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-skill occupations increased robustly, wages for both the low and middle-skill workers remained subdued. We attribute this outcome to the rise in offshoring and low-skilled immigration, and develop a three-country stochastic growth model to rationalize the pattern of employment and wages. In the model, the increase in offshoring negatively affects the middle-skill occupations, but benefits the high-skill ones, which in turn boosts demand for non-tradable services provided by the low-skill workers. However, low-skill wages remain depressed due to unskilled immigration. Native workers react to immigration 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.

JEL classification: F16, F41

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1 Introduction

Job creation, income inequality, and the disappearance of medium-skill jobs have been among the most debated topics in macroeconomics and labor economics lately. To put these issues into context, Fig. 1(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(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 experienced depressed employment as well as wages.

Our hypothesis is that the asymmetric pattern of polarization across employment and wages was closely related to the increase in offshoring and low-skilled immigration over the past three decades. The empirical evidence indicates that labor tasks executed by middle-skill workers were the most affected by the offshoring wave, which had a negative impact on employment and earnings of this group. In this category we find "blue collar" workers like machine operators and assemblers in manufacturing, as well as data entry and help desk jobs, which are likely to be offshored. However, offshoring did not affect the employment prospects of low-skill individuals, which are mostly employed in personal services that involve assisting and taking care of others (e.g. janitors, food industry workers, child care providers, gardeners). In fact, Fig. 2(a) shows that the emergence of jobs in 'service occupations' explained practically all the employment gains for the low-skilled during the last three decades.[2] By definition, these low-skill tasks

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

[2] Here we borrow from the empirical strategy in Autor and Dorn (2012) by considering a simple counterfactual scenario, in which employment in service occupations is held at its original level from 1980. Mimicking their results, the twist of the

cannot be executed remotely, but only at the location where the service is provided. Our claim is that the availability of offshore labor increased the productivity of complementary high-skill native occupations (including managers, programmers, professionals), thus leading to a robust growth in their employment and wages. As the high-skill earnings increased, so did the demand for services. Although offshoring is not an option for these non-tradable services, immigration is an alternative. Consequently, many of the jobs created in this segment were taken by low-skill immigrants that arrived in large numbers during the last decades, as shown in Figure 3. The sizable immigrant inflow dampened low-skill wages, which explains why wages and employment for the low-skilled had such a dissimilar pattern.

The goal of this paper is to rationalize this narrative 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 endogenously determines not only the extent of offshoring and migration, but also the optimal amount of training (skill acquisition) in response to changes in migration and trade policy, as well as to transitory and permanent macroeconomic shocks. The model is estimated with macroeconomic data, multilateral trade-weighted indicators, and U.S.-Mexico border enforcement data on undocumented migration.

Our framework consists of two large economies (that trade and are financially integrated), and a third small underdeveloped economy that is the source of the low-skill immigrants. 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

employment distribution at the low-skill tail becomes negligible in this counterfactual scenario. See more details in the statistical appendix.

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 productive tasks can be accomplished in the rest of the world (e.g. Indian basic programmers debug the software, Japanese technicians provide the microchips, and Chinese workers proceed with the final assembly). 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 also includes 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. They also must be executed where the final consumer is located, and thus they are 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 increase. Although these service tasks cannot be executed remotely, the increase in unskilled wages attracts immigrant labor from the underdeveloped economy. As these immigrants settle, they dampen the upward pressure on unskilled wages. Changes in migration policy (i.e. border enforcement) and macroeconomic developments also affect the migration decision in the country of origin.

Finally, or model incorporates a key endogenous training decision. Households can freely allocate unskilled labor to the non-tradable service sector, or alternatively can invest in training to create a diversity of occupations that perform different tasks. The training decision involves an irreversible investment, and there is initial uncertainty concerning the future idiosyncratic productivity of the job post created. An implication from our model is that households will either upgrade or downgrade their skills in response to the economic environment. For example, a counterfactual scenario that suppresses 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 evidence that shows that the inflow of migrant workers enhances the native population' incentive to improve their educational attainment.

It is worth highlighting the contribution of our macroeconomic structural approach in the context of the literature on migration and offshoring. Although the vast majority of these papers have the advantage of using rich microeconomic data, the trade-off is that they must rely on reduced-form econometric specifications that take covariates as given and/or rest on static theoretical frameworks for analytical convenience. More, the skill distribution of the native labor force is generally assumed to be given and not reactive to developments in offshoring and migration. In contrast, our structural approach allows to model an endogenous response of the native employment and skill distribution to offshoring and immigration, and also allows to derive the welfare implications. Thus, we find that lowering barriers to low-skilled migration and trade have a positive impact on aggregate welfare. First, the economy benefits from specializing on the production tasks in which it is more efficient. Second, although immigrants depress low-skill wages, they keep non-tradable prices low. Third, and most importantly, immigration induces natives to enhance their skill acquisition and thus increase productivity.

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, calibration, and discusses the estimation procedure. Section 5 illustrates the impact of various shocks to the growth dynamics. Section 6 assesses the fit of the model to the data by providing moments, as well as the variance and historical decompositions. Section 7 quantifies the welfare implications of alternative trade and migration policy arrangements. Section 8 concludes.

2 Related literature

Taken together, the empirical evidence in existing literature appears to be consistent with our claim that migration and offshoring play important roles in driving the polarization of the U.S. labor market. Ottaviano, Peri and Wright (2013) show that labor tasks executed by the middle-skill workers are typically offshored. In turn, offshoring is a key factor that explains the employment polarization 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 expansion in employment by this skill group is the by-product of an increase in service occupations. We link this evidence with the immigration literature. Grogger and Hanson (2008) shows that the share of foreign-born in the U.S. population more than doubled (from 6% to 13%) during the period under consideration. Peri and Sparber (2009) indicates that a disproportionate number of these immigrants were relatively unskilled, and ended up taking many of the jobs that emerged at the low end of the skill distribution. In turn, Cortes (2008) finds that the inflow of low-skilled migrants had a sizeable negative impact on wages (and prices) of service occupations.

Our paper is closely related to Ottaviano, Peri and Wright (2013), which was the first to study the effects of immigration and offshoring on U.S. manufacturing employment. Their study relies on U.S. manufacturing microeconomic data from 58 industries and employment indicators (including task content) of immigrants and natives. Consistent with our framework, they find that immigrant and native workers tend to perform tasks at opposite ends of the task complexity spectrum, with offshore workers performing tasks in the middle. Although their focus is more on the empirics, they also develop a stylized model of tasks. However, our setup differs in a number of ways. First, their model consists on a static partial equilibrium setup in which wages are exogenously predetermined. Instead, we build a structural general equilibrium model in which wages, the offshoring of tasks, the migration of unskilled labor, and the task upgrading (through training) by native labor are all endogenously derived from the households' optimization problem. Second, we also highlight the resulting polarization of employment and wages, as well as the role that unskilled immigrants play in the service sector.

Theoretical studies of the employment polarization phenomenon rest on closed-economy models based on routine-biased technological change. Some notable examples include, Autor and Acemouglu

(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. Related to this discussion, we consider in the appendix an extended version of the model with capital that include Investment-Specific Technology shocks (modelled as in Fisher, 2006). We show that the estimated IST innovations lower the relative price of capital equipment and induces firms to replace labor with capital. As a result, firms become even more selective when hiring workers, thus worsening the stance of middle-skill workers. Instead, low-skill personal service jobs that only use labor as factor of production are nor directly affected by these IST innovations. Thus, the estimated IST shocks enhance the employment polarization.

Our work is also related to the literature that models offshoring and immigration taken separately, and documents their effects on labor market outcomes. The modeling of offshoring is taken from Mandelman (2013), which consists on a *trade-in-tasks* setup with heterogenous workers. The model in Mandelman (2013) also delivers a employment polarization, but does not include labor migration, and therefore fails to account for the evolution of wages and for task upgrading, which are strongly affected by the immigrant flows. More generally, the offshoring framework is based on the modelling of trade in tasks developed by Grossman and Rossi-Hansberg (2008), which is expanded to include a continuum of tasks fulfilled by heterogeneous workers. In addition, the modeling of labor heterogeneity across skills closely 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). 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 towards 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 its variables are marked with an asterisk. Since the paper is focused on the labor market outcomes from offshoring and immigration, labor is the only factor of production in the baseline specification. We postpone to the appendix the model with capital. In what follows, we start with a description of the production sectors and the representative household in Home. 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. These tasks can either be executed at Home, or offshored to Foreign. Workers in this sector are heterogenous in skill, which they acquire after undergoing training. In short, we will refer to this sector as the "tradable" sector. Notice, however, that the meaning of tradability is 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 (native and immigrant) as an input, and which are non-tradable by definition.[3]

3.1.1 Tradable sector

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 $f_{j,t}$ units of home raw labor, and results in an idiosyncratic productivity level $\mathbf{z}$ for each worker.[4] 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: $l_{\mathbf{z},t} = \mathbf{z}l_t$, where l_t indicates raw labor. 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 training decision is described in Section 3.2.

Production In the execution of tradable tasks by each occupation, the efficiency units of labor benefit from two technological innovations.[5] 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, ε_t^T is a temporary country-specific technology shock that evolves as an AR(1) process. Thus, each efficiency unit of labor supplied is trans-

[3]The 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.

[4]The functional form of $f_{j,t}$ will be described later.

[5]As 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.

formed in a productive task $n_t(\mathbf{z})$ as follows:

$$n_t(\mathbf{z}) = (X_t \varepsilon_t^T) l_{\mathbf{z},t} = (X_t \varepsilon_t^T)\mathbf{z} l_t. \tag{1}$$

We assume that workers in each occupation 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.[6] 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: $\mathbb{N}_t = \left[\int_{\xi \epsilon \Xi_t} n_t(\mathbf{z}, \xi)^{\frac{\theta-1}{\theta}} d\xi\right]^{\frac{\theta}{\theta-1}}$, where $\theta > 1$ is the elasticity of substitution across tasks. The wage bill is $\mathbb{W}_t = \left[\int_{\xi \epsilon \Xi_t} w_t(\mathbf{z}, \xi)^{1-\theta} d\xi\right]^{\frac{1}{1-\theta}}$, 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, $P_{T,t} = \mathbb{W}_t \equiv 1$.

3.1.2 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: $Y_{N,t} = X_t L_{N,t}^A$, and the price is $P_{N,t}$. Importantly, the input on unskilled labor $L_{N,t}^A$ is a composite of native and immigrant unskilled labor ($L_{N,t}$ and $L_{\mathbf{i},t}^s$, respectively), which enter as imperfect substitutes:

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

The profit maximization problem implies the following expressions for the wages of native and immigrant unskilled labor, each expressed in units of the numeraire good $Y_{T,t}$: $w_{\mathbf{u},t} = P_{N,t} X_t \alpha_N \left(L_{N,t}^A / L_{N,t}\right)^{1/\sigma_N}$

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

and $w_{\mathbf{i},t} = P_{N,t}X_t(1-\alpha_N)\left(L^A_{N,t}/L^s_{\mathbf{i},t}\right)^{1/\sigma_N}$.

3.1.3 Trade in Tasks and the Skill Income Premium

In equilibrium, the wage paid to each worker in the tradable sector is skill-specific, $w_t(\mathbf{z},\xi) = w_t(\mathbf{z},.)$, for every task $\xi \in \Xi$. The skill premium gap $\pi_{D,t}$ in the domestic tradable sector is defined as the difference between the income obtained from a task executed for this sector and the income obtained by a raw unit of labor in the service sector:

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

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

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, Foreign demands some of the tasks executed at Home. To be offshored to Foreign, the tasks executed in Home are subject to an iceberg trade cost $\tau_t \geqslant 1$, 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: $f_{o,t} = \frac{w_{\mathbf{u},t}}{(\varepsilon^T_t X_t)}(X_t f_o)$. Changes in trade barriers are reflected in shocks ε^τ_t to the level of the iceberg trade cost τ, so that $\tau_t = \varepsilon^\tau_t \tau$. The skill premium gap, $\pi_{X,t}$,for executing a task for Foreign is:

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

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 $\mathbf{z}_{X,t} = \inf\{\mathbf{z} : \pi_{X,t}(\mathbf{z},.) > 0\}$. 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: $\tilde{\mathbf{z}}_{D,t} \equiv \left[\int_{\mathbf{1}}^{\infty} \mathbf{z}^{\theta-1} d\mathcal{F}(\mathbf{z})\right]^{\frac{1}{\theta-1}}$. 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 average productivity $\tilde{\mathbf{z}}_{D,t}$ execute tasks for the domestic market only, and a mass of workers $N_{X,t}$ with average productivity $\tilde{\mathbf{z}}_{X,t}$ accomplish tasks for the foreign market as well as the domestic one. The wages for each skill group are $\tilde{w}_{D,t} = w_{D,t}(\tilde{\mathbf{z}}_{D,t}, .)$ and $\tilde{w}_{X,t} = w_{X,t}(\tilde{\mathbf{z}}_{X,t}, .)$. Similarly, the average skill income gaps are $\tilde{\pi}_{D,t} = \pi_{D,t}(\tilde{\mathbf{z}}_{D,t}, .)$ and $\tilde{\pi}_{X,t} = \pi_{X,t}(\tilde{\mathbf{z}}_{X,t}, .)$, respectively. Taking all these into account, the wage bill of the home tradable sector can be re-written as: $\mathbb{W}_t = \left[N_{D,t} \left(\tilde{w}_{D,t}\right)^{1-\theta} + N^*_{X,t} \left(\tilde{w}^*_{X,t}\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}$, 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. We abstract from distributional issues. As in Andolfatto (1996) and Merz (1995), 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.

Consumption Household's real consumption basket is: $C_t = \left[(\gamma_c)^{\frac{1}{\rho_c}} \left(C_{T,t}\right)^{\frac{\rho_c-1}{\rho_c}} + (1-\gamma_c)^{\frac{1}{\rho_c}} \left(C_{N,t}\right)^{\frac{\rho_c-1}{\rho_c}}\right]^{\frac{\rho_c}{\rho_c-1}}$, which includes amounts of the final good $C_{T,t}$ and the non-tradable personal service $C_{N,t}$. The consumer price index is: $P_t = \left[(\gamma_c) + (1-\gamma_c)\left(P_{N,t}\right)^{1-\rho_c}\right]$. 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, $C^s_{T,t}$, so that $Y_{T,t} = C_{T,t} + C^s_{T,t}$. (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-path[7]:

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

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:

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

On the left-hand side, the total labor income is: $w_{\mathbf{u},t} L_t + N_{D,t} \tilde{\pi}_t$; 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 skilled workers, $N_{D,t}$, 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 $N_{E,t}$

[7]See Rudebusch and Swanson (2012).

are the new skilled workers created at time t, and $f_{j,t}$ is the sunk cost required for each new skilled worker. Following a path consistent with the balanced-growth, this sunk cost is expressed in units of the numeraire good as: $f_{j,t} = \frac{w_{\mathbf{u},t}}{(\varepsilon_t^T X_t)}(X_t f_j)$. The newly-created skilled workers $N_{E,t}$ join the already-existing $N_{D,t}$, and together are subject to the skill-destruction shock δ before becoming operational in the following period. Thus, the law of motion for the skilled workers is: $N_{D,t} = (1-\delta)(N_{D,t-1} + N_{E,t-1})$. The mass of middle-skill workers, $N_{M,t}$, executing tasks exclusively for the domestic firms are: $N_{M,t} = N_{D,t} - N_{X,t}$. International financial transactions are restricted to a one-period, risk free bond. Thus, the level of debt due every period is B_{t-1}, and the new debt contracted is B_t 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, $\Phi(.)$, 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 stationary along the balanced growth path.[8]

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:

$$\hat{a}_n (L_t)^{\gamma_n} (C_t)^{\gamma} = \frac{w_{\mathbf{u},t}}{P_t}, \tag{6}$$

$$q_t = \beta E_t \left\{ \frac{\zeta_{t+1}}{\zeta_t} \right\} - \Phi'(B_t), \tag{7}$$

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 (7) yields the following risk-sharing condition:

$$E_t \left\{ \frac{\zeta_{t+1}^*}{\zeta_t^*} \frac{Q_t}{Q_{t+1}} - \frac{\zeta_{t+1}}{\zeta_t} \right\} = -\frac{\Phi'(B_t)}{\beta}, \tag{8}$$

[8]In 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).

where $\mathbb{Q}_t$ is the factor-based real exchange rate (or terms of labor).[9] Finally, the optimality condition for training is pinned down by the following condition:

$$f_{j,t} = \mathbb{E}_t \sum_{s=t+1}^{\infty} \left[\beta\left(1-\delta\right)\right]^{s-t} \left(\frac{\zeta_s}{\zeta_t}\right) \tilde{\pi}_s. \tag{9}$$

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 skilled occupations, $\{\tilde{\pi}_s\}_{s=t+1}^{\infty}$.

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:

$$q_t B_t - B_{t-1} = N_{X,t}\left(\tilde{w}_{X,t}\right)^{1-\theta} N_t^* \mathbb{Q}_t - N_{X,t}^*\left(\tilde{w}_{X,t}^*\right)^{1-\theta} N_t, \tag{10}$$

where, on the right-hand side, the first term is the sum of all tasks executed by home skilled workers and exported to Foreign, and the second term represents the tasks executed by foreign skilled 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

The representative household provides raw labor without the possibility of training. This labor can either be employed in domestic production, or can emigrate to Home after incurring in a sunk migration cost. Migrants at Home work in the non-tradable 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.

[9] That is, $\mathbb{Q}_t = \frac{\varepsilon \mathbb{W}_t^*}{\mathbb{W}_t}$ (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).

Labor Migration The representative household supplies a total of $L^s_{\mathbf{u},t}$ units of raw labor every period, without the possibility of training either domestically or abroad. A portion of the household members $L^s_{\mathbf{i},t}$ reside and work abroad (i.e. in Home). The remaining $L^s_{\mathbf{u},t} - L^s_{\mathbf{i},t}$ 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 South ($0 < L^s_{\mathbf{i},t} < L^s_{\mathbf{u},t}$). The macroeconomic shocks are small enough for these conditions to hold every period.

The household sends an amount $L^s_{\mathbf{e},t}$ of new emigrant labor to Home every period, where the stock of immigrant labor $L^s_{\mathbf{i},t}$ 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.[10] Thus, the rule of motion for the stock of immigrant labor in Home is: $L^s_{\mathbf{i},t} = (1-\delta_l)(L^s_{\mathbf{i},t-1} + L^s_{\mathbf{e},t})$.

Household's Decision Problem The household has maximizes lifetime utility over real consumption, C^s_t, and leisure, $1 - L^s_{\mathbf{u},t}$.

$$\mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{1}{1-\gamma} (C^s_t)^{1-\gamma} - a^s_n X_t^{1-\gamma} \frac{(L^s_{\mathbf{u},t})^{1+\gamma_n}}{1+\gamma_n} \right], \tag{11}$$

subject to the budget constraint:

$$w_{\mathbf{i},t} L^s_{\mathbf{i},t} + w^s_{\mathbf{u},t} \left(L^s_{\mathbf{u},t} - L^s_{\mathbf{i},t} \right) \geqslant f_{e,t} L^s_{\mathbf{e},t} + P^s_t C^s_t, \tag{12}$$

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

where $w_{\mathbf{i},t}$ is the immigrant wage earned in Home, so that the emigrant labor income is $w_{\mathbf{i},t}L^s_{\mathbf{i},t}$. Also, $w^s_{\mathbf{u},t}$ is the unskilled wage in the South, so that $w^s_{\mathbf{u},t}\left(L^s_{\mathbf{u},t} - L^s_{\mathbf{i},t}\right)$ 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 $f_{e,t} = \frac{w_{\mathbf{i},t}}{(X_t)}(\varepsilon^{fe}_t X_t f_e)$. Changes in labor migration policies (i.e. border enforcement) are reflected by shocks ε^{fe}_t to the level of the sunk emigration cost in balanced-grow f_e.

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, $f_{e,t}$, and the difference between the stream of expected future wages at the destination, $w_{i,t}$, and in the country of origin, $w^s_{\mathbf{u},t}$. Using the law of motion for the stock of immigrant labor, the first order condition with respect to new emigrant $L^s_{\mathbf{e},t}$ implies:

$$f_{e,t} = \mathbb{E}_t \sum_{s=t+1}^{\infty} \left[\beta(1-\delta_l)\right]^{s-t} \left(\frac{\zeta^s_s}{\zeta^s_t}\right)(w_{\mathbf{i},t} - w^s_{\mathbf{u},t}). \tag{13}$$

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, $w_{\mathbf{i},t} - w^s_{\mathbf{u},t}$, 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: $Y^s_{N,t} = (\varepsilon^s_t Z^s_t)\varsigma\left(L^s_{\mathbf{u},t} - L^s_{\mathbf{i},t}\right)$. Thus, X_t is the unit-root global technology shock, ε^s_t is a country specific shock, and ς is a parameter that captures the wage difference between Home and South. The price for non-tradables is: $P^s_{N,t} = \frac{w^s_{\mathbf{u},t}}{X_t\varepsilon^s_t\varsigma}$.

Consumption The consumption basket is: $C^s_t = \left[(\gamma_c)^{\frac{1}{\rho_c}}\left(C^s_{T,t}\right)^{\frac{\rho_c-1}{\rho_c}} + (1-\gamma_c)^{\frac{1}{\rho_c}}\left(C^s_{N,t}\right)^{\frac{\rho_c-1}{\rho_c}}\right]^{\frac{\rho_c}{\rho_c-1}}$, which includes the final good imported from Home $\left(C^s_{T,t}\right)$, and also the non-tradable produced in South

$(C^s_{N,t} = Y^s_{N,t})$. The consumer price index is: $P^s_t = \left[(\gamma_c) + (1-\gamma_c)\left(P^s_{N,t}\right)^{1-\rho_c}\right]$, expressed in terms of the Home numeraire.

3.4 Shocks

The world technology shock has a unit root as in Rabanal et al. (2011): $\log X_t = \log X_{t-1} + \eta^X_t$. The other structural shocks in our model follow $AR(1)$ processes with i.i.d. normal error terms, $\log \varepsilon^{\hat{\imath}}_t = \rho^{\hat{\imath}} \log \varepsilon_{t-1} + \eta^{\hat{\imath}}_t$, in which the persistence parameter is $0 < \rho^{\hat{\imath}} < 1$, the error terms are $\eta \sim N(0, \sigma^{\hat{\imath}})$, and indexes $\hat{\imath} = \{T, T^*, s, b, b^*, \tau, f_e\}$ denote the technology shocks in Home, Foreign and South, the demand shocks in Home and Foreign, the iceberg trade cost shock, and the sunk emigration cost shock, respectively. As in Lubik and Schorfheide (2005), Home and Foreign shocks are independent.

4 Estimation

The Bayesian estimation technique uses a general equilibrium approach that addresses the identification problems of reduced form models. It is a system-based analysis that fits the solved DSGE model to a vector of aggregate time series (see Fernandez-Villaverde et al., 2004, or Lubik and Schorfheide, 2005, for additional details).

4.1 Data

We consider several quarterly data series to estimate the model. First, we use the per-capita real GDP in the United States as a proxy for Home, and second, we use the real GDP of the rest of the world as a proxy for Foreign, constructed as a trade-weighted aggregate of the U.S. major trade partners.[11] Third, real GDP in Mexico serves as a proxy for the South economy. Fourth, U.S. border patrol hours are used as a proxy for the intensity of border enforcement, with an increase in border patrol hours interpreted as an increase

[11] The U.S. trade partners included are: among the advanced economies, Australia, Canada, the euro area (Germany, France, Italy, Netherlands, Belgium, Spain, Ireland, Austria, Finland, Portugal, Greece), Japan, Sweden, Switzerland and the U.K.; among the emerging markets, China, India, Hong Kong, Taiwan, Korea, Singapore, Indonesia, Malaysia, Philippines, Thailand, Mexico, Brazil, Argentina, Venezuela, Chile, Colombia, Israel, Russia and Saudi Arabia. The data are collected from Haver Analytics.

in the sunk migration cost, as in Mandelman and Zlate (2012).

To evaluate the model fit, we use the data series on apprehensions (arrests) at the U.S.-Mexico border as a proxy for undocumented migration flows. We do not use apprehensions to estimate the model, but treat the flow of migrants as a latent variable in our estimated model, and compare its model-generated moments to those from the apprehensions data to assess the model fit. For this purpose, the Kalman filter is used to back out the observed (smoothed) shocks and make inferences about the latent variable through the reconstruction of the historical series.[12]

In addition, we use the evolution of employment for each skill group in the United States to assess the model adequacy. The approach we follow to construct employment by skill is similar to the one used in Acemoglu and Autor (2011) and Jaimovich and Siu (2012). In summary, we consider three categories of employment based on the skill content of the tasks executed by each occupation in the Census data: Non-Routine Cognitive (high-skilled), Routine Cognitive (medium-skilled) and Non-Routine Manual (unskilled).[13] An occupation is regarded as routine if it involves a set of specific tasks that are accomplished by executing well-defined instructions and procedures. Instead, is categorized as non-routine if it requires flexibility, problem-solving or human interaction skills. In addition, among the non-routine occupations, the distinction between cognitive and manual is given by the extent of mental versus physical activity. Following these criteria, first, the non-routine cognitive occupations include managers, computer programmers, professionals and technicians, and are located at the top of the skill distribution. Second, the routine occupations include "blue collar" jobs, such as machine operators, assemblers, data entry, helps desk, and administrative support, and are located in the middle of the skill distribution. Third, the non-routine manual occupations are mostly service jobs, which are found at the bottom of the skill distri-

[12] The series on apprehensions are not used in the estimation, as it is noisy due to the random nature of border interceptions and arrests, and therefore can serve only as a rough proxy for the flows of emigrant labor. In addition, there is an identification problem regarding the effect of border enforcement on apprehensions. In this paper, we assume that an increase in border enforcement leads to an increase in the sunk emigration cost, following the empirical findings in Orrenius (2001). However, for the same number of attempted illegal crossings, an increase in border patrol hours may also result in more arrests. Because border enforcement affects both the number of crossings and the number of arrests, and because the actual number of attempted crossings is unknown, we cannot disentangle the effect of enforcement from that of crossings on total apprehensions (see Mandelman and Zlate, 2012).

[13] We use the Current Population Survey from the Bureau of Labor Statistics available at the FRED database (St. Louis Fed).

bution. These service occupations are jobs that involve assisting and caring others, and involve tasks that must be executed where the final consumer is located. The three types of occupations span the horizontal axes in Figures 1-3, in which the occupations are ranked and assigned to percentiles using the initial wage from 1980 as a proxy for skill.

Finally, the variables are not detrended, but are seasonally adjusted and expressed in log-differences to obtain growth rates. Due to data constraints on border enforcement and apprehensions, the sample in levels covers the period from 1983:Q1 to 2004:Q3.

4.2 Calibration

Some parameters are calibrated using standard choices from the literature. These include the discount factor, $\beta = 0.99$,and the inverse of the elasticity of intertemporal substitution, $\gamma = 2$. In the utility function for Home, Foreign and South, the parameter γ_n is set at 1.33, so that the Frisch elasticity $(1/\gamma_n)$ is consistent with the micro estimates in Chetty et al. (2012). The weights on the disutility from work are $a_n = a_n^* = 2.78$ in Home and Foreign, and $a_n^s = 7$ in the South, so that labor supply in steady state is about $L_t = L_t^* = L_{\mathbf{u},t}^s = 0.5$.

For the household consumption composite in Home and Foreign, the share of the country-specific tradable good is $\gamma_c = 0.75$, so as to obtain balanced-trade in steady-state, and the intra-temporal elasticity of substitution between the tradable good and services is set at a relatively low value of $\rho_c = 0.44$, as in Stockman and Tesar (1995). The sunk training cost of Home and Foreign labor is normalized at $f_j = 1$, and the quarterly destruction rate for high-skill jobs is set at $\delta = 0.025$ as in Davis and Haltinwanger (1990). The sunk emigration cost for Southern labor is set at $f_e = 4.7$, as estimated in Mandelman and Zlate (2012), and the quarterly exit rate of immigrant labor is $\delta_l = 0.07$, following the findings in Reyes (1997).[14] The iceberg trade cost is $\tau = 1.40$, as estimated in Novy (2007). As standard, the cost of adjusting bond holdings is assigned a very low value, $\phi = 0.0035$, but which ensures their stationarity.

[14] Reyes (1997) finds that about 50% of undocumented Mexican immigrants return to the country of origin within two years after their arrival in the U.S., and 65% of immigrants return within four years. Using that 50% immigrants are still in the U.S. four years after their arrival, the quarterly exit rate is $\delta_{l,4y} = 0.064$, since $(1 - \delta_{l,4y})^8 = 0.5$. Similarly, the 35% retention rate after two years implies a quarterly return rate of 0.083.

The idiosyncratic productivity of workers, $\mathbf{z}$, follows a Pareto distribution $\mathcal{F}(\mathbf{z}) = 1 - \left(\frac{1}{\mathbf{z}}\right)^k$ defined over a support interval with the lower bound set at one without loss of generality. Thus, by definition, the idiosyncratic productivity $\mathbf{z}$ cannot take values below the lower bound attained by the unskilled (raw) labor. The shape parameter k is such that $k > \theta - 1$ so that $\mathbf{z}$ has a finite variance, where θ is elasticity of substitution across tasks. As parameter k is set at higher values, the dispersion of the productivity draws decreases and the idiosyncratic productivity becomes more concentrated toward the lower bound of the skill distribution. Using this setup, we set the Pareto shape parameter $k = 2.36$, the elasticity of substitution across tasks in the Home and Foreign final goods $\theta = 1.8$, and the per-period fixed cost of offshoring cost $f_o = 0.0233$, so that the model comes close to matching three stylized facts in steady state: (1) The ratio of U.S. exports/GDP, which averages 0.13 in the sample period, and the same in the model. (2) The ratio of high-skill/middle-skill jobs in total employment (i.e. non-routine cognitive/routine), which averages 0.6 in the data vs. 0.52 in the model. (3) The ratio of the two skill groups' labor income shares in the population, which varies between 1.73 and 2.87 depending on the survey method vs. 2.4 in the model.[15]

In addition, we set the relative productivity of the Southern economy at $\varsigma = 0.8$; the share of unskilled native in the production of Home services at $\alpha_N = 0.7$ (and hence the share of immigrant labor is $1 - \alpha_N = 0.3$); the elasticity of substitution between the native and immigrant unskilled labor at $\sigma_N = 2.4$; the share of imports in the Southern consumption composite, $\gamma_c^s = 0.2$; and the elasticity of substitution between the tradable good and services in the South, $\rho_c^s = 1.5$, so that the model in steady state mimics a number of additional facts from the data: (1) The share of Mexico's labor force residing in the United States is 10% (Hanson, 2006), which is probably an underestimation, vs. 30% in the model.[16] (2) The U.S. skill premium

[15]There is not a precise measure of this ratio, with results varying significantly on the data sources available. Naturally, the first income source we consider is the Current Population Survey (CPS) by the Census Bureau. The survey reports a "money income" that includes wages and salaries, interest, dividends, rent, retirement income as well as other tranfers. Our basic model abstracts from capital, so it is difficult map each of these income sources to the skill groups defined in our setup. In addition, the CPS faces other challenges. As explained by Saez and Picketty (2012), the CPS survey data is not suitable to study high incomes because of small sample size and top coding of high incomes. For robustness, we also consider Diaz-Gimenez, Quadrini and Rios-Rull (1992, 1998 and 2007) that uses the Survey of Consumer Finances conducted by the University of Chicago. We consider both the "income" indicator that mimic CPS estimates, and the "earnings" measure that excludes interest income, dividends, capital gains and other transfers.

[16]This is a conservative estimate, as remittances tend to be underreported, particularly between neighbor countries.

between workers with at least high-school degree and those without is 2.2 (U.S. Census, 2007), vs. 1.8 in the model. (3) The wage ratio between unskilled native and immigrant labor in the United States is 1.3 (Hanson, 2003 and U.S. Census, 2007), which the model overshoots at 2; (4) The wage ratio between Mexican workers in the United States and those residing in Mexico, controlling for age and education, is about 3.6 (Hanson, 2007), vs. 1.2 in the model, which although small, is enough to generate the migration incentive from South to Home.

4.3 Prior and Posterior Distributions

We estimate the autoregressive parameters for the seven AR(1) shocks, together with the corresponding errors terms and that of the unit root shock driving global productivity. The first four columns of Table 1 show the mean and standard deviations of the prior distributions, together with their respective density functions. The autoregressive parameters are assumed to follow a Beta distribution that covers the range between 0 and 1. Since we do not have prior information about the magnitude of these shocks, the variances of all shocks are harmonized as in Smets and Wouters (2007), and assumed to follow an Inverse Gamma distribution that delivers a relative large domain.

The last five columns of Table 1 report the posterior mean, mode and standard deviation, along with the 10th and 90th percentiles of the parameters. The technology shocks are more persistent than the demand shocks, and the technology shock in Mexico is notably volatile. The shock to border enforcement is persistent and volatile, in contrast to the trade cost shock, which displays relatively less persistence and volatility.

5 The Effect of Shocks

To examine the effects of offshoring and immigration on labor market polarization in Home, as well as the effect of unskilled immigration on task upgrading by the native labor, this section presents the impulse responses of key model variables to the relevant shocks.

Decline in the iceberg trade cost Figure 4 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 (see the top-left panels). There are similar effects on the wages of high and medium-skill workers (see the lower-left panels). In addition, the complementarity in consumption between goods – which are 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. This is the first key result from the model that we wish to highlight.

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 dampens the rise of 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.

Decline in the sunk cost of labor migration Figure 5 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 border enforcement for 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, thus "upgrading" the tasks they execute (see Ottaviano, Peri and Wright, 2013). The task upgrading can be observed in the top panels of Figure 5, as the unskilled native employment declines and the number of new skilled jobs rises, which in turn leads to a gradual increase in the employment of high and medium-skill labor. Conversely, the unskilled immigrant wage falls due to the increased supply of immigrant labor, 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 that we wish to highlight.

The process of task upgrading enhances the average productivity of native labor and its income, thus generating a negative wealth effect on labor supply. This wealth effect explains the initial slight negative responses of high and medium-skill employment, which are followed by the gradual increase related to task upgrading discussed earlier. In addition, the rising labor income resulting from task upgrading enhances the Home demand for the imports of offshored tasks, which in turn allows Home to export more, thus explaining the faster increase in high-skill jobs initially.

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 6 shows the median impulse responses to a positive shock in the South (one standard deviation). In the South economy, output and wages increase due to rising 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, immigrant entry drops and the stock of immigrant labor in Home declines below its original steady state. Given the scarcity of unskilled immigrant labor, the native labor engages in "task downgrading," i.e. it reallocates away from the high and medium-skill tradable tasks toward services. Overall, 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 Model Fit

To further examine the effects of shocks on labor market polarization and task upgrading, this section discusses the model-generated moments, as well as the variance decomposition and the historical contributions of shocks to key model variables over the sample period.

6.1 Moments

Table 2 reports the unconditional correlations generated by the model for the variables in growth rates at the posterior median estimates, and compares them to their data counterparts. Panel (a) shows the empirical correlations between the U.S. and Mexico's GDP and the number of border apprehensions, as well as their correlation with the U.S. trade balance and employment in the three skill groups (high-skilled, medium-skilled and unskilled). GDP growth in the United States and Mexico are positively correlated. However, the arrival of unskilled immigrants is linked to the relative growth performance between the United States and Mexico, since apprehensions – which serve as a proxy for the immigrant entry – are negatively correlated with Mexico's GDP. Also, the U.S. trade balance is countercyclical, and hence it is negatively correlated with apprehensions. Finally, the three types of U.S. employment are positively correlated with the U.S. GDP. However, the unskilled employment is negatively correlated with apprehensions, suggesting that the arrival of unskilled immigrants displaces the employment of unskilled natives.

The model captures well the behavior of unskilled immigration and its impact on the native unskilled employment. There is positive comovement between the Home and Southern GDPs, and their relative performance drives immigration like in the data; immigrant entry (L_e) is negatively correlated with GDP in the South and positively correlated with that in Home. In addition, the unskilled employment in Home is negatively correlated with immigrant entry, like in the data. Also, the trade balance for Home is countercylical and negatively correlated with immigrant entry.

Finally, the model-generated moments reinforce our earlier result that native workers respond to unskilled immigration by investing in task upgrading. Thus, there is a large positive correlation between the entry of unskilled immigrants (L_e) and investment in training by the native labor (N_E).

6.2 Variance decomposition

Figure 7 shows the forecast error variance decomposition for three of the four variables used in estimation (GDP growth for the United States, the rest of the world, and Mexico). In addition, it also includes a number of key variables (in levels) at various forecast horizons (Q1, Q4, Q16, Q40): the migration inflows (L_e), the new skilled jobs as a measure of task upgrading (N_E), the native high-skilled (N_X), medium-skilled (N_M) and unskilled employment (L_N). The shocks included are the unit root global technology shock, plus the seven AR(1) processes discussed before, namely the technology shocks in Home, Foreign and South, demand shocks in Home and Foreign, plus the shocks to the iceberg trade cost and the sunk emigration cost.

The unit root global technology shock does not affect migration, task upgrading and employment given their stationary nature, but it affects output in the three economies at all horizons. Even so, output in the South economy is relatively more affected by its own idiosyncratic technology shock, whereas Home and Foreign are relatively more affected by the global unit root shock.

Migration flows are affected, first of all, by the migration cost shock, but also by the technology shocks in South and Home, which constitute the countries of origin and destination for the migrant labor, respectively. The employment of native unskilled labor is affected negatively by immigration, but only at the longer horizons (16 and 40-quarters), since the stock of immigrant labor is a state variable. Similarly, task upgrading, as well as the native high and medium-skilled employment are affected by the migration cost shock at the longer horizons only. In addition, task upgrading is also driven by the Home technology and demand shocks to a large extent at all horizons. Finally, the iceberg trade cost drives the margin of offshoring, and thus affects the high and medium-skilled employment especially at the shorter horizons.

6.3 Historical decomposition

Figure 8 shows the historical contribution of shocks to some of the observable variables, namely the growth of GDP per capita in the United States and Mexico, and border enforcement as a proxy for the sunk emigration cost (panels 1-3), using the actual data. In addition, it also includes immigrant entry, native unskilled employment, and the creation of new skill jobs – which is our measure of task upgrading – as latent variables in growth rates (panels 4-6).

The U.S./Home GDP growth (panel 1) is driven by the global unit root as well as the domestic technology shocks, respectively. Domestic technology shocks explain the recession in 1990:Q3-1991:Q1 to a large extent, whereas the two types of shocks had a more balanced contribution to the recession in 2000:Q1-Q4. Unlike for the United States, the Mexican/Southern growth (panel 2) is driven by domestic shocks by more than by the global technology shock. Thus, large and negative domestic technology shocks were behind the Mexican recessions in 1985:Q4-1986:Q4, 1995:Q1-Q2, and 2000:Q4-2002:Q1.

The growth of border enforcement (panel 3) is exogenous to the model, and thus is driven entirely by the migration cost shock. Several large swings in border enforcement stand out, namely the declines in 1987-88, the early 1990s, and in 2002-2004; on the contrary, there was a spike in enforcement in 1989, and a large and persistent increase during the late-1990s. At this stage, it is interesting to observe that periods when border enforcement was tightened were followed by lagged negative effects from the shock to border enforcement on U.S. growth, and positive effects on Mexican growth. The opposite ensued from decreases in border enforcement.

Immigrant entry (panel 4) is driven mostly by the migration cost shock, and also by technology shocks in Home and South, as expected. Thus, entry declined when border enforcement was enhanced (for instance, in 1989 and the late 1990s), but rose when enforcement was relaxed (in 2002). The negative technology shock in the U.S./Home discouraged entry during the 1990-1991 recession, whereas the negative technology shock in Mexico/South boosted entry during the tequila crisis in 1995.

Finally, we illustrate the effect of unskilled immigration on the natives' unskilled employment (panel

5) and task upgrading (panel 6). The effect unfolds with a lag, since the stock of immigrant labor is a state variable that adjusts gradually over time. Thus, the border enforcement shock affects the two variables in opposite ways. Namely, periods during which border enforcement was tightened (in 1997-1998) were followed by a lagged positive effect on the native unskilled employment, but by a lagged negative effect on task upgrading. The opposite followed a relaxation in border enforcement (for instance, in 2002-2004).

7 Welfare

This section discusses the welfare outcomes for counterfactual scenarios that resemble a liberalization in either trade or immigration policy, or both at the same time. For this purpose, we consider cases in which either the iceberg trade cost or the sunk immigration cost, or both, are lowered from their benchmark calibration levels ($\tau = 1.4$ and $f_e = 4.7$) to lower values ($\tau = 1.1$ and $f_e = 1.0$). The model is solved using a second-order approximation around the deterministic steady state. The welfare net gain relative to the benchmark model is obtained as the percent of the expected stream of consumption that one should add to the benchmark case so that households would be just as well-off as in the counterfactual scenario.

Thus, we find that lowering barriers to trade and immigration has a positive impact on aggregate welfare in Home (see Table 3). First, the reduction in trade costs facilitates offshoring, and thus allows the economy to specialize in the production of tasks in which it is most efficient, as it boosts employment in the most productive occupations. Second, the reduction in migration barriers depresses wages for the native unskilled, but enhances aggregate welfare by encouraging task upgrading and by keeping the non-tradable prices low, which overall has a positive effect on welfare. Third, when trade and immigration policy are liberalized simultaneously, their positive welfare effects reinforce each other.

8 Conclusion

This paper is motivated by the evolution of employment and wages for workers of different skill groups in the United States. During the last three decades, employment became increasingly polarized: while the number of jobs available for those in the middle of the skill distribution declined, employment expanded for the low-skill and high-skill occupations. However, real wages behaved differently. While wages for the high-skill workers increased significantly, wages for low-skill occupations practically stagnated, while those for the middle-skill declined the most.

We relate this evidence to the increase in offshoring and low-skilled migration during the last three decades. As documented in the literature, labor tasks executed by middle-skill workers were the most affected by the offshoring wave, which however did not affect occupations at the bottom of the skill distribution. Since the low-skill occupations mostly consist of personal services that involve assisting and taking care of others, they cannot be executed remotely, but only at the location where the service is provided. The claim in this paper, supported by empirical evidence, is that many of these jobs were taken by low-skill immigrant labor, which in turn dampened any upward pressure on the low-skill wages. Finally, the availability of immigrant and offshore labor increased the productivity of high-skill workers, leading to a robust growth in their employment and earning prospects.

To account for these facts, we develop a three-country stochastic growth model with skill heterogeneity, offshoring and unskilled immigration. Our dynamic general equilibrium setup endogenizes not only the extent of offshoring and immigration, and also the optimal amount of training (skill acquisition) by the native households. We use high-frequency trade-weighted macroeconomic indicators for the U.S., its major trader partners, and Mexico, in conjunction with the U.S-Mexico border enforcement data to estimate the model shocks. The shocks we estimate consist of trade and immigration policy innovations, as well as transitory and permanent innovations in the macroeconomic shocks. We then quantify the impact that each of these developments had on the employment dynamics of each skill group during the sample period. Finally, we consider alternative policy scenarios in which either low-skilled migration or trade liberalization are restrained. We show that both of these scenarios not only reduce aggregate productivity, but also decrease the incentives to train and acquire skills for the native labor. Finally, we quantify the associated welfare losses in each of these scenarios.

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Offshoring, Immigration and Labor Market Polarization

(Tables and Figures)

Federico Mandelman and Andrei Zlate

Table 1: Prior and posterior distributions of estimated parameters

	Prior distribution				Posterior distribution				
Description	Name	Density	Mean	Std Dev	Sd (Hess)	Mode	Mean	10%	90%
Tech. shock (H)	ρ_T	Beta	0.75	0.1	0.1022	0.9139	0.9007	0.8424	0.9478
Tech. shock (F)	ρ_{T^*}	Beta	0.75	0.1	0.0100	0.9753	0.9707	0.9562	0.9830
Trade cost shock	ρ_τ	Beta	0.75	0.1	0.0150	0.7912	0.7744	0.6424	0.8971
Migration cost shock	ρ_{fe}	Beta	0.75	0.1	0.0511	0.9738	0.9748	0.9629	0.9853
Tech. shock (S)	ρ_s	Beta	0.75	0.1	0.0510	0.9684	0.9715	0.9558	0.9861
Demand shock (H)	ρ_b	Beta	0.5	0.05	0.0327	0.5062	0.5185	0.4501	0.5700
Demand shock (F)	ρ_{b^*}	Beta	0.5	0.05	0.0129	0.5071	0.5315	0.4859	0.5813
Tech. shock (H)	σ_T	Inv gamma	0.01	2*	0.0008	0.0066	0.0067	0.0056	0.0081
Tech. shock (F)	σ_{T^*}	Inv gamma	0.01	2*	0.0010	0.0058	0.0058	0.0049	0.0069
Trade cost shock	σ_τ	Inv gamma	0.01	2*	0.0014	0.0041	0.0042	0.0028	0.0056
Migration cost shock	σ_{fe}	Inv gamma	0.01	2*	0.0040	0.0528	0.0542	0.0483	0.0600
Tech. shock (S)	σ_s	Inv gamma	0.01	2*	0.0014	0.0145	0.0149	0.0135	0.0164
Demand shock (H)	σ_b	Inv gamma	0.01	2*	0.0009	0.0035	0.0040	0.0034	0.0048
Demand shock (F)	σ_{b^*}	Inv gamma	0.01	2*	0.0007	0.0032	0.0035	0.0027	0.0043
Global tech. shock	σ_x	Inv gamma	0.01	2*	0.0005	0.0063	0.0066	0.0058	0.0074

Notes: For the Inverted gamma function the degrees of freedom are indicated. Results are based on 50,000 simulations of the Metropolis-Hastings algorithm.

Table 2: Unconditional moments, data and model

(a) Data for the United States, ROW and Mexico			
Variable (growth)	Corr. with U.S. GDP	Corr. with Mex. GDP	Corr. with border appreh.
GDP U.S.	1		
GDP Mexico	0.15	1	
Border apprehensions	−0.05	−0.23	1
U.S. trade balance/GDP	−0.09	−0.05	−0.11
High-skill emploment, U.S.	0.28	−0.10	0.01
Medium-skill employment, U.S.	0.53	0.24	−0.02
Unskilled employment, U.S.	0.34	0.07	−0.16
(b) Estimated benchmark model			
Variable (growth)	Corr. with GDP_{Home}	Corr. with GDP_{South}	Corr. with L_e
GDP Home	1		
GDP South	0.48	1	
Immigrant entry (L_e)	0.27	−0.39	1
Home trade balance/GDP	−0.17	−0.06	−0.19
High-skill emploment, Home (N_X)	0.02	−0.02	−0.03
Medium-skill employment, Home (N_M)	−0.06	−0.02	−0.07
Unskilled employment, Home (L_N)	−0.51	−0.01	−0.27
New skilled jobs, Home (N_E)	0.59	0.01	0.40

Note: For the data, variables are transformed in $\Delta \ln$ and thus expressed in growth rates. The sample period for the variables in growth rates is 1983:Q2 to 2004:3. For the model, we report the moments for the variables in growth rates generated by the model when using the median estimates for the shock parameters reported in Table 1.

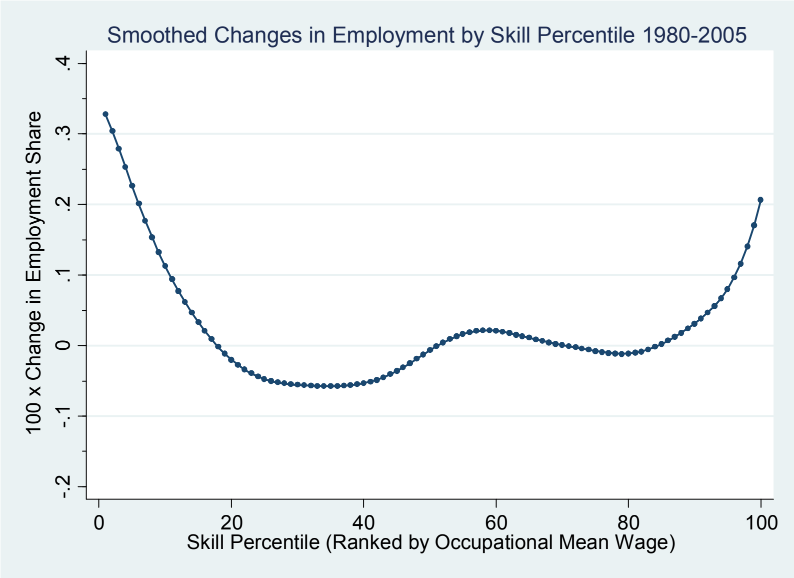
Table 3: Welfare net gain from changes in trade costs and border enforcement

	Home	Foreign
Iceberg trade cost lowered to $\tau = 1.1$	+0.33	+0.43
Migration sunk cost lowered to $f_e = 1$	+0.17	+0.02
Trade and migration costs lowered to $\tau = 1.1$ and $f_e = 1$	+0.51	+0.45

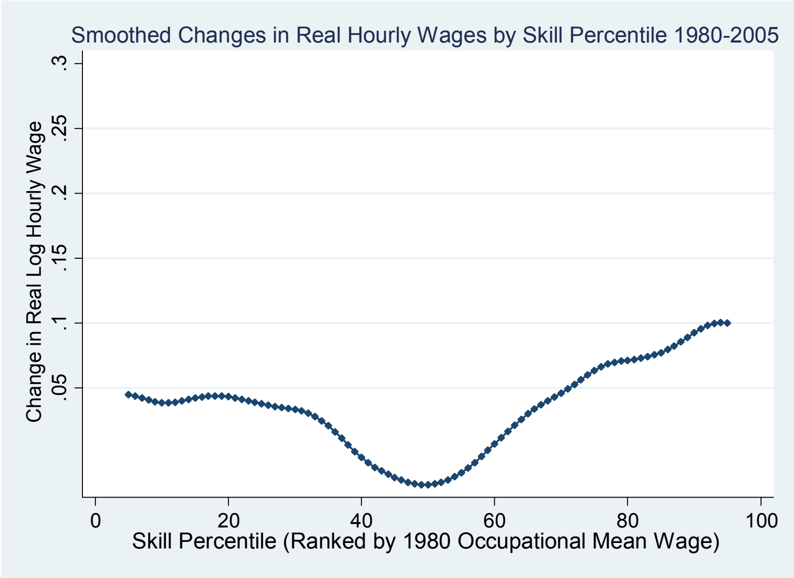
Note: The table shows the welfare net gain or loss for the representative households in Home and Foreign, expressed as a percentage of their steady-state stream of expected consumption, when lowering either the iceberg trade cost or the sunk emigration cost parameters, or both, from the benchmark calibrated values ($\tau = 1.40$ and $f_e = 4.7$) to the lower values presented in the table.

Figure 1. Labor market polarization in the United States

(a) Employment



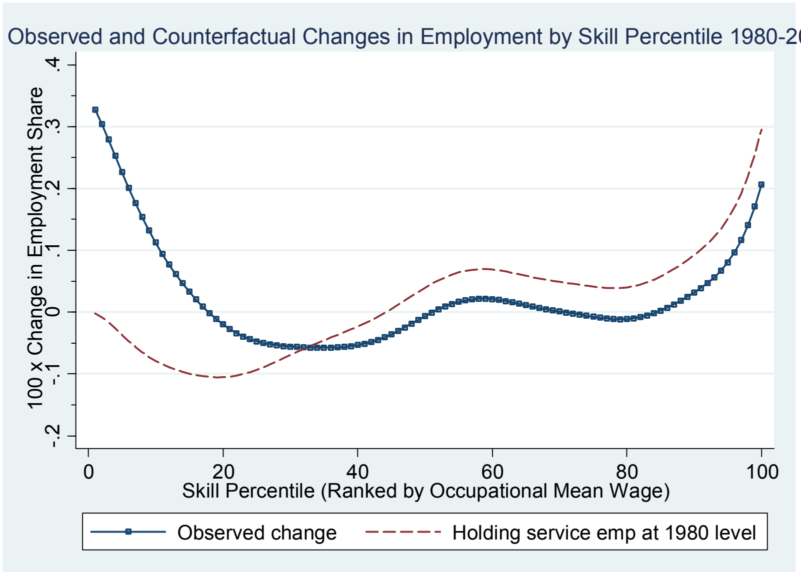
(b) Wages



Note: For the construction of Figures 1-3, we follow the methodology used in Autor and Dorn (2012), using the American Community Survey and Census data to calculate the change between 1980 and 2005. The occupations are sorted into 100 percentiles based on the mean occupational wages and the relative importance of occupations in 1980. For panel (a), the employment shares are computed for each occupation, and then are aggregated at the percentile level. The change in shares is obtained as the simple difference between the share of employment in 2005 and 1980 for each percentile. For panel (b), the average wages are estimated as the weighted mean average of wages of all occupations in a specific percentile. For years 1990 and above, the average wages are estimated using the occupation share in 1980 as weights within each percentile. Finally, the smooth changes plotted in the figure are then obtained by using a locally-weighted polynomial regression between the change in employment shares (or average wages) and the corresponding percentiles.

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

(a) Employment



(b) Wages

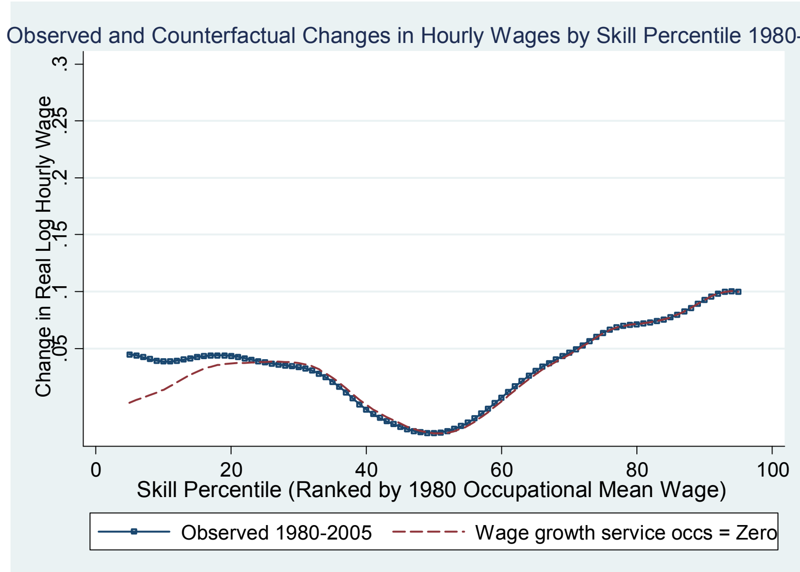
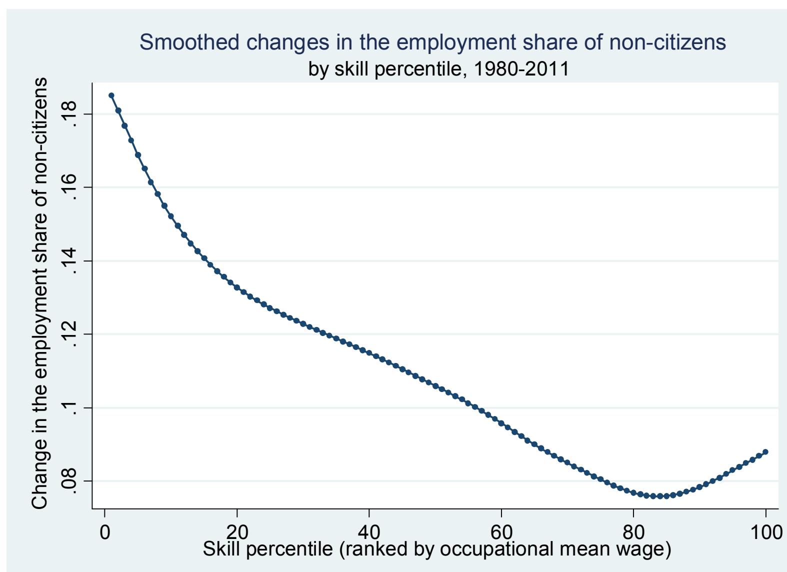
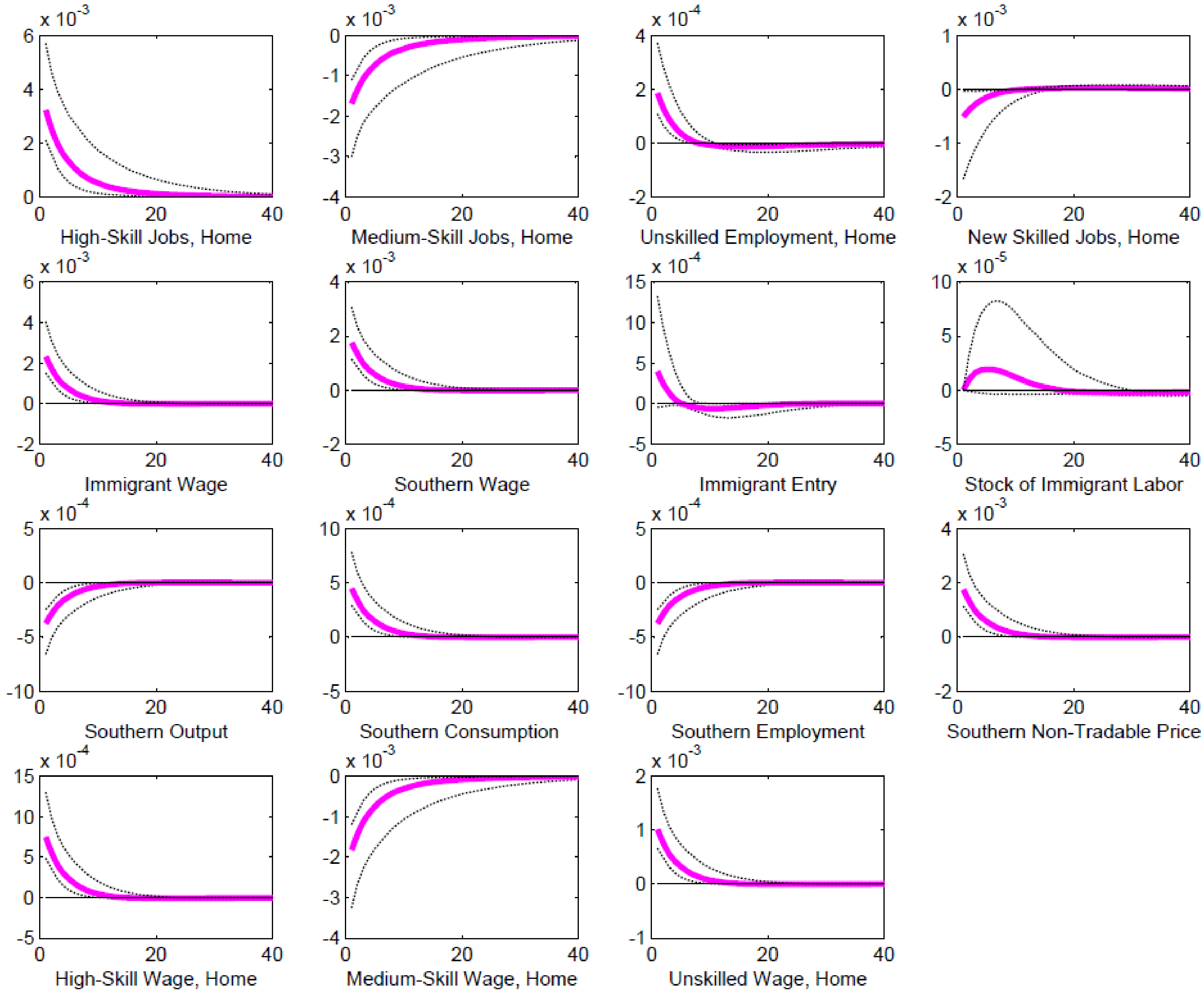


Figure 3. Change in the employment of non-citizens in the United States by skill percentile



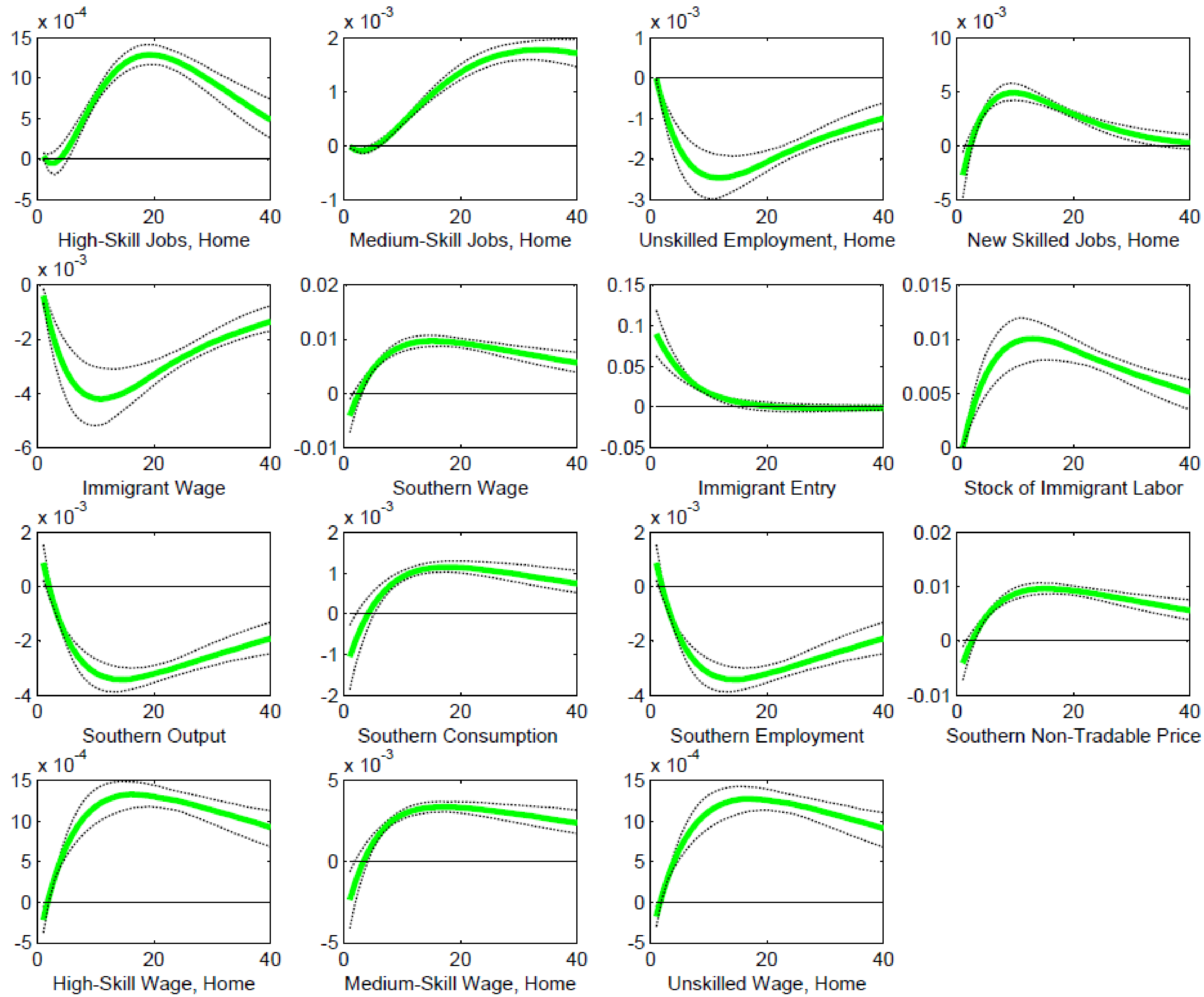
See notes to Fig. 1.

Figure 4. Impulse responses to a decline in the iceberg trade cost



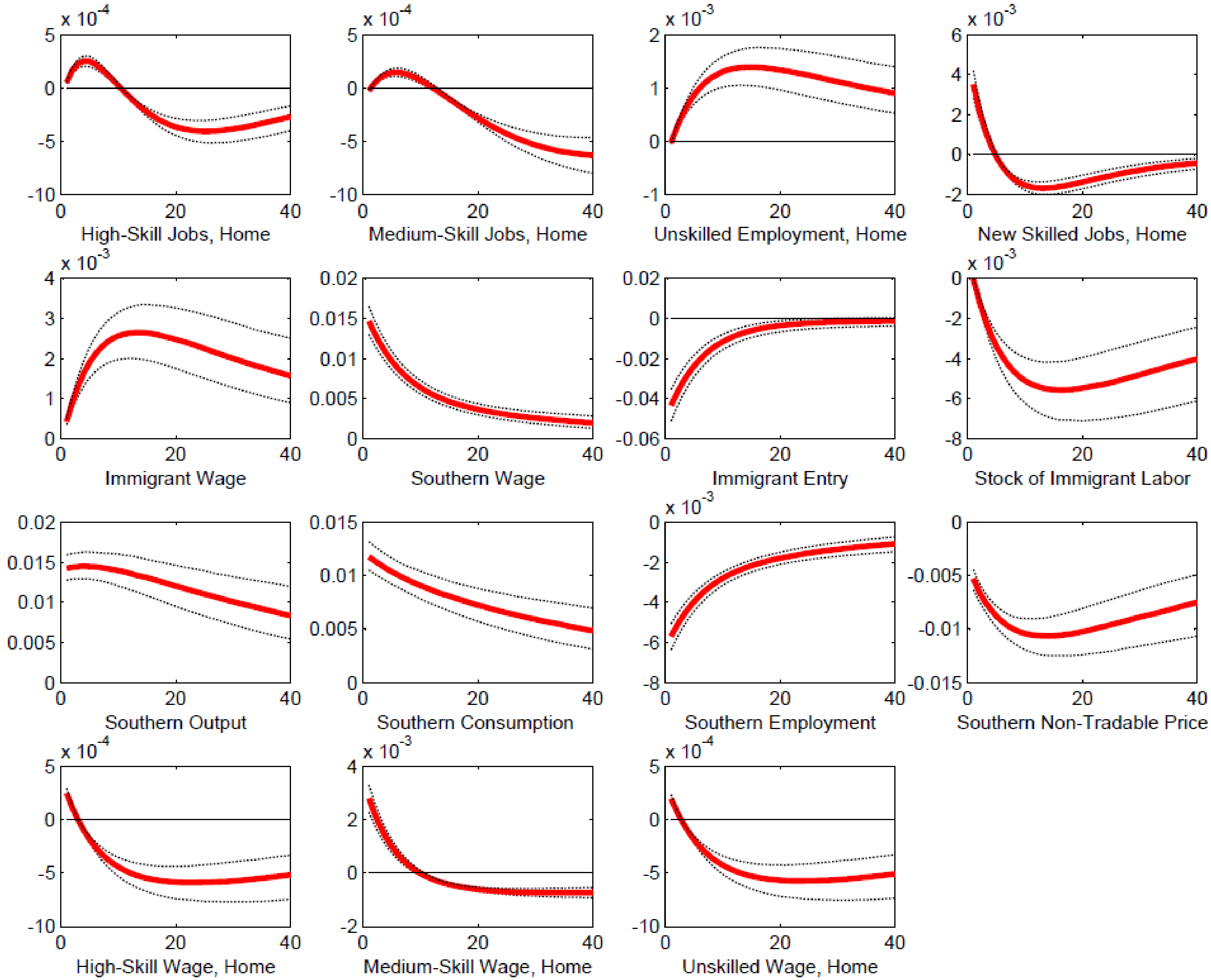
Note: Impulse responses to a decline in the iceberg trade cost (one standard deviation). The thick solid line depicts the median, and the dashed lines depict the 10 and 90 percent posterior intervals.

Figure 5. Impulse responses to a decline in the sunk cost of labor migration



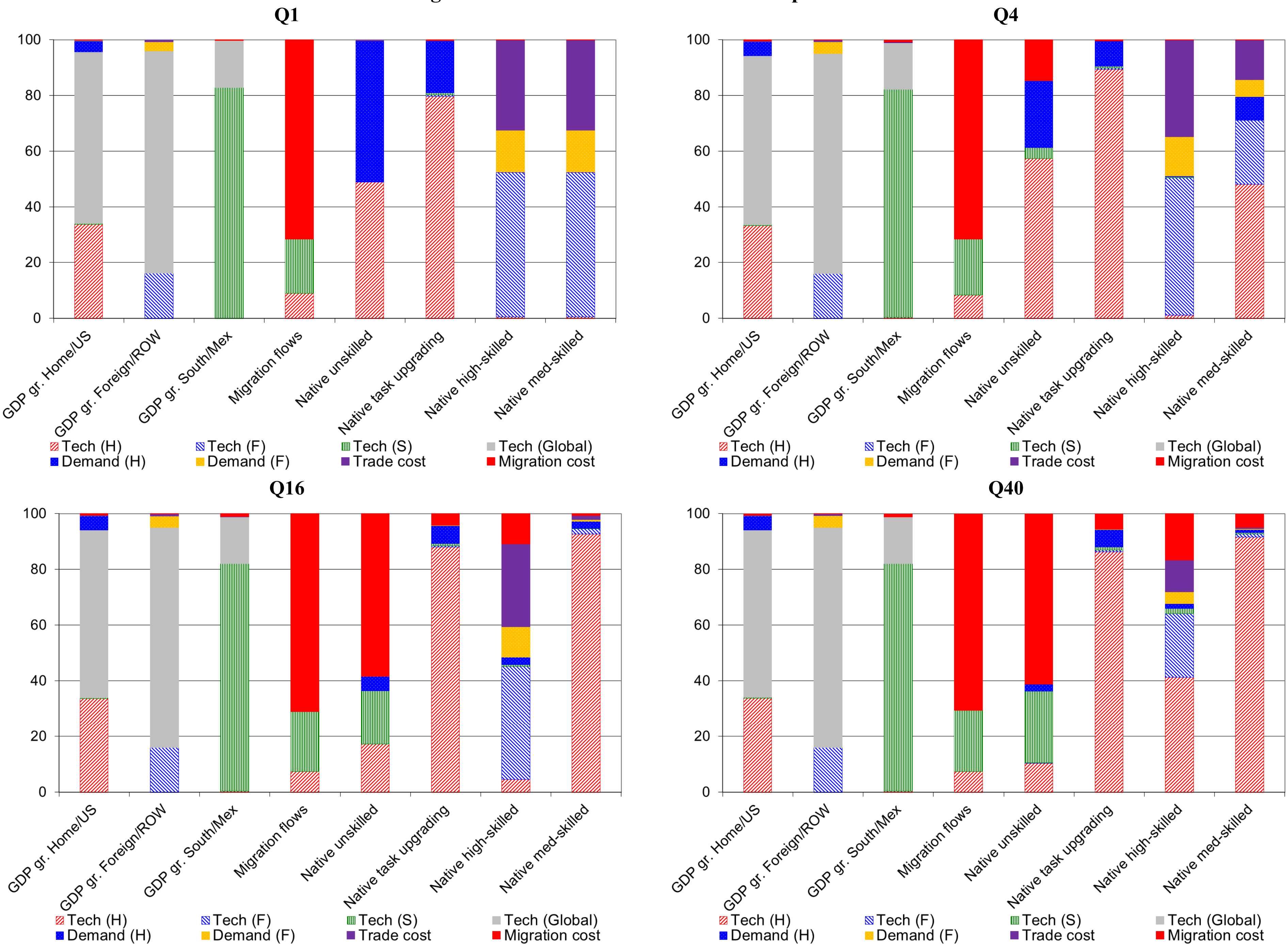
Note: Impulse responses to a decline in the iceberg trade cost (one standard deviation). The thick solid line depicts the median, and the dashed lines depict the 10 and 90 percent posterior intervals.

Figure 6. Impulse responses to a positive technology shock in South.



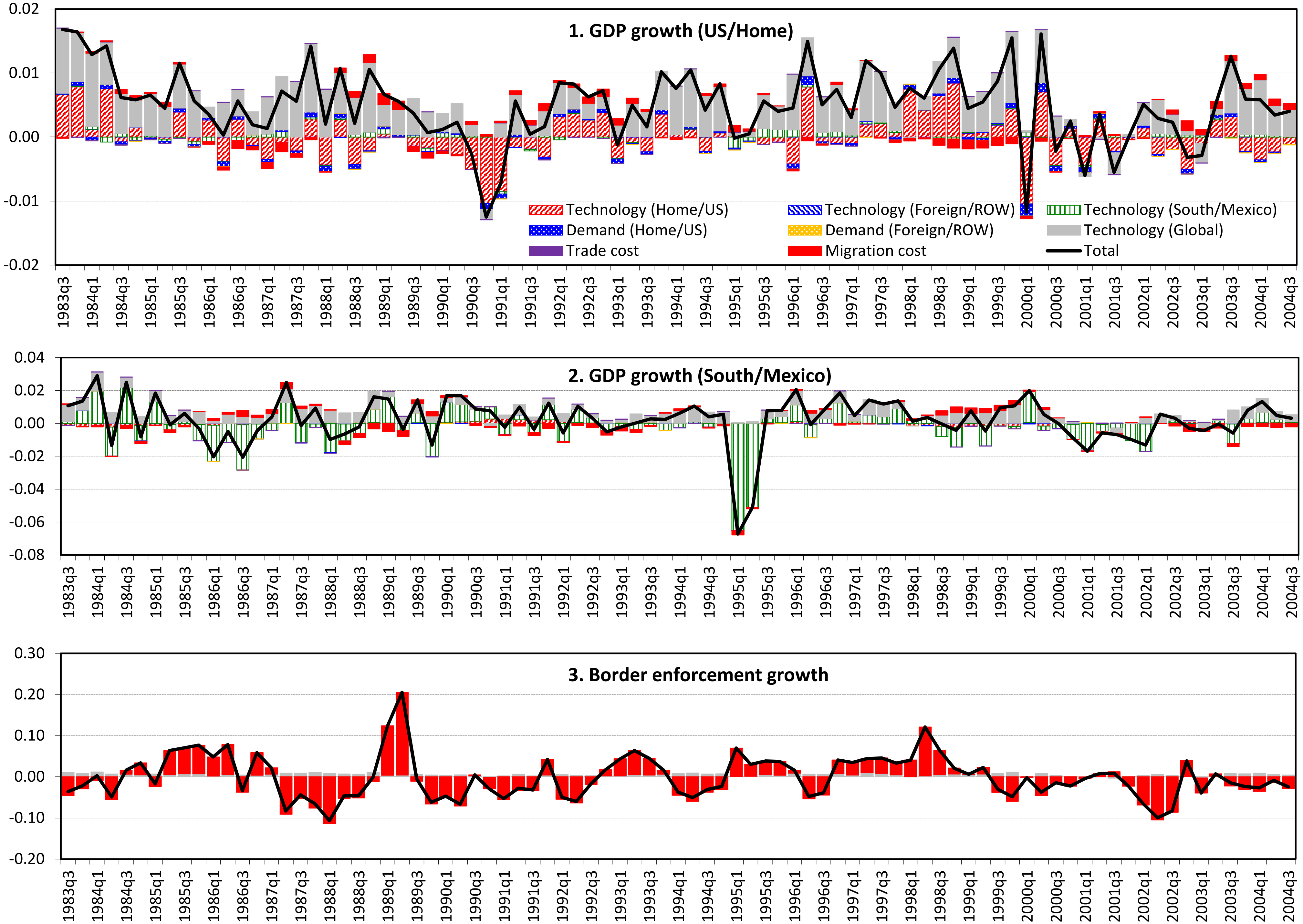
Note: Impulse responses to a decline in the iceberg trade cost (one standard deviation). The thick solid line depicts the median, and the dashed lines depict the 10 and 90 percent posterior intervals.

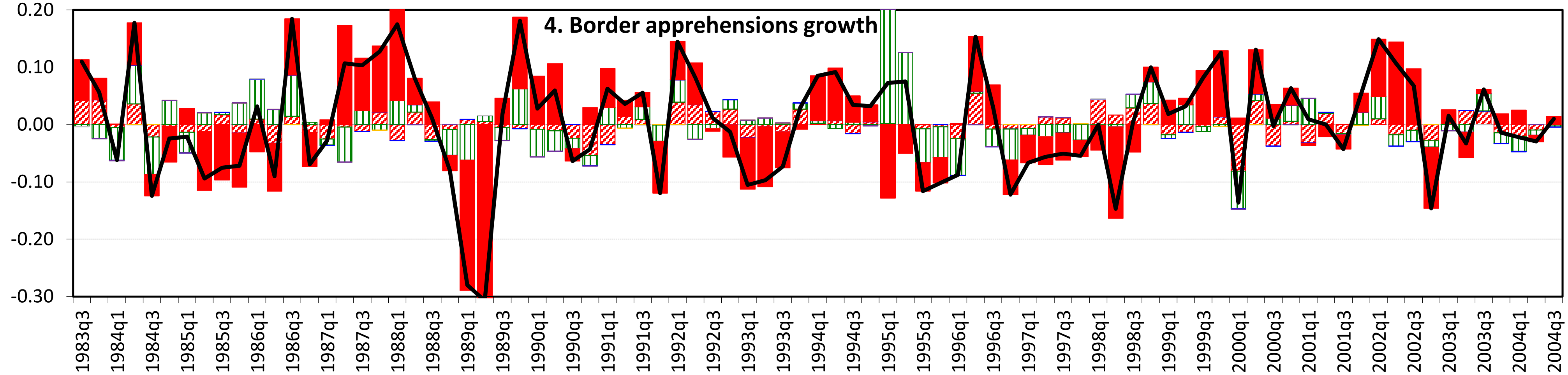
Figure 7. Forecast error variance decompositions

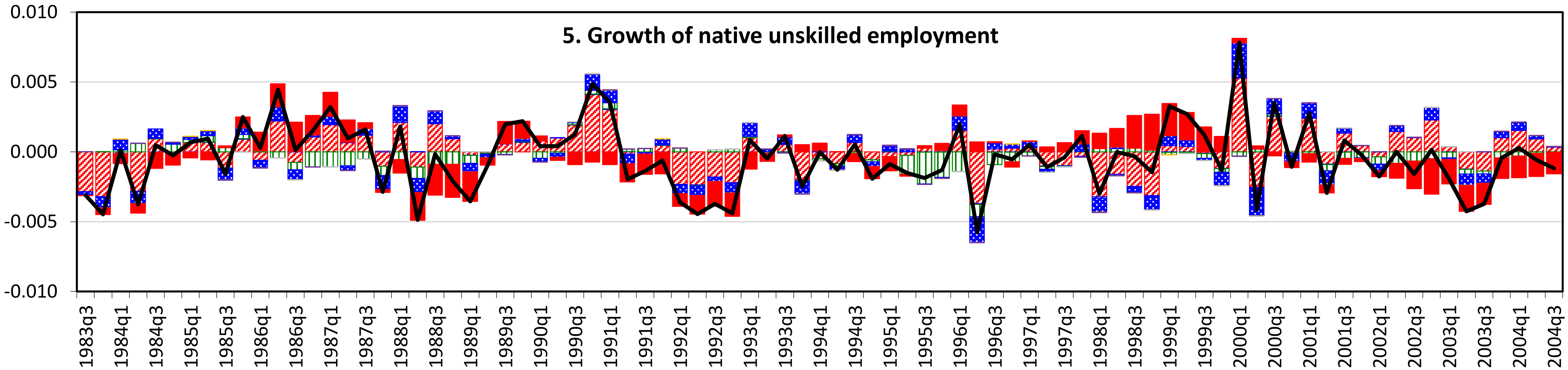


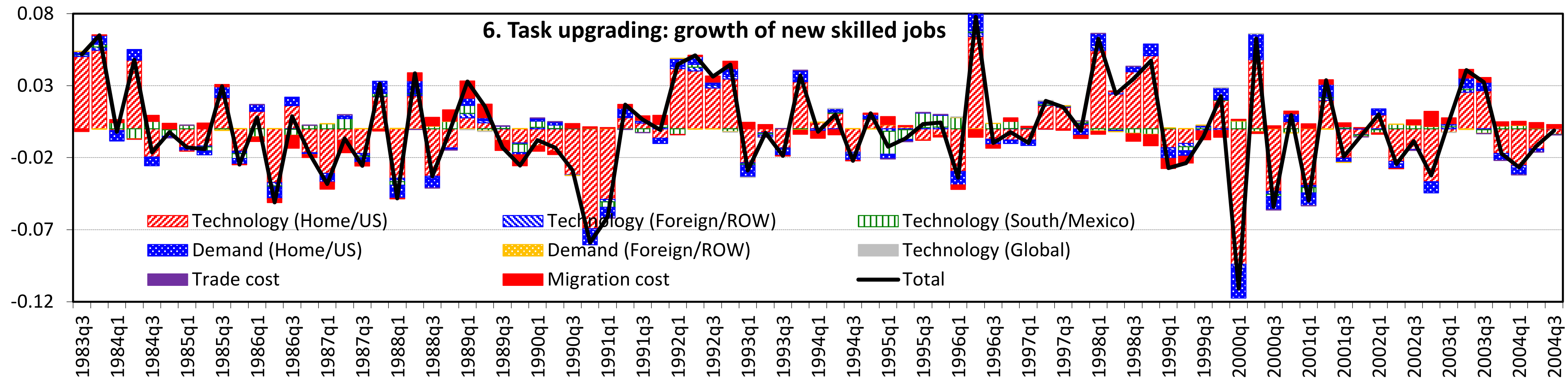
Note: Forecast variance decomposition at the posterior mode, at forecast horizons: Q1, Q4, Q16 and Q40.

Figure 8. Historical decomposition




4. Border apprehensions growth


5. Growth of native unskilled employment


6. Task upgrading: growth of new skilled jobs
Technology (Home/US)
Technology (Foreign/ROW)
Technology (South/Mexico)
Demand (Home/US)
Demand (Foreign/ROW)
Technology (Global)
Trade cost
Migration cost
Total