Labor Market Polarization and International Macroeconomic Dynamics

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Abstract

During the last thirty years, labor markets in advanced economies were characterized by their remarkable polarization. As job opportunities in middle-skill occupations disappeared, employment opportunities concentrated in the highest- and lowest wage occupations. I develop a two-country stochastic growth model that incorporates trade in tasks, rather than in goods, and reveal that this setup can replicate the observed polarization in the U.S. This polarization was not a steady process: the relative employment share of each skill group significantly fluctuated over short-to-medium horizons. I show that the domestic and international aggregate shocks estimated within this framework can rationalize such employment dynamics, while providing a good fit to the macroeconomic data. The model is estimated with employment data for different skills groups, and trade-weighted macroeconomic indicators.

JEL classification: F16, F41

Keywords: Labor Market Polarization, International Business Cycles, Heterogeneous Agents, Stochastic Growth, Two-Country models.

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1 Introduction

There is a rising concern about the disappearance of jobs available for middle-skill workers. To see this, Figure 1(a) shows the change in the share of U.S. total employment accounted by 318 occupations in the census data (where the skill rank is approximated by the average wage in each occupation). The figure reveals that middle-skill occupations witnessed a decrease in their share of total employment in the last three decades.\(^1\) Similar evidence is found in other advanced economies.\(^2\)

International trade appears to be a decisive factor. In particular, tasks typically held by middle-skill workers are increasingly offshored overseas. For instance, Firpo et al (2011) disaggregate the task content of each job and quantify the role that technology and offshoring play in the labor market polarization, finding that the last factor became predominant in the late 1990s, specially, in the 2000s.\(^3\) To account for this, in this paper, I introduce a tractable model where international trade delivers this polarization. The model will be distinguished by the presence of trade in tasks rather than in goods, as originally coined by Grossman and Rossi-Hansberg (2008, 2012). Namely, as revolutionary advances in transportation and communication take place, international trade increasingly involves bits of value added in different locations rather than a standard exchange of finished goods. Instructions can be delivered instantaneously and components of unfinished goods can moved quickly and cheaply. This allows firms to incorporate in the production process labor inputs which are located in different countries.

For instance, as trade links deepen, U.S. workers can specialize in designing and marketing a brand new computer device, while other tasks can be accomplished in the rest of the world as instructed in origin (Indian basic programmers debug the software, Thai technicians manufacture the hard drive, and Chinese workers assemble the final product). In the U.S., those high-skilled individuals working in design and marketing will benefit from trade as the new computer device will now be sold globally, but instead, those with middle-skills will be displaced by foreigners unless the offshoring costs do not justify it.

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\(^1\)See Acemoglu and Autor (2011) for data and references.
\(^2\)See, for instance, Goss and Manning (2007).
\(^3\)See also Firpo et al (2011), Goos et al (2011) and references therein.
Trade in tasks can explain why those with high skills will stand a better chance in the global marketplace, but this alone cannot explain the polarization that also benefits those at the very bottom of the skill distribution. The claim of this paper is that low skill workers select into occupations that are “protected” from the offshoring wave. As shown in Autor and Dorn (2012), this skill group specializes in manual tasks that involve assisting and caring for others, including janitors, home health aides, and child care workers. In general, their tasks are only valuable for the consumer if they are executed in the place where the final good or service is delivered. For instance, a bartender service is only useful when provided in a restaurant, while a construction laborer must work in the place where the structure is being built. Not only offshoring is not a threat for these tasks, but as the incomes of high-skill individuals increase, the demand for these type of services also increases. This ultimately benefits the employment prospects of the low-skilled.

Having said this, one puzzling aspect of the labor market polarization is that it did not occur in a steady manner. As explained in detail by Autor and Acemoglu (2011), there were some striking and pronounced ‘twists’ of the distribution of employment across occupations over the period under consideration. Fig. 1(b) shows the evidence discussed in the first paragraph, but depicted separately over each of the last three decades. During the 1980s (1979-1989) employment growth was widespread but quantitatively monotone in occupation skill. Consequently occupations at the bottom of the skill distribution declined their share of total employment, those at the middle maintained it, and the high-skilled increased it. In the next decade, this monotone relationship, gave way to the distinctive polarization pattern with a hollowing up of the middle. Finally, during the last decade (1999-2007), employment growth heavily concentrated at the bottom. That is, low-skilled jobs expanded robustly, as other skills groups stalled. To add to this evidence, Fig. 2 decomposes total employment by skill level required by each occupation, sharing the same narrative for each of the three decades considered before (always excluding the years following the 2008-2009 crisis).  

Figure 2 disaggregates total employment based on the skill content of the tasks performed in each occupation: cognitive (high), routine (medium), manual (low). The matching of occupations to their skill content follows the guidelines in Acemoglu and Autor (2011). It is similar to the one constructed in Jaimovich and Siu (2012). For a discussion, see Appendix A.
A trade model that is either static or limited to comparisons of long-run positions or growth dynamics will be unable to capture the mentioned ‘twists’. Therefore, the stochastic growth model in this paper incorporates trade in tasks within a international macroeconomic framework which is also adequate to analyze short-to medium-run business cycle dynamics. I use full information methods to estimate a model with transitory and permanent shocks. Data used in the estimation includes high frequency U.S. employment data for different skill groups, as well as domestic and trade-weighted foreign macroeconomic aggregates. In the baseline specification, I consider a set of standard shocks affecting technology (total factor productivity), trade costs, and consumption demand (i.e. inter-temporal rate of substitution).

In principle, my model can rationalize the evidence in each decade. Technology shocks can increase the productive to all labor inputs, but also magnifies the productivity of those who are relatively more skilled, leading to employment gains that are monotonic in skill (as in the 1980s). Consistent with Firpo et al (2011), that shows that offshoring became a critical factor in the 1990s, the model predicts polarization and offshoring of middle-skill tasks when barriers to trade decline and/or productivity in the rest of the world increases. Finally, global imbalances dominated much of the debate in the years preceding the crisis. Within the boundaries of this model, such scenario resembles a shock to the inter-temporal rate a substitution: the foreign economy postpone current consumption by accumulating net foreign assets and running a protracted trade surplus to finance a consumption boom in the domestic economy. In such event, the home economy leans toward the production of non-tradable (low skill) tasks in detriment of tradables tasks (which are supplied in ‘excess’ by foreigners). This is compatible with the evidence for the U.S. in the 2000s. I thus proceed with a shock historical decomposition to asses whether this narrative coincides with the empirical predictions of the model. That is, I quantify the contribution of these shocks to the growth of employment variables over the last three decades, obtaining results consistent with this chronological account.

Finally, I show that this framework can also deliver predictions for macroeconomic aggregates that coincide with some well-established international business cycle facts. In particular, the model delivers a
more accurate business cycle synchronization (output and factor comovement) and more realistic cyclical
dynamics for the real exchange rate. Furthermore, this setup is suitable to address the Backus-Smith
anomaly.

The paper is organized as follows: Section 2 characterizes the modelling approach and discusses the
related literature. Section 3 introduces the model. Section 4 presents the data, the estimation of the
stochastic processes, and a discussion of the model fit. Section 5 shows the effect of these shocks. Section
6 proceeds with a welfare analysis, following by the conclusions in Section 7.

2 Related literature and modelling approach

The analytical framework consists of a two-country stochastic growth model of trade and macroeco-
nomics. Households can freely allocate unskilled labor in the non-tradable service sector, or invest in
training, thus creating a diversity of occupations that fulfill different tasks. Job creation and hiring will
depend on macroeconomic and trade policy conditions and expectations of forward-looking agents. The
training (or job creation) cost involves an irreversible investment, and there is an initial uncertainty con-
cerning the future productivity of the job post created. Upon the job is created productivity is revealed.
Firms can hire workers in the global market to accomplish a certain number of tasks, but must pay an
“offshoring” costs. These include transportation, as well as costs associated with remote monitoring and
adaptability of the offered foreign skills to the local practice. Given these costs, multinational firms will
demand only the most productive workers from each country, benefitting high ability workers world-
wide. The evidence supports this claim, as inequality deepens when countries (at any stage of develop-
ment) lower the barriers to trade.\footnote{See for instance Goldberg and Pavcnik (2007), and Han et al (2012) for a discussion. Instead, the traditional Hecksher-Ohlin / Stolper-Samuelson trade paradigm contradicts this fact. Due to specialization, this theory predicts that the skill premium must fall in countries with relatively abundant unskilled labor once they open to trade. That said, offshoring not only takes place between countries that stand at different stages of economic development. As important as this sort of offshoring is becoming, it pales in comparison to the magnitude of the task trade between similar developed countries (See Grossman and Rossi-Hansberg, 2009, for evidence). Advanced economies routinely engage each other in an intricate web of production-sharing agreements with the same ultimate goal: find in the world the most efficient expertise at the best cost. As discussed in that paper, the new Boeing 787 Dreamliner is a good example. Its production involves 43 suppliers spread over 135 sites around the world: Wings come from Japan, the engines from UK, the fuselage from the US, the gears from France, and the doors from Sweden.}
Standard trade models find difficult to account for the protracted job losses in the middle of the skill distribution. Ricardian comparative advantage predict that some industries shrink as the country specializes where is most efficient. However, Jaimovich and Siu (2012) show that the polarization is not a sectoral phenomenon as middle-skill job losses are recorded across all industries. In addition, Acemoglu and Autor (2011) show that these employment losses are consistently documented across all countries in their sample. Consistently, my model delivers widespread middle-skill employment losses that are not sector or country specific. In this regard, there is a sizable literature on the interaction between trade, sectoral reallocation and involuntary unemployment. The literature originally focused on how minimum wages (or, alternatively efficiency wages and implicit contracts) impedes labor to move towards the sector benefited from trade, thus leading to involuntary unemployment.\textsuperscript{6} More recently the literature focused in search and matching frictions. Notably, Helpman and Itskhoki (2010), and Helpman et al (2010), incorporate Diamond-Mortensen-Pissarides (DMP) frictions in trade models. Within this setup, it is shown that more productive sectors have incentives to thoroughly screen workers in order to exclude those with lower ability. When the economy opens up to foreign competition, labor reallocates toward these sectors, thus increasing aggregate unemployment in equilibrium as screening strengthens. Such model, however, cannot explain the polarization because the unemployment rate is always decreasing in ability, and the opening up of the economy must raise unemployment for all worker abilities.\textsuperscript{7}

The literature instead focuses on closed-economy models based on routine-biased technological change to explain the polarization. Preeminent examples include Acemoglu and Autor (2011) and Jaimovich and Siu (2012). This modelling strategy captures the documented fact that middle-skill workers typically are trained to accomplish “routine” tasks. These tasks can be summarized in a well-defined set of instructions and procedures which are increasingly being replaced by technology embedded in equipment (e.g. bank tellers are replaced by ATMs). Although this type of technical change appears to play an important role;

\textsuperscript{6}Examples include Brecher (1974), Matusz (1986), and Kreickemeier and Nelson (2006).
\textsuperscript{7}Interestingly, however, the increase in screening by most productive firms do not affect as much those that with very low abilities (that were never hired) or those with very high abilities (much less affected by the the firms’ enhanced scrutiny). See Helpman et al (2010) for details.
it is hard to reconcile the notable ‘twists’ in the employment share of each skill group over the last three decades- as previously discussed- solely with a technological change that steadily erases routine tasks over time.\textsuperscript{8}

Papers related to mine also include Grossman and Rossi-Hansberg (2008, 2012) who formalize the trade in tasks hypothesis within a static framework. Their modelling strategy is quite different, though. They build a two-goods two-labor inputs model. Production involves two sets of tasks that each of these labor inputs (skilled and unskilled) must accomplish. In turn, the degree of offshoring and resulting factor payments will depend in the offshoring costs for each task.\textsuperscript{9} In my setup, job creation resembles the firm entry with idiosyncratic productivity in Melitz (2003). While only the most productive firms trade internationally in the Melitz model; in my model, high ability workers are the ones whose skills are demanded by multinational firms in the global marketplace. Indeed, my model is more closely associated with Ghironi and Melitz (2005) that appends the Melitz setup to a DSGE international business cycle framework. Two extensions of this last model are also related to my paper: Cacciatore (2010) adds DMP labor market frictions and Zlate (2009) incorporates offshoring through vertical foreign direct investment. None of these models though allow for skill heterogeneity among workers.


3 The Model

\footnotesize{\textsuperscript{8}In the appendix, I introduce Investment Specific Technology (IST) shocks that lower the relative cost of capital equipment in the model. I thus show that firms react by substituting away from less productive (middle-skill) labor inputs towards capital equipment. Further enhancing the polarization. Naturally, low-skill workers executing manual tasks in personal services are largely unaffected by this innovation affecting the price of capital equipment.}

\footnotesize{\textsuperscript{9}In their second paper, Grossman and Rossi-Hansberg (2012) emphasizes the presence of external economies of scale: a firm that execute a task in a specific location may develop an local expertise in that task, inducing others to execute the same task in that place.}

\footnotesize{\textsuperscript{10}As previously discussed, some of these papers use routine biased technical change to rationalize the documented evidence.}
The model consists of two countries, Home and Foreign. The focus is in Home, with analogous equations holding for Foreign. I denote foreign variables with an asterisk. Since the main innovation of this setup is in the modelling of the labor markets, I only include labor as a factor of production in the baseline specification. For simplicity in the exposition, I postpone to Appendix A the model with capital accumulation. I start with a description of the productive sector, and next characterize the household problem. As common, I introduce as many shocks as the data series used in the estimation to avoid stochastic singularity.

3.1 Firms

There are two sectors. The output of the first sector is the consummation of a diverse number of tasks that may be accomplished at home or overseas. Workers who accomplish these tasks require some training. Each worker reveals an idiosyncratic productivity level upon the completion of this training. For short, I will refer to this sector as the “tradable” sector. Notice, however, that the logic is different than the one typically attached to the tradable sector (i.e. a sector that produces final goods that can be internationally traded). Here tradability means that some of the tasks needed to produce the final goods may be executed overseas. The second sector comprise personal services, that only require unskilled labor as a factor of production. As previously discussed, these personal services are non-tradable by definition.

3.1.1 Tradable Sector

Every period, households can invest in training, thus creating a diversity of occupations. Training requires an irreversible investment (sunk cost), \( f_{\pi,t} \). Once the training is complete, the idiosyncratic productivity \( z \) is revealed. This productivity level remains fixed thereafter until an exogenous job destruction shock make the specific skilled obtained in training obsolete. Households draw this productivity from a common distribution \( F(z) \) with support on \([1, \infty)\). Labor provided by each occupation is measured in efficiency units, \( l_{z,t} \), which is the product of raw hours, \( l_t \), and the idiosyncratic productivity index \( z \):

\[ l_{z,t} = l_t \times z \]

\(^{11}\)The specific functional form of these costs will be discussed in Section 3.2.
$l_{z,t} = z_l$. The efficiency unit is transformed back into a raw labor unit if the job destruction shock hits. The job destruction shock is independent of the worker’s idiosyncratic productivity level, so $F(z)$ also represents the efficiency distribution for all workers in any point in time.

I assume that technology is labor-augmenting. Each efficiency unit, $l_{z,t}$, used in production is benefited by two technological innovations. The first one, $X_t$, is a permanent world technology shock, that affects all productive sectors in both countries. This global shock has a unit root as in Lubik and Schorfheide (2006), and warrants a balanced-growth for the economy. In addition, there is temporary country-specific technology, $Z_t$, that evolves as an AR(1) process. Each efficiency unit provided by each occupation can thus be transformed in a productive task $n_t(z)$, as follows:

$$n_t(z) = (X_t Z_t) l_{z,t} = (X_t Z_t) z_l.$$ (1)

I assume that each occupation can perform a given set of tasks, $\xi$, which are defined over a continuum of tasks $\Xi$ (i.e. $\xi \in \Xi$). At any given time, only a subset of these tasks $\Xi_t$ ($\Xi_t \subset \Xi$) may be demanded by firms in the global labor market and effectively used in production. The labor input of this sector consists of a compilation of productive tasks $n_t(z, \xi)$ which are imperfectly substitutable:

$$N_t = \left( \int_{\xi \in \Xi_t} n_t(z, \xi) \frac{d\xi}{\theta} \right)^{\frac{1}{\theta-1}},$$

where $\theta > 1$ is the elasticity of substitution across tasks. Some of these tasks can be executed in the foreign country. The wage bill is

$$W_t = \left[ \int_{\xi \in \Xi_t} w_t(z, \xi) \frac{d\xi}{\theta} \right]^{\theta-1},$$

where $w_t(z, \xi)$ is the corresponding wage paid to each efficiency unit labor used in production.

In the baseline specification only labor is used in the production of the tradable sector, $Y_{T,t}$. Under constant returns to scale: $Y_{T,t} = N_t$. The price of tradable output, $P_{T,t}$, is $P_{T,t} = W_t$. This model setup characterizes a real economy with no role for nominal variables. For analytical convenience, I take a standard approach and use tradable sector price level as the numeraire $P_{T,t} = W_t \equiv 1$; hence serving as a unit of account.

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12 The subset of tasks demanded by foreign companies is $\Xi_t^* \subset \Xi$, and may differ from $\Xi_t$.
13 This may capture some local specialization in a specific tasks (See Grossman and Rossi, 2012).
3.1.2 Personal Services (Non-Tradable) Sector

This sector provides personal services which are non-tradable by definition. The output of the service sector, \( Y_{N,t} \), is a linear function of unskilled labor: \( Y_{N,t} = X_t L_{N,t} \). Where \( L_{N,t} \) is an homogenous aggregate of raw (unskilled) labor units that households supply to the service sector, and \( X_t \) is the unit-root global technology shock. The price for unskilled personal services, \( P_{N,t} \), is thus: \( P_{N,t} = \frac{w_{u,t}}{X_t} \). Where \( w_{u,t} \) is the real wage paid for each unit of raw labor.

3.1.3 Trade in Tasks and Skill Income Premia

Some labor tasks can be accomplished in Foreign. These tasks are subject to a melting-iceberg trade cost, \( \tau \geq 1 \), as well as a fixed outsourcing cost \( f_{o,t} \). The fixed outsourcing costs is paid on a period-by-period basis. For consistency with the economy-wide balanced growth path, these costs are expressed in units of effective raw labor as follows: \( f_{o,t} = \frac{w_{u,t}}{(Z_t X_t)} (X_t f_o) \). Notice that these outsourcing costs must grow at a rate \( X_t \) along this path (as all real variables do in this model).

In a symmetric equilibrium, \( w_t(z, \xi) = w_t(z, \cdot) \), for every task \( \xi \in \Xi \). Therefore, the skill income gap of a unit of labor employed in the domestic tradable sector with respect to a unit of of raw labor in the nontradable service sector, \( \pi_{D,t} \), is defined as follows:

\[
\pi_{D,t}(z, \cdot) = w_{D,t}(z, \cdot)n_{D,t}(z, \cdot) - w_{u,t}l_t,
\]

where the subscript \( D \) denotes a task executed for the domestic based firm. The labor income gap for a unit of labor that is demanded overseas, denoted with an \( X \) subscript is:

\[
\pi_{X,t}(z, \cdot) = \left( w_{X,t}(z, \cdot) \frac{n_{X,t}(z, \cdot)}{\tau} - f_{o,t} \right) - w_{u,t}l_t.
\]

Due to these outsourcing and melting-iceberg costs, only the most efficient workers have their tasks demanded in Foreign. Put it differently, a worker’s tasks will take part in multinational production as long
as productivity $z$ is above a threshold $z_{X,t} = \inf\{z : \pi_{X,t}(z, .) > 0\}$. Workers with productivity below $z_{X,t}$ will accomplish tasks for the domestic market. From a different angle, some of these lower productivity tasks will not be executed by foreigners as the outsourcing costs do not justify it. Aggregate shocks to productivity, demand or barriers to trade will result in changes to this threshold level.

**Idiosyncratic productivity averages** Melitz (2003) show that these productivity weighted averages summarize the productivity distributions relevant for all macroeconomic aggregates. The average productivity of each workers is: $\bar{z}_{D,t} = \left[ \int_{0}^{\infty} z^{\theta - 1} dF(z) \right]^{\frac{1}{\theta}}$. The average efficiency of a worker whose tasks are used globally is: $\bar{z}_{X,t} = \left[ \frac{1}{1 - F(z_{t,\epsilon})} \int_{z_{t,\epsilon}}^{\infty} z^{\theta - 1} dF(z) \right]^{\frac{1}{\theta}}$. This setup is isomorphic to one where a mass of workers $N_{D,t}$ with productivity $\bar{z}_{D,t}$ execute task in the domestic market, and a mass workers $N_{X,t}$ with productivity $\bar{z}_{X,t}$ also accomplish tasks that serve as an input for foreign firms. We can define average wages for each of these skill group as follows $\bar{w}_{D,t} = w_{D,t}(\bar{z}_{D,t}, .)$, $\bar{w}_{X,t} = w_{X,t}(\bar{z}_{X,t}, .)$. Similarly, the average skill-income gap for labor employed domestically is, $\bar{\pi}_{D,t} = \pi_{D,t}(\bar{z}_{D,t}, .)$, while the corresponding outsource skill premia is $\bar{\pi}_{X,t} = \pi_{X,t}(\bar{z}_{X,t}, .)$. Taking into account all this, the wage bill of the tradable sector, $\mathbb{W}_{t}$, can be redefined as follows: $\mathbb{W}_{t} = \left[ N_{D,t} (\bar{w}_{D,t})^{1-\theta} + N_{X,t}^* (\bar{w}_{X,t})^{1-\theta} \right]^{\frac{1}{1-\theta}}$, where the asterisk indentify foreign variables.

### 3.2 Households

I do not address distributional issues in this setup. As common in the literature, I assume that household members perfectly insure each other against fluctuations in labor income resulting from changes in employment status, thus eliminating any type of ex-post heterogeneity across individuals. Following the seminal works of Andolfatto (1996) and Merz (1995), households form an extended family that pools all its income and chooses aggregate variables to maximize expected lifetime utility.

**Consumption Composites** Households preferences over real consumption, $C_t$ are defined by the composite: $C_t = \left[ (\gamma_c)^{\frac{1}{\rho_c}} (C_{T,t})^{\frac{\rho_c-1}{\rho_c}} + (1 - \gamma_c)^{\frac{1}{\rho_c}} (C_{N,t})^{\frac{\rho_c-1}{\rho_c}} \right]^{\frac{\rho_c}{\rho_c-1}}$ which comprises consumption of non-tradable
personal services \( C_{N,t} \), and the final good resulting from the composite of tradable tasks, \( C_{T,t} \). The consumer price index, always expressed in terms of the price level of the tradable sector, is:

\[
P_t = \left[ (\gamma_c) + (1 - \gamma_c) \left( P_{N,t} \right)^{1+\alpha_c} \right].
\]

There is no investment demand in this version of the model. By definition, \( C_{N,t} = Y_{N,t} \). Similarly, since only tasks are traded in this model \( Y_{T,t} = C_{T,t} \).

**Household’s Decision Problem**  
Households have standard aditive separable utility over real consumption, \( C_t \), and leisure, \( 1 - L_t \), where \( L_t \) is the labor supply. They maximize an standard utility kernel, which is modified to be consistent with balanced growth-path\(^{14}\):

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

Where \( \gamma, a_n, \gamma_n > 0. \varepsilon_t^b \) is an AR(1) shock to the intertemporal rate of substitution, which may be interpreted as a demand shock.

For simplicity, the period budget constraint expressed in terms of tradable output, or indistinctly, in units of the wage bill, \( W_t \), is:

\[
w_{u,t} L_t + N_{D,t} \bar{\pi}_t + B_{t-1} = P_t C_t + q_t B_t + \Phi(B_t) + f_{e,t} N_{e,t}. \tag{5}
\]

Where, \( \bar{\pi}_t = (N_{D,t} \bar{\pi}_{D,t} + N_{X,t} \bar{\pi}_{X,t})/N_{D,t} \), is defined as the average skill income premium for all the skilled tasks executed by all workers in Home. Households’ total labor income is: \( w_{u,t} L_t + N_{D,t} \bar{\pi}_t \)–the first term of this expression captures the renumeration from all “raw” units of labor households supply to the non-tradable service sector, as well as, those domestic and foreign based tradable sector. The second term adds the average skill income premium for all the skilled tasks performed both dometically and

\(^{14}\)See, for instance, Rudebusch and Swanson (2012).
outsourced to Foreign. International financial transactions are restricted to one period, risk free bonds. The level of debt due is $B_{t-1}$, and $q_t = 1/(1 + r_t)$ is the price of new debt–$r_t$ is the implicit interest rate. To induce model stationarity, I introduce an arbitrarily small cost of holding these bonds, $\Phi(\cdot)$, which takes the following functional form: $\Phi(B_t) = X_t \frac{\phi}{2} \left( \frac{w}{w_t} \right)^2$. It is necessary to include the level of world technology both in the numerator and denominator of this functional specification. This is needed to guarantee stationary along the balanced growth path. $N_{c,t}$ are the new skilled occupations created in period $t$. As explained, in Section 3.1.2 $f_{c,t}$ is the cost of creating these occupations. Mimicking outsourcing costs, $f_{c,t}$ is expressed in units of effective raw labor and follow a path consistent with balanced-growth:

$$f_{c,t} = \frac{w_{u,t}}{(Z_t X_t)} (X_t f_e).$$

The mass of workers executing tasks for the tradable sector, $N_{D,t}$, evolves according to the following law of motion:

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

(6)

**Optimality Conditions** Households maximize utility subject to its budget constraint and the law of motion above. The optimality conditions for labor effort, and the consumption/saving are reasonably conventional.

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

(7)

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

(8)

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

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15 In the balanced growth path, debt, $B_t$, grows in sync with technology, $X_t$, making the ratio stationary. In addition, since all real variables grow at the rate $X_t$. We also need to make the adjustment cost also grow at the same rate. See Rabanal et al (2011) for further details.
\[ E_t \left\{ \zeta_{t+1}^s \frac{Q_t}{Q_{t+1}} - \frac{\zeta_{t+1}^s}{\zeta_t} \right\} = -\frac{\Phi'(B_t)}{\beta}. \]  

(9)

Where \(Q_t\) the factor-based real exchange rate (or terms of labor).\(^{16}\) The training optimality condition is pinned down by the following condition:

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

(10)

That is the training cost incurred to create an occupation in period \(t\), \(f_{e,t}\) is evaluated against the present discounted value of the average skill income premium accounted for all the skilled tasks \(\{\tilde{\pi}_s\}_{s=t+1}^{\infty}\).

Households adjust the discount factor \(\beta\) for the possibility of job destruction, \(\delta\), that renders the acquired skills obsolete.

### 3.3 Aggregate Accounting and Balanced Trade

The evolution of the net foreign asset position of this economy is characterized as follows:

\[ q_t B_t - B_{t-1} = Q_t N_{X,t} (\bar{\omega}_{X,t})^{1-\theta} N_t - N_{X,t} (\bar{\omega}_{X,t})^{1-\theta} N_t. \]  

(11)

The first term of the right hand side is the sum of all tasks executed in Home and outsourced to Foreign. The second term reflects the opposite. Finally, Home and foreign holdings of risk free bonds are zero in net supply worldwide: \(B_t + B_t^* = 0\).

\(^{16}\) That is, \(Q_t = \frac{\bar{\epsilon} W_t}{W_t}\) (\(\epsilon\) is the nominal exchange rate, units of the home numeraire per units of the foreign one).
I develop a two-country dynamic stochastic growth model distinguished by the presence of trade in tasks rather than in goods. The model is estimated with U.S. employment data for different skill groups and trade-weighted macroeconomics indicators for the U.S and the rest of the world. In the model, a decrease in the barriers to trade leads to the distinctive polarization in the labor market. Lower trade costs and technological advances in communications allow firms to incorporate productive tasks that are executed remotely in different locations. In this context, multinational firms hire the most efficient workers from each country and exploit any existing local specialization. This outsourcing harms the employment prospects of middle-skill workers who must compete with foreigners. In turn, low-skilled workers are protected from the offshoring wave because they specialize in the provision of non-tradable services (e.g. child/elderly care, gardening, janitors, and construction) that require their task to be executed in the same place where the service is provided. Trade leads to more specialization and increases aggregate productivity, further enhancing the demand for personal services and the employment prospects for the low-skilled.

In the extended model, I introduce capital and consider the effect of Investment-specific technological (IST) innovations that lower the relative price of equipment and machinery. The polarization is enhanced in this scenario: Firms substitute away from labor towards capital, so that multinational firms can be even more selective when hiring workers in the global market place. This relatively more capital-intensive production technology enhances aggregate productivity and wages for workers at the top of the skill distribution. As aggregate income increases, so does the demand for services. Since the service sector is
labor intensive, it is not directly affected by these IST innovations. Consequently, low-skill employment increases in tandem with the demand for services.

Low-skill service jobs cannot be offshored, but immigration can be an alternative. During the last decades, the emergence of these service jobs coincided with an increase in low-skilled migration inflows. Immigrants may contain the increase in wages for the low-skilled, thus forcing the natives to keep on training and acquiring skills. The interaction between migration and trade is part of our ongoing research agenda.
References


A Appendix—Model with Capital

As in Mandelman et al (2011), Household’s capital accumulation evolves as follows

\[ K_t = (1 - \delta^k)K_{t-1} + V_t \left( I_t - \frac{\phi^k}{2} I^i_{t-1} \frac{V_{t-1}}{V_t} \left( \frac{I_t V_t}{I_{t-1} V_{t-1}} - \Lambda_X \right)^2 \right), \]

where \( V_t \) the Investment-Specific Technology Shock, following an AR(1) specification. In a competitive equilibrium, \( V_t^{-1} \) may be interpreted as the relative price of capital goods with respect to the price of consumption goods. The adjustment cost must be rescaled to account for the long-run gross rate of growth of investment along the balanced growth path: \( \Lambda_X \). The parameter \( \phi^k \) controls the elasticity of the adjustment cost in the capital stock to changes in investment. \( \delta^k \) is the rate of depreciation.

The budget constraint becomes:

\[ w_{u,t} L_t + N_{D,t} \tilde{\pi}_t + B_{t-1} + (1 + r^K_t)K_{t-1} = P_t (C_t + I_t) + q_t B_t + \Theta(B_t) + f_{c,t} N_{c,t}. \]

where \( r^K_t \) is the rental rate of capital. The first-order conditions with respect to capital and investment deliver:

\[ \lambda_t = \beta \mathbb{E}_t \left\{ (1 + r^K_{t+1}) \tilde{\zeta}_{t+1} + \lambda_{t+1} (1 - \delta) \right\}, \tag{12} \]

and

\[ P_t \tilde{\zeta}_t = \lambda_t V_t \left( 1 - \phi^k \Omega_t \right) + \beta \mathbb{E}_t \left\{ \lambda_{t+1} V_{t+1} \left[ \phi^k \Omega_{t+1} \frac{I_{t+1}}{I_t} - \frac{\phi^k}{2} \frac{V_t}{V_{t+1}} (\Omega_{t+1})^2 \right] \right\}, \tag{13} \]

where \( \Omega_{t+1} = \frac{X_t V_t}{X_{t-1} V_{t-1}} - \Lambda_X \).

On the firm side, production in the tradable sector is a CES composite of labor and capital.

\[ Y^T_t = \left[ \alpha K_t^{\frac{\sigma - 1}{\sigma}} + (1 - \alpha) N_t^{\frac{\sigma - 1}{\sigma}} \right]^{\frac{\sigma}{\sigma - 1}}. \]

The first-order condition for physical capital and the labor input are: \( (1 - \alpha) \left( \frac{Y_T}{N_t} \right)^{\frac{1}{\sigma'}} = \frac{1}{P_t'; \alpha} \left( \frac{Y_T}{K_{t-1}} \right)^{\frac{1}{\sigma'}} = \)
\[ \frac{1}{P_t}, \text{ respectively.}^{17} \]

\[ \text{The numeraire is } W_t \equiv 1. \text{ When we introduce capital, the identity } P_t^T \equiv W_t \text{ no longer holds.} \]
B Appendix-Trade Between Asymmetric Countries

To be completed.
### Table 1: Prior and posterior distributions of estimated parameters, model without capital

<table>
<thead>
<tr>
<th>Description</th>
<th>Name</th>
<th>Density</th>
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<th>Std Dev</th>
<th>Mode</th>
<th>Mean</th>
<th>10%</th>
<th>90%</th>
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### Table 2: Prior and posterior distributions of estimated parameters, model with capital

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Figure 1a. Changes in Employment

![Smoothed Changes in Employment by Skill Percentile 1980-2005](image)

Figure 1b. Changes in Employment (by decade)

![Smoothed Changes in Employment by Occupational Skill Percentile 1979-2010](image)

Figure 1c. Changes in employment (holding service sector constant)

![Observed and Counterfactual Changes in Employment by Skill Percentile 1980-2005](image)

Note: Smoothed changes in employment by skill percentile.
Figure 2. Employment by occupation groups

Top: High-Skill (Non-Routine Cognitive), Middle: Middle-Skill (Routine), Low-Skill (Non-Routine Manual)
Figure 3. Data and Predicted values from the model

Note: Data (solid line) and benchmark model’s Kalman filtered one-sided predicted values (dashed line). Variables are expressed in growth rates.
Figure 4-Neutral Technology Shock

Note: Impulse Response to a decline in the global barriers to trade (one standard deviation). The solid line depicts the median, and the dashed line depicts the 10 and 90 percent posterior intervals.
Figure 5-Decline in Barriers to Trade

Note: Impulse Response to a decline in the global barriers to trade (one standard deviation). The solid line depicts the median, and the dashed line depicts the 10 and 90 percent posterior intervals.
Figure 6-Shock to the Discount Factor

Note: Impulse Response to a decline in the global barriers to trade (one standard deviation). The solid line depicts the median, and the dashed line depicts 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.

1. Growth in high-skill employment (Home)

2. Growth in medium-skill employment (Home)

3. Growth in low-skill employment (Home)