Offshoring, Low-skilled Immigration and Labor Market Polarization*

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Abstract

During the last three decades, the U.S. labor market was characterized by its employment polarization. As jobs in the middle of the skill distribution disappeared, employment expanded for the high and low-skill occupations. Real wages did not follow the same pattern. While earnings for the high-wage occupations increased robustly, wages for both low and middle-skill workers remained subdued. We relate this evidence to the increase in offshoring and low-skilled migration, and develop a multi-country stochastic growth model to rationalize the patterns of employment and wages. Offshoring negatively affects the middle-skill occupations, but increases aggregate productivity. This benefits the high-skill occupations, and in turn leads to increased demand for the non-tradable personal services, which employ mostly low-skill workers. However, low-skill wages remain depressed due to the rising migration inflows. Native workers react by upgrading the skill content of their labor tasks as they invest in training. The model is estimated with multilateral trade-weighted macroeconomic indicators and U.S.-Mexico border enforcement data.

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1 Introduction

Job creation, income inequality, and the stance of the middle-income households have been among the most debated topics in macro and labor economics. To put these issues into context, Fig. 1 (panel a) illustrates the change in the share of U.S. employment across 318 non-farm occupations, which are ranked by skill on the horizontal axis.¹ The figure shows that the employment share of occupations typically held by middle-skill workers decreased over the last three decades. Instead, the employment gains were concentrated both in the high and low-skill occupations. Fig. 1 (panel b) shows the corresponding evolution of wages for these same occupations, similarly ranked by skill. The pattern observed for wages is quite different than for employment. Notably, for occupations at the bottom of the skill distribution, the strong expansion in employment was not accompanied by a similarly robust increase in wages. However, the high-skill occupations witnessed a healthy wage growth that mirrored the growth of employment over the sample period. Similarly, the middle-skill occupations witnessed depressed employment as well as wages.

Our hypothesis is that the asymmetric pattern of polarization across employment and wages is closely related to the increase in offshoring and low-skilled immigration over the past three decades. When taken together, the empirical evidence appears to be consistent with this claim. Ottaviano, Peri and Wright (2012) show that labor tasks executed by middle-skill workers are typically offshored. In turn, offshoring is a key factor that explains the polarization of employment and its dampening effect on the wages of the middle-skilled (see Goos et al. 2011, and Firpo et al. 2011, respectively). Autor and Dorn (2012) focus their analysis on the bottom of the skill distribution, showing that the upward twist of the left tail of employment in Fig 1. is practically accounted for by a single cause: the increase in ‘service occupations’. Service occupations are jobs that involve assisting and caring for others, including food service workers, janitors, gardeners, home health aides and child care workers. To illustrate the contribution of service occupations, in Fig. 2 we implement the empirical strategy in Autor and Dorn (2012) by considering a

¹The skill rank is approximated by the initial average wage in each occupation. See Acemoglu and Autor (2011) and Autor and Dorn (2012) for data and references.

simple counterfactual scenario, in which employment in service occupations is held at its original level from 1980. Mimicking their results, the twist of the employment distribution at the low-skill tail would become negligible in this counterfactual scenario. Considering this last evidence, it is worth connecting it to the labor migration literature. During the last three decades, the share of foreign-born in the U.S. population more than doubled (from 6% to 13%; see Grogger and Hanson, 2008). A disproportionate number of these immigrants were relatively unskilled, and ended up taking many of the service occupations that emerged at the low end of the skill distribution (see Peri and Sparber, 2009). In turn, Cortes (2008) show the inflow of low-skilled migrants had a sizeable negative effect on wages in service occupations. This evidence, when taken altogether, may explain why the evolution of wages for the low-skilled did not match the robust growth in demand for service jobs. Finally, the quantitative analysis in Ottaviano, Peri and Wright (2012) show that the U.S. native workers that specialize in high-skill tasks (which can hardly be outsourced) benefit significantly from the cost savings associated with employing cheaper immigrant and offshore labor in the execution of low and middle-skill tasks. This so-called ‘productivity effect’ for the native high-skilled leads to a robust growth in their group-specific employment and earnings.

The goal of this paper is to rationalize this compelling empirical narrative of labor market polarization, offshoring and immigration in a unified structural model specification. We develop a tractable stochastic growth model that features skill heterogeneity, offshoring, and unskilled labor migration within a general equilibrium context. In this dynamic specification, the households’ optimization behavior will endogenously determine not only the extent of offshoring and migration, but also the optimal amount of training (skill acquisition) in response to these developments. These endogenous decisions in turn will respond to innovations in migration and trade policy, as well as to transitory and permanent macroeconomics shocks. The model is estimated with macroeconomic data, multilateral trade-weighted indicators, and U.S.-Mexico border enforcement data on undocumented migration. It is worth highlighting an advantage of the macro structural approach that we follow relative to the literature. The vast majority of these papers, that use rich microeconomic data, rely on reduced-form econometric specifications (that

take some of these key mentioned covariates as given) and/or rest on static theoretical frameworks for analytical convenience. For instance, in the literature, the skill distribution of the labor force is generally assumed to be given and not reactive to developments in offshoring and migration.

One key feature of our model is the presence of trade in *tasks* rather than in *goods*, as originally coined by Grossman and Rossi-Hansberg (2008). Namely, as revolutionary advances in transportation and communication take place, international trade increasingly involves bits of value added executed at different locations, rather than a standard exchange of finished goods. Instructions can be delivered instantaneously and components of unfinished goods can be moved quickly and cheaply. This allows firms to incorporate labor inputs from different countries in the production process. In this context, multinational firms only hire the most skilled workers from each economy and exploit the existing local specialization. To illustrate this idea with an example, as trade links deepen, U.S. multinationals can employ professionals in the Silicon Valley area to work on the design of a state-of-the-art computer device, while other less productive tasks can be accomplished in the rest of the world (e.g. Indian basic programmers debug the software, Thai technicians provide a functioning hard drive, and Chinese workers proceed with the final assembling). The ‘offshoring’ costs in the model capture transportation, as well as costs associated with remote monitoring and adaptability of the offered foreign skills to the local practice. A decline in these costs of offshoring enhances task specialization and leads to global productivity gains.

The model will also include the presence of a service sector that, by assumption, only employs unskilled workers. As explained above, these jobs consist of manual tasks that require practically no training. By definition, they also must be executed where the final consumer is located, and thus they will be strictly non-tradable. Following a productivity increase, either as a result of task specialization or of technological progress, the demand for personal services and the associated unskilled wages will increase. Although these service tasks cannot be executed remotely, the increase in unskilled wages attracts immigrant labor. As these immigrants settle, the increased supply of unskilled labor offsets the increased demand and dampens the upward pressure on unskilled wages, thus leading to the asymmetric pattern

of changes in employment and wages at the low end of the skill distribution shown in Fig. 1. Changes in migration policy (i.e. border enforcement) and macroeconomic developments also affect the migration decision in the country of origin.

Finally, our model incorporates a key endogenous training decision. Households can freely allocate unskilled labor to the non-tradable service sector, or alternatively invest in training to create a diversity of occupations that perform different tasks. The sunk training cost involves an irreversible investment, and there is an initial uncertainty concerning the future idiosyncratic productivity of the job post created. An implication of this model is that households will either upgrade (or downgrade) their skills in response to the economic environment. For example, a counterfactual scenario that abstracts from the migration inflows recorded in recent decades would lead to a sizable increase in unskilled wages (as the rising demand for service jobs is not offset by the immigrant supply). This scenario would dampen the native labor's incentives to train, leading to skill downgrade and a decrease in aggregate productivity. This last prediction is consistent with the empirical results in Hunt (2012), which show that the inflow of migrant workers enhances the native population's incentive to improve their educational attainment.

The rest of the paper is organized as follows. Section 2 describes the related literature. Section 3 introduces the model. Section 4 presents the data, discusses the estimation procedure, and assesses the fit of the model to the data. Section 5 quantifies the impact of various shocks to the growth dynamics. Section 6 quantifies the welfare implications of alternative trade and migration policy arrangements. Section 7 concludes.

2 Related literature

Our paper adds to the existing literature that examines the determinants of labor market polarization in the United States and other industrialized economies over the past three decades. It is closely related to Mandelman (2012), who argues that offshoring has been a key determinant of labor market polarization, whereby the decline in trade costs enhances the international trade in tasks, thus benefiting the high-skill

workers while hurting the medium-skill ones. It is also related to Autor and Dorn (2013), who argue that skill-biased technological change has also contributed to labor market polarization, as automation has made the routine-intensive jobs in the middle of the skill distribution obsolete. Along the same lines, Jaimovich and Siu (2012), propose a search-and-matching model of the labor market with occupational choice, in which routine-biased technological change leads to the loss of medium-skill jobs especially during recessions, and hence results in jobless recoveries. Thus, our work is consistent with the empirical findings in Firipo, Fortin and Lemieux (2011), who show that both offshoring and technological change have contributed to labor market polarization in the United States over the past three decades.

Importantly, we add to the literature by analyzing the joint effects of two related processes – i.e. the offshoring of medium-skill jobs and the immigration of unskilled labor – on the pattern of labor market polarization and task upgrading. In particular, offshoring and immigration taken together can explain labor market outcomes that would have evaded studies in which offshoring and immigration are considered in isolation. Thus, since the inflows of unskilled immigrant labor dampen the wage of the unskilled natives, the latter have an incentive to undergo training, and thus to gradually shift toward the relatively high-skill occupations over time. This outcome could not be reproduced by a model that only allows for offshoring (Mandelman, 2012) or for the automation of medium-skilled jobs (Autor and Dorn, 2012), in which the native labor reallocates from the medium to low-skill occupations, rather than from the medium to high-skill occupations. In addition, offshoring alone cannot explain the divergent dynamics of employment and wages at the low end of the skill distribution, as shown in Figure 1. Thus, our framework that considers the joint effects of immigration and offshoring provides novel insights on the dynamics of labor market polarization in the United States.

Among the scarce literature that considers offshoring and immigration jointly, our paper is most closely related to Ottaviano, Peri and Wright (2013), who study the effects of immigration and offshoring on the U.S. native labor. However, our work differs in a number of ways. First, the afore-mentioned study is focused on the substitution between immigrant, offshore and native workers, whereas we examine the

effect of immigration and offshoring on labor market polarization and task upgrading by the native workers. Second, we examine the effect of immigration and offshoring on both employment and wages, not just on employment. Third, we build a general equilibrium model in which the offshoring of tasks, the migration of unskilled labor, and the task upgrading by native labor are endogenous microfounded decisions.

Our work is also related to the literature that models offshoring and immigration taken separately, and documents their effects on labor market outcomes. On the modeling of offshoring, we borrow from the framework with trade in tasks developed by Grossman and Rossi-Hansberg (2008), which we expand to include a continuum of tasks fulfilled by heterogeneous workers. However, in our model, ‘offshoring’ occurs when the tasks performed abroad enter the production of the country-specific good as imperfect (rather than perfect) substitutes with the tasks performed domestically. In addition, our modeling of labor heterogeneity across skills resembles the framework with firm heterogeneity across productivity levels proposed in Ghironi and Melitz (2005), and adapted to offshoring through vertical FDI in Zlate (2012). Our results on labor market polarization are consistent with the empirical literature that documents the ‘displacement effect’ of offshoring on the relatively low-skill native workers, and the indirect ‘productivity effect’ benefiting the high-skill ones, like in Crino (2010), Ottaviano, Peri and Wright (2013), and Wright (2013).

On immigration, we model the inflows of unskilled labor with sunk migration costs as in Mandelman and Zlate (2012), using a mechanism that resembles the sunk firm entry cost in Ghironi and Melitz (2005), or the one with sunk firm exporting cost in Alessandria and Choi (2007). We model the immigrant labor as mostly unskilled, following the evidence in Grogger and Hanson (2008) and the ‘cost of hardship’ that immigrant labor encounters in terms of forgone productivity at the destination (Ottaviano, Peri and Wright, 2013). Regarding the impact of immigration on labor market outcomes, our results are consistent with empirical findings of a negative effect on the wages and employment of low-skill native workers (Ottaviano and Peri, 2012; Borjas, Grogger and Hanson, 2011; Borjas, 2003; Friedberg and Hunt, 1995), but

a positive effect on wages in the source country (Mishra, 2007). In addition, the endogenous relocation of native labor toward high and medium-skill occupations ('task upgrading') in response to unskilled immigration is consistent with the empirical evidence in Hunt (2012).

3 Model

Our model consists of two large economies (Home and Foreign), and also a third small economy (South) that neighbors Home. In this section, the discussion is focused mainly on the Home and the South economies. For Foreign, the equations are similar to those for Home, and the variables are marked with an asterisk. Since the paper studies the labor market outcomes from offshoring and immigration, labor is the only factor of production in the baseline specification. In what follows, we start with a description of the production sectors and the representative household in Home (which are similar to those in Foreign). Then we describe the South economy, which is the source of unskilled migrant labor going to Home.

3.1 Production

There are two sectors in the home economy. The first sector produces a country-specific final good, which is obtained from the aggregation of a continuum of labor tasks. In turn, these tasks are executed in Home and Foreign by skilled workers. (The native workers executing these tasks undergo training endogenously in order to acquire "skill," as described below.) In short, we will refer to this sector as the "tradable" sector. Notice, however, that the meaning of tradability is slightly different from the one typically encountered in the literature, in that the tasks needed to produce the final good, rather than the final good itself, can be traded internationally. The second sector produces personal services, which require unskilled labor (domestic and immigrant) as an input, and which are non-tradable by definition. Thus, the model features the offshoring of tasks in the tradable sector and the immigration of unskilled labor in the non-tradable sector.²

²The model is symmetric for Home and Foreign, with the only exception being that Home receives immigrant unskilled labor from the South, whereas Foreign does not.

Training The tradable sector employs a continuum of native skilled workers for the execution of tasks. In order to obtain the skill required for employment in the tradable sector, the home household invests in training every period, thus creating a diversity of occupations. The training of new native workers requires an irreversible sunk cost of f_j units of home raw labor, and results in an idiosyncratic productivity level $\mathbf{z}$ for each worker. Workers draw this productivity from a common distribution $\mathcal{F}(\mathbf{z})$ over the support interval $[1, \infty)$. Thus, after training, the labor provided by each worker expressed in efficiency units is equal to: $l_{\mathbf{z},t} = \mathbf{z}l_t$. The productivity level remains fixed thereafter, until an exogenous skill destruction shock makes the skill obtained from training obsolete, and the efficiency unit is transformed back into raw labor. The job destruction shock is independent of the workers' idiosyncratic productivity level, so $\mathcal{F}(\mathbf{z})$ also represents the efficiency distribution for all workers at any point in time. The household's endogenous decision to undergo training is described in Section 3.2.

Tradable Sector In the execution of tradable tasks, each efficiency unit of labor benefits from two technological innovations.³ First, X_t is a permanent world technology shock that affects all productive sectors in the three economies. This global shock has a unit root as in Lubik and Schorfheide (2006), and warrants a balanced-growth path for the economy. Second, Z_t is a temporary country-specific technology shock that evolves as an AR(1) process. Thus, each efficiency unit of labor supplied is transformed in a productive task $n_t(\mathbf{z})$ as follows:

$$n_t(\mathbf{z}) = (X_t Z_t) l_{\mathbf{z},t} = (X_t Z_t) \mathbf{z} l_t. \quad (1)$$

We assume that each worker/occupation $\mathbf{z}$ can perform a given set of tasks, ξ , which are defined over a continuum of tasks Ξ (i.e. $\xi \in \Xi$). At any given time, only a subset of these tasks Ξ_t ($\Xi_t \subset \Xi$) may be demanded by firms in the global labor market and effectively used in production.⁴ Thus, the labor input of the tradable sector is obtained by aggregating over the continuum of tasks $n_t(\mathbf{z}, \xi)$ that are imperfect substitutes: $\mathbb{N}_t = \left[\int_{\xi \in \Xi_t} n_t(\mathbf{z}, \xi)^{\frac{\theta-1}{\theta}} d\xi \right]^{\frac{\theta}{\theta-1}}$, where $\theta > 1$ is the elasticity of substitution across tasks. The

³As common in the literature, in order to estimate the model, we introduce as many shocks as the data series used in the estimation to avoid stochastic singularity.

⁴The subset of tasks demanded by foreign companies is $\Xi_t^* \subset \Xi$, and may differ from Ξ_t

wage bill is $\mathbb{W}_t = \left[\int_{\xi \in \Xi_t} w_t(\mathbf{z}, \xi)^{1-\theta} d\xi \right]^{\frac{1}{1-\theta}}$, where $w_t(\mathbf{z}, \xi)$ is the wage paid to each efficiency unit of labor. Importantly, some of these tasks are executed in Foreign, as described next.

In the baseline specification, when labor is the only input in production, the final good output is $Y_{T,t} = \mathbb{N}_t$, and the price of the final good is $P_{T,t} = \mathbb{W}_t$. We take the standard approach and use the price of the final good as the numeraire, $P_{T,t} = \mathbb{W}_t \equiv 1$.

Non-Tradable Sector The second sector produces personal services that are non-tradable by definition. The output of the service sector is a linear function of unskilled labor: $Y_{N,t} = X_t L_{N,t}^A$. Importantly, the input on unskilled labor $L_{N,t}^A$ is a composite of native and immigrant unskilled labor ($L_{N,t}$ and $L_{i,t}^s$, respectively), which enter as imperfect substitutes:

$$L_{N,t}^A = \left[\alpha_N (L_{N,t})^{\frac{\sigma_N-1}{\sigma_N}} + (1 - \alpha_N) (L_{i,t}^s)^{\frac{\sigma_N-1}{\sigma_N}} \right]^{\frac{\sigma_N}{\sigma_N-1}}.$$

Trade in Tasks and the Skill Income Premium Some of the tasks imbedded in the home final good are executed in Foreign and imported (i.e. they are offshored by the home economy to Foreign). Similarly, some of the tasks imbedded in the foreign final good are executed in Home and exported (i.e. they are offshored by the foreign economy to Home). To be exported to Foreign, the tasks executed in Home are subject to an iceberg trade cost $\tau \geq 1$, and also to a period-by-period fixed offshoring cost f_o , which is defined in terms of home raw labor. For consistency with the economy-wide balanced growth path, this fixed cost is expressed in units of the home numeraire as: $f_{o,t} = \frac{w_{u,t}}{(\mathbf{Z}_t \bar{X}_t)} (X_t f_o)$. Changes in trade barriers are reflected by shocks ε_t^τ to the level of the iceberg trade cost τ , so that $\tau_t = \varepsilon_t^\tau \tau$.

In equilibrium, the wage paid to each worker in the tradable sector is skill-specific, $w_t(\mathbf{z}, \xi) = w_t(\mathbf{z}, \cdot)$, for every task $\xi \in \Xi$. Therefore, for a unit of raw labor from Home employed domestically, the skill income gap $\pi_{D,t}$ is the difference between the income obtained from the domestic tradable sector (after

training) relative to the service sector (without training):

$$\pi_{D,t}(\mathbf{z}, \cdot) = w_{D,t}(\mathbf{z}, \cdot) n_{D,t}(\mathbf{z}, \cdot) - w_{u,t} l_t, \quad (2)$$

where $n_{D,t}(\mathbf{z}, \cdot)$ denotes the efficiency units of labor executing tasks in the tradable sector for the home market, and $w_{D,t}(\mathbf{z}, \cdot)$ is the corresponding wage.

Similarly, for a unit of raw labor from Home executing tasks for Foreign, the skill income gap $\pi_{X,t}$ is:

$$\pi_{X,t}(\mathbf{z}, \cdot) = \left(\frac{w_{X,t}(\mathbf{z}, \cdot)}{\tau_t} n_{X,t}(\mathbf{z}, \cdot) - f_{o,t} \right) - w_{u,t} l_t. \quad (3)$$

Thus, all home workers have their tasks sold domestically. However, due to the iceberg trade cost and the fixed offshoring cost, only the most efficient home workers execute tasks for Foreign, in addition to the tasks sold domestically. Thus, a worker will take part in multinational production as long as the idiosyncratic productivity level $\mathbf{z}$ is above a threshold $\mathbf{z}_{X,t} = \inf\{\mathbf{z} : \pi_{X,t}(\mathbf{z}, \cdot) > 0\}$. In other words, the home workers execute tasks for the foreign market only if they obtain a positive skill income premium after forgoing the trade and fixed cost of offshoring. Conversely, home workers with productivity below $\mathbf{z}_{X,t}$ execute tasks for the domestic market only. Shocks to aggregate productivity, demand, and the iceberg trade cost will result in changes to the threshold level $\mathbf{z}_{X,t}$.

Idiosyncratic Productivity Averages To solve the model with heterogeneous workers, it is useful to define average productivity levels for two representative groups, like in Melitz (2003). First, the average productivity of all workers is: $\tilde{\mathbf{z}}_{D,t} \equiv \left[\int_1^\infty \mathbf{z}^{\theta-1} d\mathcal{F}(\mathbf{z}) \right]^{\frac{1}{\theta-1}}$. Second, the average efficiency of the workers whose tasks are traded globally is: $\tilde{\mathbf{z}}_{X,t} \equiv \left[\frac{1}{1-\mathcal{F}(\mathbf{z}_{X,t})} \int_{\mathbf{z}_{X,t}}^\infty \mathbf{z}^{\theta-1} d\mathcal{F}(\mathbf{z}) \right]^{\frac{1}{\theta-1}}$. Thus, our original setup is isomorphic to one where a mass of workers $N_{D,t}$ with productivity $\tilde{\mathbf{z}}_{D,t}$ execute tasks for the domestic market only, and a mass of workers $N_{X,t}$ with productivity $\tilde{\mathbf{z}}_{X,t}$ also accomplish tasks for the foreign market, in addition to the domestic one. The wages for each skill group are $\tilde{w}_{D,t} = w_{D,t}(\tilde{\mathbf{z}}_{D,t}, \cdot)$ and $\tilde{w}_{X,t} = w_{X,t}(\tilde{\mathbf{z}}_{X,t}, \cdot)$. Similarly, the average skill income gaps are $\tilde{\pi}_{D,t} = \pi_{D,t}(\tilde{\mathbf{z}}_{D,t}, \cdot)$ and $\tilde{\pi}_{X,t} = \pi_{X,t}(\tilde{\mathbf{z}}_{X,t}, \cdot)$,

respectively. Taking all these into account, the wage bill of the home tradable sector can be re-written as: $W_t = \left[N_{D,t} (\tilde{w}_{D,t})^{1-\theta} + N_{X,t}^* (\tilde{w}_{X,t}^*)^{1-\theta} \right]^{\frac{1}{1-\theta}}$, where $N_{X,t}^*$ denotes foreign workers executing tasks imported by Home, and $\tilde{w}_{X,t}^*$ is the corresponding wage expressed in units of the home numeraire.

3.2 Households

Household members form an extended family that pool their labor income – obtained from working in the tradable and non-tradable sectors – and choose aggregate variables to maximize expected lifetime utility. Thus, we assume that household members perfectly insure each other against fluctuations in labor income resulting from changes in their employment status, thus eliminating any type of ex-post heterogeneity across individuals, like in Andolfatto (1996) and Merz (1995).

Consumption Household's real consumption basket is: $C_t = \left[(\gamma_c)^{\frac{1}{\rho_c}} (C_{T,t})^{\frac{\rho_c-1}{\rho_c}} + (1 - \gamma_c)^{\frac{1}{\rho_c}} (C_{N,t})^{\frac{\rho_c-1}{\rho_c}} \right]^{\frac{\rho_c}{\rho_c-1}}$,

which includes amounts of the final good $C_{T,t}$ and the non-tradable personal service $C_{N,t}$. The consumer price index is: $P_t = \left[(\gamma_c) + (1 - \gamma_c) (P_{N,t})^{1-\rho_c} \right]^{\frac{1}{1-\rho_c}}$. Since international trade involves tasks rather than the final good, and the model does not include investment, the home final good is used entirely for consumption by the home household, $C_{T,t}$, and also by the Southern immigrant workers established in Home, $C_{T,t}^s$, so that $Y_{T,t} = C_{T,t} + C_{T,t}^s$. (The problem of the Southern household is described in Section 3.3.) Likewise, the non-traded personal services are used entirely in consumption by the home household, $C_{N,t} = Y_{N,t}$.

Household's Problem The home representative household has standard additive separable utility over real consumption, C_t , and leisure, $1 - L_t$, where L_t is the supply of raw labor. They maximize a standard utility kernel, which is modified to be consistent with balanced growth-path⁵:

$$\mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \varepsilon_t^b \left[\frac{1}{1-\gamma} C_t^{1-\gamma} - a_n X_t^{1-\gamma} \frac{L_t^{1+\gamma_n}}{1+\gamma_n} \right], \quad (4)$$

⁵See Rudebusch and Swanson (2012).

where parameter $\beta \in (0, 1)$ is the subjective discount factor, $\gamma > 0$ is the inverse inter-temporal elasticity of substitution, $\gamma_n > 0$ is the inverse elasticity of labor supply, and $a_n > 0$ is the weight on the disutility from labor. Also, ε_t^b is an AR(1) shock to the intertemporal rate of substitution, which may be interpreted as a demand shock.

The period budget constraint expressed in units of the numeraire good is:

$$w_{u,t}L_t + \tilde{\pi}_t N_{D,t} + B_{t-1} = f_{j,t}N_{E,t} + P_t C_t + q_t B_t + \Phi(B_t). \quad (5)$$

On the left-hand side, the total labor income is: $w_{u,t}L_t + N_{D,t}\tilde{\pi}_t$; in this expression, the first term captures the remuneration of all “raw” units of labor L_t , which includes the income of those employed in the non-tradable service sector, as well as the virtual income forgone by the raw labor that undergoes training and works in the tradable sector. The second term captures the skill income premium that results from training, defined as the product between the efficiency units of labor, $N_{D,t}$, and the average skill income premium of workers executing tradable tasks for the domestic and foreign markets, $\tilde{\pi}_t = (N_{D,t}\tilde{\pi}_{D,t} + N_{X,t}\tilde{\pi}_{X,t})/N_{D,t}$.

On the right-hand side of (5), the first term represents the total investment in training, in which $N_{E,t}$ are the new efficiency units of labor created at time t , and f_j is the sunk cost required for each new unit of efficiency labor. Following a path consistent with the balanced-growth, this sunk cost is expressed in units of the numeraire good as: $f_{j,t} = \frac{w_{u,t}}{(\mathbf{Z}_t \mathbf{X}_t)}(X_t f_j)$. The newly-created efficiency units of labor $N_{E,t}$ join the already-existing units $N_{D,t}$, and together are subject to the skill-destruction shock δ before becoming operational in the following period. Thus, the law of motion for the efficiency units of labor is:

$$N_{D,t} = (1 - \delta)(N_{D,t-1} + N_{E,t-1}). \quad (6)$$

International financial transactions are restricted to a one-period, risk free bond. Thus, the level of debt due every period is $B_{t-1} < 0$, and the new debt contracted is $B_t < 0$ at price $q_t = 1/(1 + r_t)$, with r_t

representing the implicit interest rate. To induce model stationarity, we introduce an arbitrarily small cost of debt, $\Phi(\cdot)$, which takes the following functional form: $\Phi(B_t) = X_t^{\frac{\phi}{2}} \left(\frac{B_t}{X_t} \right)^2$. It is necessary to include the level of global technology in the numerator and the denominator of this functional specification, in order to guarantee stationarity along the balanced growth path.⁶

Optimality Conditions The household maximizes utility subject to its budget constraint and the law of motion for efficiency units of labor explained above. The optimality conditions for labor effort and consumption/saving are reasonably conventional:

$$\hat{a}_n (L_t)^{\gamma_n} (C_t)^{\gamma} = \frac{w_{u,t}}{P_t}, \quad (7)$$

$$q_t = \beta \left\{ \frac{\zeta_{t+1}}{\zeta_t} \right\} - \Phi'(B_t), \quad (8)$$

where $\hat{a}_n = a_n X_t^{1-\gamma}$, and $\zeta_t = \varepsilon_t^b (C_t)^{-\gamma} / P_t$ characterizes the marginal utility of consumption. The optimality governing the choice of bonds for foreign households in conjunction with the Euler equation in (8) yields the following risk-sharing condition:

$$E_t \left\{ \frac{\zeta_{t+1}^*}{\zeta_t^*} \frac{Q_t}{Q_{t+1}} - \frac{\zeta_{t+1}}{\zeta_t} \right\} = - \frac{\Phi'(B_t)}{\beta}, \quad (9)$$

where Q_t is the factor-based real exchange rate (or terms of labor).⁷ Finally, the optimality condition for training is pinned down by the following condition:

$$f_{j,t} = \mathbb{E} \sum_{s=t+1}^{\infty} [\beta (1 - \delta)]^{s-t} \left(\frac{\zeta_s}{\zeta_t} \right) \tilde{\pi}_s. \quad (10)$$

which shows the trade-off between the sunk training cost, $f_{j,t}$, and the present discounted value of the future skill income premiums resulting from the creation of a new efficiency units of labor, $\{\tilde{\pi}_s\}_{s=t+1}^{\infty}$.

⁶In the balanced growth path, debt B_t grows in sync with technology X_t , making the ratio stationary. Therefore, the adjustment cost must grow at the same rate. See Mandelman et al. (2011).

⁷That is, $Q_t = \frac{\varepsilon W_t^*}{W_t}$ (the real exchange rate is expressed in units of the foreign numeraire per units of the home one, where ε is the nominal exchange rate).

Aggregate Accounting and Balanced Trade For simplicity, we define a consolidated current account for Home and South. Thus, the evolution of the net foreign asset position for this economy is:

$$q_t B_t - B_{t-1} = N_{X,t} (\tilde{w}_{X,t})^{1-\theta} N_t^* Q_t - N_{X,t}^* (\tilde{w}_{X,t}^*)^{1-\theta} N_t, \quad (11)$$

where, on the right-hand side, the first term is the sum of all tasks executed by home workers and exported to Foreign, and the second term represents the tasks executed by foreign workers and imported in Home, expressed in units of the home numeraire. This trade in tasks is one of the key characteristics of this model. The home and foreign risk-free bonds are in zero net supply: $B_t + B_t^* = 0$.

3.3 South Economy

We introduce cross-border mobility for the southern labor. The representative household provides raw labor without the possibility of training, which is either employed in domestic production, or can emigrate to Home subject to a sunk cost, where it works in the nontradable service sector for a relatively higher wage. The household members pool their income – obtained from domestic and emigrant labor – and choose aggregate variables to maximize lifetime utility. The consumption basket of the South includes the final good imported from Home and a locally-produced nontradable service.

Labor Migration The representative household supplies a total of $L_{u,t}^s$ units of raw labor every period, without the possibility of training either domestically or abroad. A portion of the household members $L_{i,t}^s$ reside and work abroad (in Home), where they work as unskilled immigrant workers in the non-tradable service sector. The remaining $L_{u,t}^s - L_{i,t}^s$ work in the country of origin (South). The calibration ensures that the unskilled wage is higher in Home than in South, so that the incentive to emigrate from South to Home exists every period. However, a fraction of the foreign unskilled labor always remains in the South ($0 < L_{i,t}^s < L_{u,t}^s$). The macroeconomic shocks are small enough for these conditions to hold every period.

The household sends an amount $L_{e,t}^s$ of new emigrant labor to Home every period, where the stock of immigrant labor $L_{i,t}^s$ is built gradually over time. The time-to-build assumption in place implies that the new immigrants start working one period after arriving at the destination (Home). They continue to work in all subsequent periods until a return-inducing exogenous shock, which hits with probability δ_l every period, forces them to return to the South. This shock reflects issues such as termination of employment in the destination economy, likelihood of deportation, or voluntary return to the country of origin, etc.⁸ Thus, the rule of motion for the stock of immigrant labor in Home is:

$$L_{i,t}^s = (1 - \delta_l)(L_{i,t-1}^s + L_{e,t}^s).$$

Household's Decision Problem The household has maximizes lifetime utility over real consumption, C_t^s , and leisure, $1 - L_{u,t}^s$.

$$\mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{1}{1-\gamma} (C_t^s)^{1-\gamma} - a_n X_t^{1-\gamma} \frac{(L_t^s)^{1+\gamma_n}}{1+\gamma_n} \right], \quad (12)$$

subject to the budget constraint:

$$w_{i,t} L_{i,t}^s + w_{u,t}^s (L_{u,t}^s - L_{i,t}^s) \geq f_{e,t} w_{i,t} L_{e,t}^s + P_t^s C_t^s, \quad (13)$$

where $w_{i,t}$ is the immigrant wage earned in Home, so that the emigrant labor income is $w_{i,t} L_{i,t}^s$. Also, $w_{u,t}^s$ is the unskilled wage in the South, so that $w_{u,t}^s (L_{u,t}^s - L_{i,t}^s)$ denotes the total income from hours worked by the non-emigrant labor. On the spending side, each new unit of emigrant labor sent to Home requires a sunk cost $f_{e,t}$, expressed in units of immigrant labor. Changes in labor migration policies (i.e. border enforcement) are reflected by shocks ε_t^{fe} to the level of the sunk emigration cost f_e , so that $f_{e,t} = \varepsilon_t^{fe} f_e$.

⁸Our endogenous emigration-exogenous return formulation is similar to the framework with firm entry and exit in Ghironi and Melitz (2005).

Optimality Conditions The optimization problem delivers a typical conditions for consumption and labor supply. In addition, potential emigrants face a trade-off between the sunk emigration cost, $f_{e,t}w_{i,t}$, and the difference between the stream of expected future wages at the destination, $w_{i,t}$, and in the country of origin, $w_{u,t}^s$. Using the law of motion for the stock of immigrant labor, the first order condition with respect to new emigrant $L_{e,t}^s$ implies:

$$f_{e,t}w_{i,t} = \sum_{s=t+1}^{\infty} [\beta(1 - \delta_l)]^{s-t} E_t \left[\left(\frac{\zeta_s^s}{\zeta_t^s} \right) (w_{i,t} - w_{u,t}^s) \right]. \quad (14)$$

In equilibrium, the sunk emigration cost equals the benefit from emigration, with the latter given by the expected stream of future labor income gains from being abroad, $w_{i,t} - w_{u,t}^s$, adjusted for the stochastic discount factor and the probability of return to the country of origin every period.

Non-Tradable Sector Southern output is non-tradable, and is a linear function of the unskilled non-emigrant labor: $Y_{N,t}^s = (X_t Z_t^s \zeta) (L_{u,t}^s - L_{i,t}^s)$. Thus, X_t is the unit root global technology shock, Z_t^s is a country specific shock, and ζ is a parameter that captures the wage difference between Home and South. The price for unskilled personal services is: $P_{N,t}^s = \frac{w_{u,t}^s}{X_t Z_t^s \zeta}$.

Consumption The consumption basket is: $C_t^s = \left[(\gamma_c)^{\frac{1}{\rho_c}} (C_{T,t}^s)^{\frac{\rho_c-1}{\rho_c}} + (1 - \gamma_c)^{\frac{1}{\rho_c}} (C_{N,t}^s)^{\frac{\rho_c-1}{\rho_c}} \right]^{\frac{\rho_c}{\rho_c-1}}$, which includes the final good imported from Home $(C_{T,t}^s)$, and also the non-tradable personal services produced in South $(C_{N,t}^s = Y_{N,t}^s)$. The consumer price index expressed in terms of the Home numeraire is: $P_t^s = \left[(\gamma_c) + (1 - \gamma_c) (P_{N,t}^s)^{1-\rho_c} \right]^{\frac{1}{1-\rho_c}}$.

4 Estimation

To be completed.

5 The Effect of Shocks

Decline in the iceberg trade cost Figure 3 shows the median impulse responses of key model variables to a negative shock to the iceberg trade cost (one standard deviation), expressed as percentage deviation from steady state, reflecting the effect of a temporary decline in the cost of offshoring. In Home, easier offshoring encourages the employment of high-skill workers that execute tasks for the global market, and decreases the employment of the medium-skill workers that are only involved in the execution of tasks for the domestic market. (There are similar effects on the wages of high and medium-skill workers, not shown). In addition, the complementarity in consumption between goods (produced with tradable tasks) and services boosts the employment and wages of the unskilled workers along with those of high-skill workers, thus leading to labor market polarization.

At the same time, the rising demand for unskilled workers leads to an increase in immigrant entry and to a gradual increase in the stock of immigrant labor, which in turn dampen the rise in the unskilled wage. Thus, immigration – in conjunction with offshoring – generates the asymmetric pattern of employment and wage polarization at the low end of the skill distribution described in the introduction (i.e. the unskilled employment rises by more than unskilled wages). This is the first key result from the model that we wish to highlight.

Decline in the sunk cost of labor migration Figure 4 shows the median impulse responses to a negative shock to the sunk migration cost (one standard deviation), reflecting the effect of a temporary decline in the cost of unskilled immigration. Immigrant entry rises on impact, and hence the stock of immigrant labor rises gradually over time. As a result, the native household in Home reallocates labor away from services and toward the high and medium-skill tradable occupations by investing in training, allowing household to “upgrade” the tasks they execute (see Ottaviano, Peri and Wright, 2013). This outcome can be observed from the gradual decline in the employment of unskilled native labor, and the long-term increase in the employment of high and medium-skill labor. Conversely, the unskilled

immigrant wage falls due to the increased supply, while the unskilled native wage rises due to the home household's reallocation of labor toward the high and medium-skill occupations. The task upgrading by the native labor that arises in the presence of unskilled immigration is the second key model implication.

Notably, the process of task upgrading enhances the average productivity of native labor and its income, and thus leads to a positive wealth effect that leads to a decline in the native labor supply, which explains the initial hump-shaped responses of high and medium-skill employment (i.e. initial decline followed by a long-term increase). In addition, the rising labor income resulting from task upgrading leads to increased demand in Home for the imports of offshored tasks, which in turn allows Home to export more – thus explaining the faster increase in the high skill tasks.

In the South, employment and output decline due to the labor input lost to emigration. Consumption reflects two opposing forces that affect the labor income of immigrants established in Home, namely the falling immigrant wage vs. the rising stock of immigrant labor. Thus, consumption initially falls below its original steady state (as the wage effect prevails), but gradually recovers and rises above the steady state (as the effect from the rising stock of immigrant labor takes over).

Positive technology shock in the South Figure 5 shows the median impulse responses to a positive shock in the South (one standard deviation). In the South, output and wages rise due to the increase in productivity, while employment decreases due to the negative wealth effect on labor supply.

Notably, the rising wage in the South reduces the incentive for Southern labor to emigrate to Home. As a result, the immigrant entry drops and the stock of immigrant labor in Home declines below its original steady state, prompting the native labor to engage in “task downgrading,” i.e. to reallocate away from the high and medium-skill tradable tasks toward services, given the scarcity of unskilled immigrant labor. Overall, the task downgrading reduces the average productivity of native labor and its total income, which in turn generates a positive wealth effect on labor supply, as seen by the initial increase in high and medium-skill native employment that takes place despite the reallocation toward services.

6 Welfare

To be completed.

7 Conclusion

To be completed.

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Offshoring, Immigration and Labor Market Polarization

(Tables and Figures)

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Table 1: Prior and posterior distributions of estimated parameters, low migration cost

Description	Prior distribution				Posterior distribution				
	Name	Density	Mean	Std Dev	Sd (Hess)	Mode	Mean	10%	90%
Tech. shock (H)	ρ_z	Beta	0.5	0.2	0.0343	0.9224	0.9346	0.8815	0.9715
Tech. shock (F)	ρ_{z^*}	Beta	0.5	0.2	0.0109	0.9852	0.9853	0.9725	0.9952
Trade cost shock	ρ_τ	Beta	0.5	0.2	0.2718	0.5519	0.5239	0.2657	0.7941
Migration cost shock	ρ_{fe}	Beta	0.5	0.2	0.0100	0.9808	0.9792	0.9685	0.9890
Tech. shock (S)	ρ_{z^S}	Beta	0.5	0.2	0.0144	0.9787	0.9606	0.9419	0.9833
Demand shock (H)	ρ_b	Beta	0.5	0.2	0.2364	0.7479	0.6633	0.3174	0.9113
Demand shock (F)	ρ_{b^*}	Beta	0.5	0.2	0.2499	0.7518	0.7684	0.5645	0.9216
Tech. shock (H)	σ_z	Inv gamma	0.01	2*	0.0008	0.0067	0.0068	0.0056	0.0077
Tech. shock (F)	σ_{z^*}	Inv gamma	0.01	2*	0.0011	0.0058	0.0062	0.0047	0.0073
Trade cost shock	σ_τ	Inv gamma	0.01	2*	0.0012	0.0040	0.0047	0.0032	0.0066
Migration cost shock	σ_{fe}	Inv gamma	0.01	2*	0.0040	0.0527	0.0531	0.0484	0.0583
Tech. shock (S)	σ_{z^S}	Inv gamma	0.01	2*	0.0014	0.0145	0.0141	0.0124	0.0156
Demand shock (H)	σ_b	Inv gamma	0.01	2*	0.0016	0.0041	0.0052	0.0035	0.0079
Demand shock (F)	σ_{b^*}	Inv gamma	0.01	2*	0.0010	0.0035	0.0036	0.0024	0.0048
Global tech. shock	σ_x	Inv gamma	0.01	2*	0.0005	0.0063	0.0059	0.0055	0.0064

Table 2: Prior and posterior distributions of estimated parameters, high migration cost

Description	Prior distribution				Posterior distribution				
	Name	Density	Mean	Std Dev	Sd (Hess)	Mode	Mean	10%	90%
Tech. shock (H)	ρ_z	Beta	0.5	0.2	0.0236	0.9430	0.9430	0.9127	0.9689
Tech. shock (F)	ρ_{z^*}	Beta	0.5	0.2	0.0062	0.9915	0.9843	0.9746	0.9933
Trade cost shock	ρ_τ	Beta	0.5	0.2	0.2753	0.5485	0.4919	0.2240	0.7497
Migration cost shock	ρ_{fe}	Beta	0.5	0.2	0.0024	0.9915	0.9911	0.9890	0.9934
Tech. shock (S)	ρ_{z^S}	Beta	0.5	0.2	0.0461	0.8892	0.9079	0.8481	0.9657
Demand shock (H)	ρ_b	Beta	0.5	0.2	0.2762	0.6875	0.6457	0.3742	0.8844
Demand shock (F)	ρ_{b^*}	Beta	0.5	0.2	0.2540	0.7395	0.6452	0.3894	0.8977
Tech. shock (H)	σ_z	Inv gamma	0.01	2*	0.0010	0.0077	0.0082	0.0067	0.0097
Tech. shock (F)	σ_{z^*}	Inv gamma	0.01	2*	0.0010	0.0064	0.0067	0.0058	0.0079
Trade cost shock	σ_τ	Inv gamma	0.01	2*	0.0013	0.0040	0.0045	0.0030	0.0062
Migration cost shock	σ_{fe}	Inv gamma	0.01	2*	0.0039	0.0524	0.0563	0.0510	0.0613
Tech. shock (S)	σ_{z^S}	Inv gamma	0.01	2*	0.0010	0.0116	0.0133	0.0118	0.0152
Demand shock (H)	σ_b	Inv gamma	0.01	2*	0.0012	0.0038	0.0034	0.0024	0.0048
Demand shock (F)	σ_{b^*}	Inv gamma	0.01	2*	0.0009	0.0034	0.0032	0.0024	0.0040
Global tech. shock	σ_x	Inv gamma	0.01	2*	0.0005	0.0060	0.0061	0.0055	0.0070

Figure 1. Labor market polarization in the United States.

(a) Employment

(b) Wages

Figure 2. Labor market polarization in the United States: actual vs. counterfactual.

(a) Employment

(b) Wages

Figure 3. Impulse responses to a decline in the iceberg trade cost.

Note: Impulse responses to a decline in the iceberg trade cost (one standard deviation). The solid line depicts the median, and the dashed line depicts the 10 and 90 percent posterior intervals.

Figure 4. Impulse responses to a decline in the sunk cost of labor migration.

Note: Impulse responses to a decline in the sunk cost of labor migration from South to Home (one standard deviation). The solid line depicts the median, and the dashed line depicts the 10 and 90 percent posterior intervals.

Figure 5. Impulse responses to a positive technology shock in South.

Note: Impulse response to a positive technology shock in the South (one standard deviation). The solid line depicts the median, and the dashed line depicts the 10 and 90 percent posterior intervals.

Figure 6. Forecast error variance decompositions.

Note: Forecast variance decomposition at the posterior mode, at forecast horizons: Q1, Q4, Q16 and Q40.

Figure 7. Historical decomposition.