobtur* is a firm's yearly sum of inflows and outflows of workers divided by average employment level in the year. *** p<0.01, ** p<0.05, * p<0.1.

Appendix

Appendix 1 Conditional demand for factors

From the maximization problem (5) we obtain

$$K^* = D\frac{(\gamma b)^\sigma}{\left[b^{\sigma-1}\gamma^\sigma + (1-\gamma)^\sigma B^\sigma r^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}}} \tag{21}$$

$$n^* = D\frac{[r(1-\gamma)B]^\sigma}{\left[b^{\sigma-1}\gamma^\sigma + (1-\gamma)^\sigma B^\sigma r^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}}}, \tag{22}$$

where

$$B = \begin{cases} (Z_1^\alpha)^{\frac{\sigma}{\sigma-1}} & \text{if no screening} \\ \left[\dfrac{Z_2^\alpha}{\Phi^{\alpha-1}\eta^\alpha}\right]^{\frac{\sigma}{\sigma-1}} & \text{if screening.} \end{cases} \tag{23}$$

and b is the search cost.

Appendix 2 Proofs

Proof of Lemma 1

Non-screening firms - Rewrite equation (15) as (18). The proof follows directly.

Screening firms - By equations (9) and (16) we obtain:

$$\begin{aligned}\frac{\partial \ln k_S^*}{\partial \beta} =& \frac{\sigma(\Omega_F - \Omega_N)}{\beta\eta^{\varepsilon_F}\Omega_F + (1-\beta)\eta^{\varepsilon_N}\Omega_N} - \frac{\sigma(\eta^{\varepsilon_F} - \eta^{\varepsilon_N})}{\Phi} \\ &-\alpha(\sigma-1)\left(\frac{E_F\eta^{\varepsilon_F} - E_N\eta^{\varepsilon_N}}{Z_2} - \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi}\right) - \frac{\sigma(\eta^{\varepsilon_F} - \eta^{\varepsilon_N})}{\Phi} \\ &= -\left[\alpha(\sigma-1) - \sigma\right]\left(\frac{E_F\eta^{\varepsilon_F} - E_N\eta^{\varepsilon_N}}{Z_2} - \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi}\right) - \frac{\sigma(\eta^{\varepsilon_F} - \eta^{\varepsilon_N})}{\Phi}\end{aligned} \tag{24}$$

It is straightforward to show that

$$-\frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi} > 0 \tag{25}$$

$$\frac{E_F\eta^{\varepsilon_F} - E_N\eta^{\varepsilon_N}}{Z_2} - \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi} = \frac{1}{\beta + \frac{\eta^{\varepsilon_N} E_N}{\eta^{\varepsilon_F} E_F - \eta^{\varepsilon_N} E_N}} - \frac{1}{\beta + \frac{\eta^{\varepsilon_N}}{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}} < 0 \tag{26}$$

since $\frac{\eta^{\varepsilon_N}}{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}} < \frac{\eta^{\varepsilon_N} E_N}{\eta^{\varepsilon_F} E_F - \eta^{\varepsilon_N} E_N} < 0.$

Conditions (25) and (26) prove the lemma for screening firms.

□

Proof of Lemma 2

If wages are stickier than productivity, both screening and non-screening firms increase the capital labor ratio as a consequence of the increase in the share of immigrants in the province. The difference between the effect of an increase in the share of immigrants on the capital-labor ratio for screening and non-screening firms is equal to

$$\begin{aligned}\frac{\partial \ln k_S^*}{\partial \beta} - \frac{\partial \ln k_{NS}^*}{\partial \beta} =& \frac{\sigma(\Omega_F - \Omega_N)}{\beta\eta^{\varepsilon_F}\Omega_F + (1-\beta)\eta^{\varepsilon_N}\Omega_N}\frac{\eta^{\varepsilon_F}\eta^{\varepsilon_N}}{\Phi} - \frac{\sigma(\Omega_F - \Omega_N)}{\beta\Omega_F + (1-\beta)\Omega_N} \\ &-\alpha(\sigma-1)\left(\frac{E_F\eta^{\varepsilon_F} - E_N\eta^{\varepsilon_N}}{Z_2} - \frac{E_F - E_N}{Z_1} - \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi}\right) \\ &-\sigma\frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi}.\end{aligned} \tag{27}$$

Provided that by equation (12) we can set $\Omega_l = \lambda E_l$

$$\begin{aligned}=& \frac{\sigma\lambda(\eta^{\varepsilon_F} E_F - \eta^{\varepsilon_N} E_N)}{\lambda\left[\beta\eta^{\varepsilon_F} E_F + (1-\beta)\eta^{\varepsilon_N} E_N\right]} - \frac{2\sigma(\eta^{\varepsilon_F} - \eta^{\varepsilon_N})}{\Phi} - \frac{\sigma\lambda(E_F - E_N)}{\lambda\left[\beta E_F + (1-\beta)E_N\right]} \\ &- \alpha(\sigma-1)\left(\frac{E_F\eta^{\varepsilon_F} - E_N\eta^{\varepsilon_N}}{Z_2} - \frac{E_F - E_N}{Z_1} - \frac{\eta^{\varepsilon_F} - \eta^{\varepsilon_N}}{\Phi}\right)\end{aligned}$$

By the definitions of Φ, Z_1, and Z_2 we have that

$$E_F\eta^{\varepsilon_F} - E_N\eta^{\varepsilon_N} = \frac{1}{\beta}(Z_2 - E_N\eta^{\varepsilon_N}), E_F - E_N = \frac{1}{\beta}(Z_1 - E_N),$$

$$\eta^{\varepsilon_F} - \eta^{\varepsilon_N} = \frac{1}{\beta}(\Phi - \eta^{\varepsilon_N}), \quad \text{so that}$$

$$\frac{\partial \ln k_S^*}{\partial \beta} - \frac{\partial \ln k_{NS}^*}{\partial \beta} = \frac{1}{\beta\Phi Z_1 Z_2}\Bigg\{ Z_1 Z_2 \left[\alpha(\sigma-1) - 2\sigma\right](\Phi - \eta^{\varepsilon_N}) + \alpha(\sigma-1)E_N\Phi(Z_1\eta^{\varepsilon_N} - Z_2) + E_N E_F \Phi\sigma(\Phi - \eta^{\varepsilon_N})\Bigg\} \tag{28}$$

$$= \frac{1}{\beta\Phi Z_1 Z_2}\Big\{ Z_1 Z_2 \left[\alpha(\sigma-1) - 2\sigma\right](\Phi - \eta^{\varepsilon_N}) + \alpha(\sigma-1)E_N E_F \beta(\eta^{\varepsilon_N} - \eta^{\varepsilon_F}) + E_N E_F \Phi\sigma(\Phi - \eta^{\varepsilon_N})\Big\}$$

using $\beta(\eta^{\varepsilon_N} - \eta^{\varepsilon_F}) = \eta^{\varepsilon_N} - \Phi$

$$= \frac{1}{\beta\Phi Z_1 Z_2}\Big\{ -Z_1 Z_2 \left[\alpha(\sigma-1) - 2\sigma\right](\eta^{\varepsilon_N} - \Phi) + \left[\alpha(\sigma-1) - \sigma\right] E_N E_F \Phi(\eta^{\varepsilon_N} - \Phi)\Big\}$$

$$= \frac{1}{\beta\Phi Z_1 Z_2}\Big\{ \left[\alpha(\sigma-1) - \sigma\right](E_N E_F \Phi - Z_1 Z_2) + Z_1 Z_2 \sigma\Big\}$$

$$= \frac{1}{\beta\Phi Z_1 Z_2}\Big\{ \left[\alpha(\sigma-1) - \sigma\right](1-\beta)E_N E_F(\eta^{\varepsilon_N} - \eta^{\varepsilon_F}) - \left[\alpha(\sigma-1) - \sigma\right]\left[(1-\beta)\beta(E_N^2\eta^{\varepsilon_N} - E_F^2\eta^{\varepsilon_F})\right] + Z_1 Z_2 \sigma\Big\}$$

$$= \frac{1}{\beta\Phi Z_1 Z_2}\Big\{ \left[\alpha(\sigma-1) - \sigma\right](1-\beta)E_N E_F(\eta^{\varepsilon_N} - \eta^{\varepsilon_F}) + (1-\beta)E_N^2\eta^{\varepsilon_N}\left[(1-\beta)\sigma - \beta\alpha(\sigma-1) + \beta\sigma\right] + \left[\alpha(\sigma-1) - \sigma\right](1-\beta)\beta E_F^2\eta^{\varepsilon_F} + \sigma\Big[\beta^2 E_F^2\eta^{\varepsilon_F} + \beta(1-\beta)E_F E_N(\eta^{\varepsilon_N} + \eta^{\varepsilon_F})\Big]\Big\} \tag{29}$$

which is larger than zero, provided that

$$\alpha > \frac{\sigma}{\sigma - 1} = \underline{\alpha} \tag{30}$$

$$\alpha < \frac{\sigma}{\beta(\sigma - 1)} = \bar{\alpha}. \tag{31}$$

The fourth term is always positive, condition (30) assures that the first and the third terms are positive, while condition (31) assures that the second term is positive. Notice that since β is small $\underline{\alpha} < \bar{\alpha}$ and the range of α for which the lemma holds is "large". □

Lemma 3

In this economy i) $b_{NS} < b_S$ *and ii)* $Z_1 \Phi \eta / Z_2 < 1$.

Proof of Lemma 3

Let us prove i) first:

$$b_{NS} < b_S \quad \text{since}$$

$$\beta \Omega_F + (1-\beta)\Omega_N < \frac{1}{\Phi}\left[\beta \eta^{\varepsilon_F} \Omega_F + (1-\beta)\eta^{\varepsilon_N} \Omega_N\right]$$

$$\beta E_F + (1-\beta)E_N < \frac{1}{\Phi}\left[\beta \eta^{\varepsilon_F} E_F + (1-\beta)\eta^{\varepsilon_N} E_N\right]$$

$$\left[\beta \eta^{\varepsilon_F} + (1-\beta)\eta^{\varepsilon_N}\right]\left[\beta E_F + (1-\beta)E_N\right] < \left[\beta \eta^{\varepsilon_F} E_F + (1-\beta)\eta^{\varepsilon_N} E_N\right] \tag{32}$$

$$\beta(1-\beta)\eta^{\varepsilon_F} E_N + \beta(1-\beta)E_F \eta^{\varepsilon_N} < (1-\beta)\beta \eta^{\varepsilon_F} E_F + (1-1+\beta)(1-\beta)\eta^{\varepsilon_N} E_N$$

$$\eta^{\varepsilon_F} E_N + E_F \eta^{\varepsilon_N} < \eta^{\varepsilon_F} E_F + \eta^{\varepsilon_N} E_N$$

$$\eta^{\varepsilon_F}(E_N - E_F) < \eta^{\varepsilon_N}(E_N - E_F).$$

Let us now prove ii):

$$\frac{Z_1 \Phi \eta}{Z_2} < 1 \quad \text{since}$$

$$Z_1 \Phi \eta < Z_2$$

$$\left[\beta E_F + (1-\beta)E_N\right]\phi\eta < \beta \eta^{\varepsilon_F} E_F + (1-\beta)\eta^{\varepsilon_N} E_N$$

which we know holds by condition (32) and the fact that $\eta < 1$. □

Proof of proposition 1

The effect on sales is determined by the screening behavior of firms. In what follows, we show that the decision to screen is taken by larger firms only. As Lemma 2 shows, screening firms increase their capital-labor ratio by more than non-screening firms. Using conditional factor demands we can compute

$$\Pi^*_{NS}(D) = D - rK^*_{NS}(D) - b_{NS}n^*_{NS}(D), \tag{33}$$

$$\Pi^*_{S}(D) = D - rK^*_{S}(D) - b_{S}n^*_{S}(D) - f_S. \tag{34}$$

Firms screen only if their profits from doing so are greater than from not screening:

$$\Pi^*_S(D) - \Pi^*_{NS}(D) \geq 0 \tag{35}$$

Since firms do not direct their search $b_S n^*_S(D) = b_{NS} n^*_{NS}(D)$, (35) boils down to comparing

$$r[K^*_{NS}(D) - K^*_S(D)] \geq f_S$$

$$Dr\left\{\frac{(\gamma b_{NS})^\sigma}{\left[\gamma^\sigma b_{NS}^{\sigma-1} + (1-\gamma)^\sigma\left(Z_1^\alpha r\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}}} - \frac{(\gamma b_S)^\sigma}{\left\{\gamma^\sigma b_S^{\sigma-1} + (1-\gamma)^\sigma\left[\left(\frac{Z_2}{\Phi\eta}\right)^\alpha \Phi r\right]^{\sigma-1}\right\}^{\frac{\sigma}{\sigma-1}}}\right\} \geq f_S$$

$$\frac{Dr}{\gamma}\left\{\left[\frac{1}{1+\left(\frac{1-\gamma}{\gamma}\right)^\sigma\left(\frac{Z_1^\alpha r}{b_{NS}}\right)^{\sigma-1}}\right]^{\frac{\sigma}{\sigma-1}} - \left[\frac{1}{1+\left(\frac{1-\gamma}{\gamma}\right)^\sigma\left[\left(\frac{Z_2}{\Phi\eta}\right)^\alpha\frac{\Phi r}{b_S}\right]^{\sigma-1}}\right]^{\frac{\sigma}{\sigma-1}}\right\} \geq f_s$$

$$\frac{Dr}{\gamma}\left[\Delta_{NS} - \Delta_S\right] \geq f_s \tag{36}$$

where

$$\Delta_{NS} = \left[\frac{1}{1 + \left(\frac{1-\gamma}{\gamma}\right)^{\sigma} \left(\frac{Z_1^{\alpha} r}{b_{NS}}\right)^{\sigma-1}} \right]^{\frac{\sigma}{\sigma-1}}, \quad \Delta_S = \left[\frac{1}{1 + \left(\frac{1-\gamma}{\gamma}\right)^{\sigma} \left[\left(\frac{Z_2}{\Phi\eta}\right)^{\alpha} \frac{\Phi r}{b_S}\right]^{\sigma-1}} \right]^{\frac{\sigma}{\sigma-1}}$$

From which we obtain D^* as

$$D \geq D^* = \frac{f_s \gamma}{r\left[\Delta_{NS} - \Delta_S\right]} \quad if \quad \Delta_{NS} - \Delta_S > 0. \tag{37}$$

We now show that the condition $\Delta_{NS} - \Delta_S > 0$ holds. Since $\sigma/(\sigma-1) > 1$, this amounts to showing that

$$\frac{Z_1^{\alpha} r}{b_{NS}} < \left(\frac{Z_2}{\Phi\eta}\right)^{\alpha} \frac{\Phi r}{b_S}$$

$$\left(\frac{Z_1 \Phi \eta}{Z_2}\right)^{\alpha} < \frac{\Phi b_{NS}}{b_S} \tag{38}$$

Notice that by lemma 3, both $\Phi b_{NS}/b_S < 1$ and $Z_1\Phi\eta/Z_2 < 1$, and that if $\alpha \to +\infty$ $(Z_1\Phi\eta/Z_2)^{\alpha}$ converges to zero. Hence for α large enough condition (38) holds.

Finally, we compute the minimum value of α for which (38) holds. Equalizing the LHS and the RHS of (38),

$$\left(\frac{Z_1 \Phi \eta}{Z_2}\right)^{\alpha} = \frac{\Phi b_{NS}}{b_S}, \quad \text{or} \quad \left(\frac{Z_1 \Phi \eta}{Z_2}\right)^{\alpha} = \frac{\Phi^2 Z_1}{Z_2}$$

we take logs of both sides

$$\alpha \ln\left(\frac{Z_1 \Phi \eta}{Z_2}\right) = \ln\left(\frac{\Phi^2 Z_1}{Z_2}\right)$$

$$\breve{\alpha} = \frac{\ln\left(\frac{\Phi^2 Z_1}{Z_2}\right)}{\ln\left(\frac{Z_1 \Phi \eta}{Z_2}\right)} < 1 \tag{39}$$

provided that $\eta > \Phi$, implying $\eta\Phi > \Phi^2$. Since $\alpha > 1$, (38) always holds. □

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