Essays in Skilled Immigration Policy

Mishita Mehra

A dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2018

Reading Committee:

Fabio Ghironi, Chair

Federico Mandelman

Oksana Leukhina

Program Authorized to Offer Degree:
Economics

University of Washington

Abstract

Essays in Skilled Immigration Policy

Mishita Mehra

Chair of the Supervisory Committee:
Professor Fabio Ghironi
Department of Economics

This dissertation studies the impact of skilled immigration and skilled immigration policy changes in the U.S. Chapter 1 studies the macroeconomic general equilibrium effects of skilled immigration policy changes by explicitly taking into account the role of firm demand for foreign skilled labor. To this end, I develop a two-sector dynamic stochastic general equilibrium model with monopolistically competitive firms and heterogeneous workers. Unlike most previous studies that view immigration as a supply-induced shock, the paper models skilled labor immigration as an endogenous response to an increase in firm labor demand in the receiving economy. The model is calibrated to mimic the U.S. economy with its current immigration policy: Firms face hiring costs and there is an occasionally binding cap on the foreign skilled workers that can be hired each period. The results indicate that a less restrictive skilled immigration policy via an immigration cap increase leads to heterogeneous effects on skilled and unskilled workers — unskilled domestic workers gain but skilled domestic workers lose. However, the magnitude of the welfare impacts depends on the state of the economy at the time of the cap change and also on the structure of the labor market (presence of search frictions). This paper also evaluates the welfare and efficiency gain from moving toward an alternate skilled immigration policy with a market-driven allocation of permits for hiring skilled foreign workers. Such a policy increases welfare and brings the economy's allocation closer to the social planner's first-best allocation.

Chapter 2 studies the interaction between skilled immigration policy changes in the U.S. and the offshoring decision of domestic firms in the skilled services sector. Given the substitutability between immigrant and offshore workers (Ottaviano et al. (2013), Olney and Pozzoli (2018), Ottaviano et al. (2018)) and frictions imposed by the current skilled immigration policy, firms have an incentive to incur additional costs and hire labor offshore. To study this channel and the associated welfare impacts on skilled and unskilled domestic households, we build a two-country model with skilled immigration, offshore labor hiring, and trade in intermediate inputs. Monopolistically competitive firms in the domestic skill-intensive intermediate goods sector produce output using domestic and immigrant skilled labor, and skilled labor hired offshore. Firms optimally hire immigrant skilled workers subject to a policy imposed cap, a sunk hiring cost, and an exogenous probability of return to the foreign economy. In the calibrated model, firms adjust their production towards higher offshore labor hired following a stricter domestic immigration policy . We show that it is important to account for the role of offshoring when evaluating the welfare impacts of skilled immigration policy changes on domestic households — by ignoring firm adjustments in offshore labor hired, we would overestimate the wage (and welfare) gain to domestic skilled households after an immigration cap reduction. We also show that the welfare impacts depend on the profit distribution across households and the presence of labor market frictions. This paper has two main contributions. First, as Ottaviano et al. (2018) note, much of the literature has focused on offshoring in the manufacturing sector and ignored an analysis of immigration and offshoring in the services sector. Given the growing importance of skill-intensive services trade, our paper takes a step in this direction. Second, unlike much of the literature, the paper studies the interaction between immigration and offshoring in a dynamic general equilibrium model with a realistic skilled immigration policy setup.

Chapter 3 estimates key parameters in a search and matching model with skilled immigration using Bayesian estimation techniques using U.S. quarterly data from 1995 to 2017.

Results indicate that the bargaining power of native skilled workers is higher than the bargaining power of foreign-born skilled workers. The estimation results also indicate deviations from the Hosios condition. This has potential implications for how the economy responds to immigration policy changes. The future goal is to employ the estimated model to study the impact of skilled immigration policy reform.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The author is extremely grateful to her adviser, Fabio Ghironi, for his constant guidance and support. She is also extremely thankful to Federico Mandelman and Oksana Leukhina for their guidance and encouragement. She is grateful to financial support from the Alfred P. Sloan Foundation Pre-doctoral Fellowship on the Economics of High Skill Immigration, awarded through the NBER and is also extremely thankful to the Federal Reserve Bank of Atlanta for their generous support and hospitality.

DEDICATION

To my grandparents and parents.

Chapter 1

SKILLED IMMIGRATION, FIRMS, AND POLICY

Mishita Mehra

1.1 Introduction

There has been a rapid increase in the number of foreign skilled workers in the U.S. labor force. Among all foreign-born individuals, those with at least a bachelor's degree witnessed the sharpest increase (42 percent) during the 2004 - 2015 period (Figure A.1). The corresponding increase for the native born in the same skill group was 26 percent. This led to an increase in the proportion of college-educated foreign born in the U.S. labor force from 14 percent to 16 percent (Figure A.2).[1]

Firm demand for foreign skilled workers has played an important role in generating this increase. Since its inception in 1990, the H1-B visa program remains the dominant entry route of foreign skilled workers into the U.S. labor force (Figure A.3).[2] Firms play a crucial role in hiring, sponsoring, and incurring costs at each stage of the H1-B application process for a foreign worker. The first step requires a firm that wants to hire a foreign worker to file a Labor Condition Application (LCA) with the Department of Labor in which one of the items that they need to specify is the number of foreign workers they would like to hire for a particular occupation. These LCAs signal vacancies or firm demand for foreign skilled

[1]Over a longer horizon of two and a half decades, the foreign-born share of the total population with a bachelor's degree in the U.S. labor force increased from 10 percent in 1990 to 17 percent in 2015 (U.S. Census Bureaus 1990 and 2000 Decennial Census). Data from 2004 - 2015 is complied from the Current Population Survey (CPS). Foreign born in this survey include legally-admitted immigrants, refugees, temporary residents and temporary workers, and undocumented immigrants. However, the number of undocumented unskilled immigrants is likely to be underreported. In this study, I do not distinguish between foreign born and immigrants even though the legal definitions are different.

[2]The Appendix discusses details on the H1-B visa program.

labor. However, the actual number of visas issued to foreign workers is determined by a policy-imposed cap.

The gap between firm demand, measured by the number of workers requested in the LCAs filed, and visas issued tends to grow during expansionary periods (Figure 1.1).[3] Moreover, the visa cap was met in each year since 2004, in less than a week in seven of those years (Figure 1.2), and visas for foreign skilled workers were allocated according to a lottery process.[4] These facts indicate that there is a strong demand for foreign skilled workers that is not accommodated by the current immigration policy.

The role of firm demand of foreign skilled workers and the current allocation mechanism of foreign workers across them have implications for how an increase in skilled immigration and changes in immigration policies impact the aggregate economy. However, these implications are not fully understood in the current literature since most studies view immigration as a supply-induced shock.

Motivated by these facts, the goal of this paper is to the address the following questions within a macroeconomic general equilibrium framework: First, what are the determinants of firm demand for foreign skilled workers and what are the impacts of an increase in skilled immigration on labor market outcomes, output, and welfare of domestic households? Second, can an alternate immigration policy in which the government allocates the same quota of visas according to a market-driven allocation of permits increase welfare of domestic households? Specifically, would such a policy close the gap between the decentralized economy's allocation and the efficient allocation chosen by a social planner?

To this end, I develop a two-sector dynamic general equilibrium model with uncertainty in aggregate productivity. This is the baseline model in the paper. Heterogeneous monopo-

[3] An LCA is submitted for every H-1B request, whether new or a renewal, and each LCA can contain multiple H-1B workers. A more conservative estimate of the demand for foreign skilled workers may be to count each LCA filed as a request for one employee. Analyzing the total number of LCAs filed as compared to Figure 1 that plots the total number of employees requested in LCAs filed does not change the main motivation regarding business cycle correlation and rising excess demand during expansionary periods.

[4] Firms have from April 1st until the beginning of the next fiscal year to file petitions for H1-B visa applications.

listically competitive firms in the skill-intensive sector produce output by employing skilled domestic and foreign labor. The main incentive for hiring foreign labor in the baseline model is the inelastic supply of domestic skilled labor.[5] Skilled labor immigration is modeled as an endogenous response to an increase in firm labor demand in the domestic economy, subject to immigration policy restrictions that mimic current U.S. policy: Firms face hiring costs and there is a cap on the number of foreign workers that can be hired each period. This cap binds when economic conditions are such that the aggregate demand for foreign labor exceeds the policy-imposed quota. If the cap is met, the endogenously determined probability of being able to hire each foreign worker is less than one. This is the allocation mechanism of foreign workers across firms in the baseline model. Firms take into account these immigration policy restrictions and optimally choose to hire foreign labor until the expected discounted benefit from hiring foreign skilled workers is equal to the expected cost. Since a significant proportion of foreign skilled workers on an H1-B visa are temporary workers, the model allows for an exogenous probability of return to the country of origin. Revenue from immigration policy is collected by the government and transferred to domestic households. Perfectly competitive firms in the second sector employ unskilled labor to produce a homogeneous product.[6] In the labor market of the baseline model, other than sunk hiring costs and the role of immigration policy, there are no other frictions. In an extenstion to the model, I also explore how search and matching frictions alter the results.

The baseline model matches and explains evidence regarding U.S. labor markets. More productive firms demand more skilled labor. Moreover, the probability of hiring foreign skilled labor reduces during expansionary times. I calibrate the main parameters of the

[5] This assumption is relaxed in the extended model with search and matching frictions.

[6] This two-sector model is qualitatively similar to a one-sector version of the model in which firms hire both skilled and unskilled workers. In the two-sector version, complementarities between skilled and unskilled workers exist through the consumption basket, while in the one-sector version, these complementarities exist through the production technology. In the context of a model studying skilled immigration, it is realistic to separate the two sectors as more than 70 percent of the Labor Condition Applications are requested by the relatively skill-intensive NAICS Sector 54 — Professional, Scientific, Technical services Sector (United States Department of Labor).

baseline model that pertain to immigration to match the U.S. economy during the 2004 - 2014 period. I then employ the calibrated model to study dynamics of economic variables in response to productivity shocks and changes in immigration policy. I calculate the welfare effect on domestic households of an increase in the policy-imposed cap. I also study how this welfare impact quantitatively depends on the realized state of the economy at the time of the cap change. This experiment is motivated by the fact that the cap has been non binding during certain, especially recessionary periods. For instance, the cap was increased to 195,000 between the 2001 to 2003 period, during the start of which the economy entered a recessionary phase. The cap did not bind during this period as firms did not increase hiring by the full amount of the cap increase (Figure 1.2).[7]

The results highlight some key insights that emphasize the importance of focusing on the role of the firm when studying skilled immigration. Under the baseline policy, unskilled domestic households gain (due to complementarities that increase unskilled wages) but skilled domestic households lose (due to substitutabilities that reduce skilled wages) from a ten percent immigration cap increase. The welfare gain (including transitional dynamics) amount to 0.0558 percent of annualized steady-state consumption for unskilled workers. For skilled domestic workers, the welfare loss amounts to 0.0603 percent of annualized steady-state consumption. An increase in the stock of foreign skilled labor also increases firm output and profits over time. However, the magnitude and impact of an increase in the cap may depend on two relatively overlooked factors.

First, the welfare changes for both skilled and unskilled domestic workers are smaller in magnitude if the cap change is implemented at a time when the economy is transitioning after a negative productivity shock. In this case, firms do not increase hiring by the full amount of the cap increase and the foreign labor stock increases by less. Therefore, it is important to take into account the state of the economy at the time of the cap change in order to evaluate the welfare implications of an immigration cap change.

[7]This recession particularly hit the technology sector.

Second, the structure of the labor market is important. The extension of the baseline model that includes search and matching frictions (with the same immigration policy) shows that the welfare impact on domestic households differs (qualitatively and quantitatively), when compared to the baseline model. Even with perfectly substitutable domestic and foreign workers, an immigration cap increase leads to a higher employment of domestic skilled workers and an overall positive welfare gain for these workers, despite a fall in their wages. The welfare gain to unskilled households is also more than double compared to the baseline model.

The main mechanism behind this is that the cap increase encourages firms to post more vacancies, and this increases both domestic and foreign matches. In the search and matching framework, firms can be matched with either domestic or foreign workers (depending on the relative proportion of job searchers). However, under the current immigration policy, if the cap binds, firms are able to hire only a fraction of their foreign matches (given by the probability of an application being selected as in the baseline model). When the cap increases, this probability increases, and firms are able to retain more foreign matches. This increases their expected surplus from posting a vacancy. Higher job creation has a spillover effect on skilled domestic workers as their employment and welfare increase, despite a fall in wages.

The main result from analyzing the alternate skilled immigration policy with a market-driven allocation of permits is that such a policy increases welfare of both skilled and unskilled domestic workers, compared to the baseline model. This is because immigration policy revenues collected by the government are about 36 percent higher. This has important implications because it shows that an alternate allocation of the same quota of foreign workers can potentially increase welfare (if the revenues are used in a productive manner or are simply transferred to domestic households) and close a part of the inefficiency wedge between the decentralized economy's allocation and the first-best allocation chosen by a social planner. This is particularly relevant if the government wants to keep the cap on skilled foreign workers unchanged due to political resistance.

This paper has three main contributions. First, it includes a more realistic skilled immigration policy with an occasionally binding entry cap on foreign workers. The results show that this is relevant for evaluating the welfare impact of a cap change in the U.S. economy. In contrast, most studies that analyze the impact of skilled immigration policy changes view immigration as a supply-induced shock. Second, apart from studying the impact of skilled immigration policy reform via changes in the cap alone, this paper also begins to evaluate the impact of an alternate skilled immigration policy setup through a market-driven allocation of permits, which is related to the skilled immigration policy reform proposed in Peri (2012). Third, by incorporating a more realistic skilled immigration policy setup within the search and matching framework, the paper shows that even when U.S. and foreign workers are perfectly substitutable, an increase in the immigration cap can increase welfare of domestic workers. This is relevant because a key debate in the empirical literature is regarding the elasticity of substitution between native and immigrants in the same skill group and this is one of the reasons behind the lack of consensus regarding the impact of immigration on domestic workers (Ottaviano and Peri (2012), Borjas et al. (2008)). However, if labor markets are imperfectly competitive, domestic workers can gain from an immigration increase despite perfect substitution between domestic and foreign workers.

1.2 Related Literature

This research adds to the emerging literature that examines the implications of high skilled migration. This includes Borjas and Doran (2012), Ottaviano, Shih, and Sparber (2015), and Kerr and Lincoln (2010). The paper is also related to studies that measure the welfare gains from lowering barriers to labor mobility (Urrutia (1998); Klein and Ventura (2007, 2009); Iranzo and Peri (2009); Levchenko et. al. (2015); Ehrlich and Kim (2015)). In the context of DSGE models of international business cycles, the paper is related to Mandelman and Zlate (2012), who develop a two-country business cycle model with unskilled labor migration.

This paper is also related to empirical studies that highlight the role of firms in the context of skilled immigration (Kerr et al. (2013) and Ottaviano, Peri, and Wright (2015)). Kerr et al. (2014) stress the "need to increasingly develop a better understanding of the general equilibrium effects of skilled immigration with firms as a central element." Some recent studies have explicitly focused on the role of firms in a macroeconomic general equilibrium framework while discussing impacts of skilled immigration. Waugh (2017) studies the impact of a larger labor force (through an expansion of the H1-B visa program) on dynamics of firm entry and exit, and the effect on wages, aggregate output, and welfare. Bound et al. (2016) also use a general equilibrium model to study the effect of an increase in high-skill foreign born on domestic workers, consumers and firms, during the 1990s. My baseline model is consistent with their results — skilled immigration reduces wages of domestic skilled households, while redistributing gains to complements in production. Immigration lowers prices and raises output and profits of firms in the relevant sectors. However, skilled immigration is modeled as a labor supply shock in these studies. The explicit focus on the role of firm hiring of foreign skilled labor leads to some new insights that are relevant for evaluating skilled immigration policy changes — particularly that the welfare impacts of current immigration policy changes depend on how firms respond to the policy change, which in turn depends on the realized state of the economy.

The extended model with search and matching frictions is related to recent literature that studies the effects of immigration on the welfare of native individuals in a general equilibrium model featuring search frictions and wage bargaining (Chassamboulli and Palivos (2014), Battisti et al. (2014), Kingi (2015)). In all these, as long as immigrants have inferior outside options compared to natives, an increase in immigration raises firms incentives to create vacancies which benefits all workers, including native skilled workers. My results are consistent with these papers — unskilled native workers gain unambiguously. Skilled native workers, on the other hand, gain in terms of employment despite wage losses. However, by focusing on a more realistic immigration policy that is relevant to the U.S., the extended version of my model with search and matching frictions is able to capture an additional channel by which immigration impacts vacancy postings and hence employment of domestic households — an increase in the immigration cap increases the probability of being able to retain a foreign match, and therefore the overall surplus from posting a vacancy.

1.3 Baseline Model

The baseline model features a two-sector economy that is populated by skilled and unskilled households and households with the same skill level are identical. Heterogeneous monopolistically competitive firms (as in Melitz (2003)) in sector 1 (the skill-intensive sector) produce differentiated goods using domestic and foreign skilled labor.[8] In the background, there is a foreign country that is assumed to have a large elastic supply of skilled workers that can be hired by domestic firms, subject to domestic firm demand and migration policy restrictions that mimic U.S. immigration policies - costs of hiring and a cap that occasionally binds, depending on the state of the economy.[9] Therefore, the constraint that firms face for hiring skilled labor is an outcome of immigration policy, rather than the supply of foreign skilled labor.[10]

Foreign and domestic skilled workers are perfect substitutes in the baseline model and earn the same wage under competitive labor markets. This is consistent with the overall evidence on relative earnings of foreign born as a percent of native born for workers with a bachelors degree or higher (Figure A.5). Moreover, when filing a Labor Condition Application, firms attest that they will pay the worker the prevailing compensation for that occupation. Given the debate surrounding the degree of substitutability between domestic and foreign workers, I show how the model can be modified to include complementarities between the workers in the appendix.[11]

---

[8] Kerr et al. (2014) highlight heterogeneity in demand of foreign skilled workers across firms (Figure A.4).

[9] For the H1-B visa program, it does not matter whether the foreign-born worker is employed directly from the foreign country or from the domestic economy (for instance, after studying in the U.S.), as firms need to go through the same procedures in both cases. Although there is an additional quota for workers who obtain a master's degree or higher from a U.S. institution, I ignore this distinction in the model.

[10] This assumption is realistic due to the significant wage differences between OECD and developing countries. If hired, there is a strong incentive for a foreign skilled worker to migrate. Empirically, Clemson (2012) estimates that there is a six-fold increase in salary for skilled workers who migrate to the US.

[11] The estimated degree of imperfect substitutability between native and immigrants within the same education and experience group is around 20 (Ottaviano and Peri (2012)). In the model with complementaries

I ignore emigration from the domestic economy as I treat the domestic economy as OECD countries like the U.S. and the foreign economy as developing countries (China, India, and the Philippines) and there is a very small share of migration from OECD to developing countries (OECD, 2013).[12] Here, I focus on the domestic economy and do not model foreign explicitly.

For immigrants, there is an exogenous probability of return to the country of origin, to account for the fact that a bulk of foreign skilled workers are on a temporary work visa and a fraction returns every period. Moreover, the exogenous return to the country of origin helps ensure that even in the absence of shocks, there is some demand for foreign skilled labor in every period, as is evident in the data.

Representative perfectly competitive firms in sector 2 (the unskilled sector) produce output using unskilled domestic labor. There is a government that collects revenue from immigration policy and rebates it symmetrically to domestic households. All contracts and prices are written in nominal terms, and prices and wages are flexible. Thus, the model solution will focus only on real variables.

1.3.1 Domestic Households

The Home economy consists of a continuum of two types of infinitely-lived domestic households that supply units of skilled and unskilled labor inelastically. The labor supply of the representative skilled household is normalized to 1, and that of the representative unskilled household is $\bar{l}_u$. Each skilled and unskilled representative household has the same preferences over a basket of goods produced at Home. The lifetime utility of skilled and unskilled households is given by:

(Appendix A), this corresponds to $\gamma = 0.9477$, and therefore results are similar to the baseline model where $\gamma = 1$.

[12] Theoretically, this can be justified in terms of technology differences between the domestic economy and the foreign economy that ensure that wages in the home economy will always be higher than wages at foreign, which would removes the incentive to migrate to the foreign economy.

$$\max_{C_{j,t}} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t}\Big(lnC_{j,\tau}\Big) \quad \forall j \in \{s,u\}$$

where $C_{j.t} = (\frac{c_{1,t}}{\alpha})^{\alpha}(\frac{c_{2,t}}{1-\alpha})^{1-\alpha}$ is the consumption basket of each household. $c_{1,t}$ is the basket of sector 1 goods consumed, and $c_{2,t}$ is the sector 2 good consumed. $\alpha \in (0,1]$ is the weight of sector 1 goods in consumption. The consumption-based price index is $P_t = (p_{1,t})^{\alpha}(p_{2,t})^{1-\alpha}$, where $p_{1,t}$ and $p_{2,t}$ are the price indices of sector 1 and sector 2 goods, respectively. The price indices in units of the consumption basket are $\rho_{1,t} = p_{1,t}/P_t$ and $\rho_{2,t} = p_{2,t}/P_t$. Therefore, the consumption-based price index can also be expressed as $1 = (\rho_{1,t})^{\alpha}(\rho_{2,t})^{1-\alpha}$ in units of the consumption basket. The basket of sector 1 goods is given by $c_{1,t} = \int_{\omega\in\Omega}(c_{1,t}(\omega)^{\frac{\theta-1}{\theta}}d\omega)^{\frac{\theta}{\theta-1}}$, where $\theta > 1$ is households' symmetric elasticity of substitution across sector 1 goods. Thus, the price index of sector 1 output is $p_{1,t} = \int_{\omega\in\Omega}(p_{1,t}(\omega)^{1-\theta}d\omega)^{\frac{1}{1-\theta}}$ where $p_{1,t}(\omega)$ is the price of the good ω. The demand for each good in sector 1 by household type $j \in \{s,u\}$ is given by $\alpha(\frac{p_{1,t}(\omega)}{p_{1.t}})^{-\theta}\frac{P_t}{p_{1,t}}C_{j,t}$ or $\alpha(\frac{\rho_{1,t}(\omega)}{\rho_{1.t}})^{-\theta}\frac{1}{\rho_{1,t}}C_{j,t}$.

The demand for the sector 2 good by household j is given by $(1-\alpha)\frac{P_t}{p_{2,t}}C_{j,t} = (1-\alpha)\frac{1}{\rho_{2,t}}C_{j,t}$, where $\rho_{2,t}$ is the price of sector 2 output in units of the consumption basket. The budget constraint for the domestic skilled household is $w_{s,t} + d_t + T_{s,t} = C_{s,t}$ where d_t is the profit income of sector 1 firms and $T_{s,t}$ are the transfers from the government, both in units of the consumption basket. $w_{s,t}$ is the real wage paid to skilled labor, which will be determined in the competitive labor market for skilled workers. Skilled households are the sector 1 firm owners in the baseline model. Unskilled households consume the sum of their labor income and transfers from the government i.e. $C_{u,t} = w_{u,t}l_{u,t} + T_{u,t}$, where $w_{u,t}$ is the real wage paid to unskilled labor, and is also determined competitively in a separate labor market for unskilled labor.

1.3.2 Production

Skill-Intensive Sector (Sector 1)

There are a continuum of heterogeneous monopolistically competitive firms, each producing a differentiated variety $\omega \in \Omega$. There is no endogenous firm entry or exit. The constant mass of firms is normalized to 1. Production requires skilled (Home or Foreign) labor. Aggregate labor productivity is Z_t which is exogenous and follows an AR[1] process in logs. Firms are heterogeneous as they produce with different technologies indexed by relative productivity z. Firm specific productivity z follows a Pareto distribution $G(z)$, with shape parameter k, and support on $(z_{min}, \infty]$. Output supplied by firm z in sector 1 is $y_{1,t}(z) = Z_t z l_{s,t}(z)$, where the total mass of skilled labor employed is

$$l_{s,t}(z) = l^s_{h,t}(z) + l^s_{f,t}(z)$$

where h and f denote domestic and foreign skilled labor respectively. The domestic supply of skilled labor at home is inelastic and normalized to 1. $l^s_{f,t}(z)$ is the stock of Foreign skilled labor employed at firm z. Skilled domestic and Foreign labor are assumed to be perfect substitutes.

Domestic firms face certain immigration policy restrictions when hiring foreign workers: Firms have to pay hiring costs, and there is a government-imposed cap on the number of foreign workers that can be hired each period. The sunk hiring costs can be decomposed into two components — costs due to immigration policy, and technological costs of hiring foreign workers. Firms have to pay cost g_t to the government for each foreign skilled worker they apply for, which is refunded back if the worker is not allocated to the firm (unless it is discovered that multiple H1-B petitions are submitted for the same employee).[13] This reflects actual policy in which the filing fees is refunded back to firms for the workers that are not selected in the lottery, in the event that the cap for foreign skilled workers is binding. Firms also have to incur a sunk cost, $f_{R,t}$, for all foreign workers they apply for, which

[13]This includes various fees firms have to pay when filing the H1-B petition for each worker, which on average amount to $3,000.

reflects the regulatory component of the immigration policy cost — legal fees and other administrative costs involved in the various processes for hiring foreign skilled workers.[14] To facilitate comparison with the Social Planner's allocation, an additional cost that firms face is the technologically imposed cost of hiring skilled foreign workers, $f_{T,t}$, which is the same cost that a social planner would face for hiring a foreign worker. One way to interpret this cost would be to think of this as the cost incurred by firms on airfare or relocation of foreign workers, once they are hired and approved by immigration policy to join the firm. Therefore, these costs are only applicable to foreign workers that firms are actually able to bring to the firm after the approval of the application. All costs are in units of the consumption basket. If firm z optimally chooses to submit applications for $N_{e,t}(z)$ workers, then the total cost that the firm will incur is $f_{R,t}N_{e,t}(z)+(g_t+f_{T,t})N_{e,t}(z)q_t$, where q_t turns out to be the endogenous probability or fraction of workers that firms are allocated if the cap binds, and is described below. Higher immigration policy costs imply a more restrictive immigration policy.

The entry cap for foreign skilled workers is exogenously set at $\bar{N}_{e,t}$. Since each firm submits applications for $N_{e,t}(z)$ foreign skilled workers, the probability of each application being selected will be $q_t = min[\frac{\bar{N}_{e,t}}{(\int_{z_{min}}^{\infty} N_{e,t}(z)dG(z))}, 1]$, where $q_t < 1$ if the aggregate demand of foreign skilled workers, $\int_{z_{min}}^{\infty} N_{e,t}(z)dG(z)$, exceeds the cap, and the cap endogenously binds. Each firm knows that if it submits $N_{e,t}(z)$ applications, it will get $q_tN_{e,t}(z)$ workers. Each firm is of measure 0 and takes q_t as given in its hiring decision.[15]

The timing is as follows. A fraction δ of the foreign skilled workers currently employed by domestic firms (including newly hired workers from the previous period) are separated

[14]Firms in multiple surveys (for instance, by the Government Accountability Office (GAO)), document a range of direct and indirect costs associated with the H-1B program, including legal and administrative costs. Firms note that apart from the filing fees paid to the Department of Homeland Security, the main cost incurred is due to the opportunity cost of the time and effort spent in the process, which is captured by the regulatory component of the sunk cost, $f_{R,t}$, in the model.

[15]While no actual risk in the realization of the share of foreign workers allocated to firms may seem restrictive, it is consistent with how U.S. firms in the economy behave. To mitigate risk, U.S. firms subcontract a large part of the H1-B hiring process to large IT management firms. These firms substantially reduce the risk of procuring H-1B visas by applying in bulk. These outsourcing firms were awarded almost 20 percent of total H-1Bs in 2016, and the workers were then allocated to U.S. employers through subcontracting.

from firms at the beginning of the period. The state Z_t of the economy is realized, wages are determined, and firms produce period-t output. Firms then maximize expected discounted profits and optimally choose the number of foreign skilled workers to hire (or submit applications for), after taking into account the immigration policy restrictions. The realized state of the economy and the corresponding firm demand for foreign workers determine whether the cap binds, and an endogenously-determined fraction q_t of the applications are approved. These are the workers that firms are able to 'bring' to the firm for production. There is a time to build lag and those workers that survive the separation shock are added to the stock of next period's skilled labor stock.

Thus, the stock of foreign skilled labor at firm z in period $t+1$ is given by:

$$l^s_{f,t+1}(z) = (1-\delta)(l^s_{f,t}(z) + q_t N_{e,t}(z)) \tag{1.1}$$

Expressed in units of the consumption basket, the inter-temporal profit function of firm z is given by:

$$E_t \sum_{\tau=t}^{\infty} \beta_{\tau,t} \Big[\rho_{1,\tau}(z) Z_\tau z l_{s,\tau}(z) - w_{s,\tau}(l_{s,\tau}(z)_{-} f_{R,\tau} N_{e,\tau}(z) - (g_\tau + f_{T,\tau}) N_{e,\tau}(z) q_\tau \Big]$$

The inter-temporal discount factor that the firm applies to its profits is $\beta_{\tau,t} \equiv \beta(u'(C_{s,\tau})/u'(C_{s,t}))$, which is the inter-temporal discount factor of domestic skilled households, who are assumed to be domestic firm owners.

Optimal Hiring of Skilled Foreign Workers:

Firms maximize inter-temporal profits subject to (1.1). Each period, firms hire and submit applications for skilled foreign workers such that the expected discounted profit generated from an additional skilled foreign worker, v_t, is equal to the expected sunk hiring cost:

$$v_t = f_{R,t}/q_t + g_t + f_{T,t}$$

where

$$v_t = \sum_{\tau=t+1}^{\infty} E_t\{\beta_{\tau,t}(1-\delta)^{\tau-t}[\rho_{1,\tau}(z)Z_\tau z - w_{s,\tau}]\}$$

Hiring of foreign skilled workers can be viewed as an investment decision for firms that is governed by the following Euler equation:

$$f_{R,t}/q_t + g_t + f_{T,t} = (1-\delta)E_t\{\beta(C_{s,t+1}/C_{s,t})^{-1}[\rho_{1,t+1}(z)Z_{t+1}z - w_{s,t+1} + \frac{f_{R,t+1}}{q_{t+1}} + g_{t+1} + f_{T,t+1}]\} \quad (1.2)$$

where $w_{s,t}$ is the real wage paid to each skilled foreign worker. Labor markets are competitive and the real marginal cost of production for firm z is given by $\psi_{1,t} = \frac{w_{s,t}}{Z_t z}$. Thus differences in productivity across firms translate into different marginal costs, and firms with higher z have a lower marginal cost of production.

Firms serve only the domestic market. Market clearing for each firm z is given by $Z_t z l_{s,t}(z) = (\frac{\rho_{1,t}(z)}{\tilde{\rho}_{1,t}})^{-\theta} Y_t^c/\tilde{\rho}_{1,t}$, where the price $\rho_{1,t}(z)$ set by the firm is a proportional markup over the marginal cost: $\rho_{1,t}(z) = \frac{\theta}{\theta-1}\psi_{1,t}(z)$. The average sector 1 price, $\tilde{\rho}_{1,t}$, and aggregate demand, Y_t^c, are given in section on aggregate accounting. As is standard in the Melitz (2003) model, more productive firms face a higher demand for their output due to lower prices, and hence employ more skilled labor, including skilled foreign labor. Firm profits in period t are given by $d_t(z) = \rho_{1,t}(z)y_{1.t}(z)/\theta - f_{R,t}N_{e,t}(z) - (g_t + f_{T,t})q_t N_{e,t}(z)$.

Unskilled Sector (Sector 2)

Sector 2 output is produced by competitive firms that have an identical technology:

$$Y_{2,t} = Z_t l_{u,t}$$

where $l_{u,t}$ is the unskilled labor employed by the representative firm. The marginal cost of production for the firm is $w_{u,t}/Z_t$. Thus the price of the representative sector 2 good in units of the consumption basket is $\rho_{2,t} = w_{u,t}/Z_t$.

Government

The government collects revenue from immigration policy — the total revenue collected in units of the consumption basket is $R_t = g_t q_t \int_{z_{min}}^{\infty} N_{e,t}(z)dG(z)$. The revenue depends on the aggregate applications filed by all firms, and the cap, which affects q_t. The Government's budget constraint is given by $T_t = R_t$, where $T_t = T_{s,t} + T_{u,t}$ is lumpsum transfer to domestic households. I assume that $T_{s,t} = T_{u,t} = T_t/2$.

Aggregate Accounting and Equilibrium

The distribution of firm productivities is given by a Pareto distribution $G(z) = 1 - (\frac{z_{min}}{z})^k$, with lower bound z_{min} and shape parameter $k > \theta - 1$. As in Melitz (2003), aggregate productivity is defined as $\tilde{z} = [\int_{z_{min}}^{\infty} z^{\theta-1} dG(z)]^{\frac{1}{\theta-1}}$. From each firm's market clearing in sector 1, we can write the aggregate stock of foreign labor as a function of firm specific productivity i.e. $l_{s,t}(z) = f(z^{\theta-1})$. Thus, we can aggregate skilled labor as $\tilde{l}_{s,t} = l_{s,t}(\tilde{z}_t) = 1 + \tilde{l}^s_{f,t}$. The aggregate sector 1 output is $Y_{1,t} = Z_t \tilde{z}(1 + \tilde{l}^s_{f,t})$. The aggregate sector 1 price index is given by $\tilde{\rho}_{1,t} = \int_{z_{min}}^{\infty} (\rho_{1,t}(z))^{1-\theta} dG(z)\Big)^{\frac{1}{1-\theta}} = \rho_{1,t}(\tilde{z}_t)$.

Aggregate consumption by households is given by $C_{s,t} + C_{u,t} + C_{i,t}$ i.e. the sum of consumption by domestic skilled, unskilled, and immigrant workers residing at Home. Immigrants consume their labor income, $C_{i,t} = w_{s,t}\tilde{l}^s_{f,t}$. Domestic labor market clearing requires that the aggregate domestic labor employed is equal to the inelastic supply i.e. $\int_{z_{min}}^{\infty} l^s_{h,t}(z)dG(z) = 1$ and $l_{u,t} = \bar{l}_u$. Firm demand for skilled foreign workers is met at the prevailing skilled wages as foreign households are assumed to elastically meet all domestic firm demand.

Aggregate accounting in the economy requires that $\tilde{\rho}_{1,t} Z_t \tilde{z} \tilde{l}_{s,t} + \rho_{2,t} Z_t \bar{l}_u = C_{s,t} + C_{u,t} + C_{i,t} + f_{R,t}\tilde{N}_{e,t} + f_{T,t} q_t \tilde{N}_{e,t}$.[16]

Table 1.1 summarizes the key equilibrium conditions in the model. There are 17 equations in 17 endogenous variables of interest: $Y_{1,t}$, $Y_{2,t}$, $\tilde{l}^s_{f,t}$, $\tilde{N}_{e,t}$, q_t, $w_{u,t}$, $w_{s,t}$, d_t, $\tilde{\rho}_{1,t}$, $\rho_{2,t}$, $\psi_{1,t}$, $C_{u,t}$,

[16]As in Cacciatore (2012), aggregate demand (Y^c_t) includes a component other than household consumption. However, it is in the same units as the consumption basket.

$C_{s,t}$, Y_t^c, R_t, T_t, $C_{i,t}$. Z_t follows an exogenous AR[1] process in logs. f_R, g, f_T,and $\bar{N}_{e,t}$ are exogenously set and calibrated in Section 1.5.

1.4 The Steady State

I now turn to the consequences of skilled immigration and skilled immigration policy changes by studying how skilled immigration responds to a temporary productivity shock, as well as the transitional dynamics and the long-run effects of a permanent increase in the immigration cap. Before presenting these results, I discuss implications of some key steady-state relationships that highlight some of the main model mechanisms. The analytical solution for the steady state of the model is given in Appendix A.

Steady-state stock of foreign born

Since the model features an occasionally binding constraint, the model is equivalent to one with two regimes.[17] The constraint is binding under one regime and slack under the other and each regime has a separate non-stochastic steady state. In the appendix, I derive the steady-state stock of foreign-born labor in the regime when the cap does not bind ($q = 1$) as follows:

$$\tilde{l}_f^s = \frac{\alpha \tilde{z}^{\frac{\alpha}{(1-\alpha)}} \bar{l}_u}{(1-\alpha)} \left[\frac{(1-\delta)\beta Z}{\theta(f_R + f_T + g)(1-(1-\delta)\beta)} \right]^{\frac{1}{(1-\alpha)}} - 1 \qquad (1.3)$$

Equation (1.3) helps identify the factors that influence a larger firm demand for foreign skilled labor, and consequently a larger stock of foreign skilled workers. The model predicts that the stock of foreign skilled labor will be higher when a country has a higher aggregate labor productivity, Z; a higher aggregate firm specific productivity, $\tilde{z}$; the skill-intensive sector has a larger weight, α, in the consumption basket; the stock of domestic unskilled workers, $\bar{l}_u$, is higher (due to complementarities via the consumption basket); the hiring costs of foreign skilled workers (g, f_R, and f_T) are lower (less restrictive immigration policy); there is a lower probability of return, δ, to the country of origin; when elasticity of substitution across goods

[17] Guerrieri and Iacoviello (2015)

(θ) is lower (which increases firm profits from each unit produced); and when there is a lower stock of domestic skilled workers available.

Long run consumption: skilled native households

In this section I show how the stock of foreign-born workers affects firm profits and skilled wages. One of the key hurdles facing policy easing comes from critics of skilled immigration who highlight the adverse impacts of an increase in the supply of skilled immigrants on the wages and income of native skilled workers. In order to analyze this, I decompose the steady-state impact of an increase in the stock of skilled foreign labor on the various components of consumption of skilled domestic workers as below.

$$C_s = \underbrace{(\theta - 1) Z \tilde{z}^{\alpha} \left(\frac{\alpha \bar{l}_u}{(1-\alpha)(1+\tilde{l}_f^s)} \right)^{1-\alpha} / \theta}_{\text{Wage income of domestic skilled households}} \tag{1.4}$$

$$+ \underbrace{\left(\frac{\alpha \bar{l}_u}{1-\alpha} \right)^{1-\alpha} Z \tilde{z}^{\alpha} (1+\tilde{l}_f^s)^{\alpha} / \theta - (f_R + g + f_T) \delta \tilde{l}_f^s / (1-\delta)}_{\text{Firm Profits}} + \underbrace{g \delta \tilde{l}_f^s / (2(1-\delta))}_{\text{Transfers}} \tag{1.5}$$

In the model, an increase in skilled immigrant workers would reduce real wages (due to substitutabilities between domestic and foreign skilled workers) and thus have an adverse impact on long-run real consumption of domestic skilled workers (equation 1.4). However, an increase in skilled foreign immigrants also increases long-run output and firm profits. Even though a larger stock of foreign skilled workers implies larger hiring costs incurred by firms which would negatively affect their profit, as long as these costs are relatively low, firm profits would rise. If some of these profits are distributed back to skilled households as dividend (profit) income, this channel would mitigate some of the adverse effects on native skilled households' long-run real income and consumption (equation 1.5). Moreover, a larger foreign labor stock also ensures larger revenue collected as part of immigration policy. if some of the revenue from immigration policy is transferred back to skilled domestic households, then the adverse impact on wages due to an increase in foreign skilled workers can be further mitigated.

An important implication is that in order to carry out accurate welfare analysis of immigration policy changes, it is important to empirically estimate the profit distribution of firms across households. For instance, if part of the dividend income goes to immigrant workers (as part of stock options given to them), then the negative impact of immigration on domestic skilled workers would be worse.

Steady state when cap binds

In the alternate regime, when the entry constraint binds in steady state, the aggregate stock of foreign skilled workers is given by: $\tilde{l}_f^s = (1-\delta)\bar{N}_e/\delta$ (using (1.1) and $q\tilde{N}_e = \bar{N}_e$). In this case, the appendix shows that steady state hiring probability is given by:

$$q = f_R\left[\frac{(1-\delta)\beta(\alpha\delta\bar{l}_u)^{1-\alpha}Z\tilde{z}}{\theta(1-(1-\delta)\beta)((1-\alpha)\tilde{z}(\delta+(1-\delta)\bar{N}_e))^{1-\alpha}} - f_T - g\right]^{-1}$$

The probability of hiring each foreign skilled worker is higher when the demand for foreign skilled workers is lower, or when the entry cap $\bar{N}_e$ is lower. A larger cap makes it easier for firms to hire and get workers that they apply for. However, any of the factors that increase foreign skilled worker demand, reduce the probability of hiring such workers. The aggregate flow of foreign labor demanded is given by $\tilde{N}_e = \bar{N}_e/q$.

1.5 Calibration

In order to study the dynamics numerically, I calibrate the parameters of the model under the assumption that the steady state mimics the U.S. economy during the 2004 - 2014 period. I interpret each period as a year to accommodate the annual allocation of the H-1B visa cap. I calibrate the parameters that pertain to immigration to match average annual U.S. data from the Current Population Survey (CPS), and the United States Citizenship and Immigration Service (USCIS), between 2004 to 2014. I rely on existing literature for the values of the other parameters. I set $\beta = .96$, which implies an annual real interest of 4 percent. Following

Ghironi and Melitz (2004), I set the elasticity of substitution across product varieties equal to $\theta = 3.8$, the dispersion of firm productivity draws, $k = 3.4$, and normalize z_{min} to 1. I set the exogenous return shock to the country of origin at $\delta = 0.1$, in order to match the annual return migration rate of 10 percent (Center for Immigration Studies, 2011).[18]

The share of sector 1 goods in consumption is set at $\alpha = 0.4$ to match the share of unskilled income in total aggregate income.[19] The immigration cap $\bar{N}_e$ is set to 0.0022 in order to match the average cap imposed by actual policy (85,000) as a proportion of the normalized average domestic skilled labor in the economy. I calibrate the filing fees paid to the government g to 0.0519, to match the average filing fees incurred while submitting the H1-B petition as a proportion of annual skilled wages over the same period.[20] The sunk regulatory cost f_R is set to 0.8 to target the average petitions filed during the period which would generate a steady-state application selection probability of about 0.4. The domestic unskilled labor supply is calibrated to 1.84 (given the normalization of domestic skilled labor supply to 1) to match the share of domestic workers in the U.S. with less than a bachelor's degree of 34 percent. I set the technological part of the hiring cost at 0.0833 to target one month's real wage in the data.[21] These sunk hiring costs are assumed to stay fixed in the baseline setup.

Given that the model is calibrated to a period when the cap is binding, the model economy is in a binding steady-state regime.

---

[18] In reality, H1-B visas are allocated for a period of three years, and can be extended for another three years. However a sizeable proportion of H1-B workers stay for longer as firms sponsor their green card application. There is no concrete estimate of this proportion. Moreover some workers may end up leaving before the visa expires. Thus I take an annual average rate of return to the country of origin.

[19] This follows from sector two's good market clearing: $Z\bar{l}_u = (1-\alpha)Y^c/\rho_2$, which implies that $w_u\bar{l}_u/Y^c = (1-\alpha)$.

[20] The average filing fees at the time of submitting the petitions adds up to about $3, 000.

[21] While there is no direct estimate of this cost in the data, a month's wage is a reasonable estimate of the relocation and other expenses that are meant to capture this cost.

1.6 Transition Dynamics and Welfare Results in the Baseline Model

In this section, I solve the calibrated model numerically to study dynamics in response to a temporary positive productivity shock and changes in immigration policy. I then calculate the welfare effects of a perfect foresight increase in the immigration policy cap. I also show how these welfare impacts vary with the state of the economy and with the structure of the labor market. All the welfare experiments in the paper are summarized in Table 1.2.

1.6.1 Dynamic Response to a Temporary Productivity Increase

I study the responses (percent deviation from the steady state) to a temporary 1 percent increase in aggregate productivity (Z_t) in the baseline model. In order to analyze the impact of the cap on the economy's dynamic responses to a productivity shock, I compare two cases. In case 1 (the benchmark case), there is a policy-imposed entry cap on foreign skilled workers in the economy. In case 2, there is no entry cap.

Figure 1.3 shows that in the presence of an entry cap, the increase in firm demand for foreign skilled workers in response to the productivity increase is less than half, when compared to case without the cap. This is because firms have to pay the sunk cost f_R for hiring workers that may not eventually be able to join the firm due to the binding cap, and thus would not contribute to firms' output and profit. In other words, to hire one worker, the firm needs to pay for f_R/q_t workers. Therefore, costs associated with the current immigration policy may distort firms' incentives for hiring foreign skilled workers. An implication of this is that the costs incurred due to the burdensome current immigration policy may lead to an inaccurate signal of firm demand for foreign workers.

Figure 1.3 also shows that the stock of skilled labor is inelastic in the short run and rises only slowly due to the time-to-build lag. In the presence of the cap, the stock of foreign skilled labor rises by much less. As a result, the increase in output, profits, and real wages of unskilled workers (and thus their consumption) is smaller in the presence of the cap. Without the entry cap, firm profits initially fall more as more resources are spent on hiring. However, this quickly recovers as the stock of foreign skilled workers increases over time and firms are able to produce more output. Unskilled wages are higher without the cap as a larger stock of foreign workers increases demand for goods produced in sector 2, which increases demand for unskilled labor and puts an upward pressure on their wages.[22] However, the real wage of skilled labor falls by less in the presence of the entry cap due to the smaller increase in the stock of skilled labor in the domestic economy. Despite a lower decrease in wages of skilled workers, their consumption is not higher in the presence of an entry cap during most of the transition period as the increase in firm profits is also lower in this case. However, an alternate distribution of firm profits could lead to an unambiguously lower consumption of domestic skilled workers. Overall, the presence of the constraint dampens the economy's response to aggregate shocks.

1.6.2 Welfare Analysis

The above dynamic responses indicate that an increase in skilled foreign labor has different impacts on heterogeneous workers. In order to draw inferences about the impact of current migration policy changes, it is important to quantify the welfare changes across different sets of workers. I calculate welfare impacts after a 10 percent perfect foresight increase in the entry cap. The long-run welfare gain of each type of native worker from the immigration policy easing is computed as the percentage increase (Δ) in consumption that would leave the households indifferent between the initial policy and the new policy with the higher cap, when the new policy is implemented at time $t = 0$. Transitional dynamics have been included in the welfare computations. Thus, Δ solves:

$$u\left[C_j(1 + \frac{\Delta}{100})\right] = (1 - \beta)\sum_{t=0}^{\infty} \beta^t u(C_{j,t}) \quad \forall\{j \in s, u\}$$

Suppose the cap increases by 10 percent. Since the baseline model is calibrated to a period when the cap is 'very' binding in the sense that the gap between firm demand for

[22] This is consistent with empirical evidence in Hong and McLaren (2015).

foreign labor and the cap is very large, firms increase hiring by the full 10 percent. The dynamics following this cap change are given in Figure 1.4. Firms increase hiring of foreign skilled labor following the cap increase and as the stock of skilled workers builds up, sector 1 output, unskilled wages, and consumption rise. As before, the increase in unskilled wages and therefore consumption is due to the higher demand for sector 2 output by the larger stock of skilled foreign labor. Average firm profits in sector 1 fall initially as they have to bear costs of hiring more foreign workers (the cost of hiring foreign skilled workers remains unchanged). However, profits recover over time as output increases. Skilled wages fall due to the larger inflow of foreign workers. The net effect on real consumption of domestic skilled workers is negative, despite their profit income increasing. The probability of hiring a foreign worker is higher in the new steady state due to the higher cap.

Table 1.2 shows that the welfare gain (including transitional dynamics) amount to 0.0558 percent of annualized steady-state consumption for unskilled workers. For skilled domestic workers, the welfare loss amounts to 0.0603 percent of annualized steady-state consumption. Thus, there are different effects of a skilled immigration policy change on heterogeneous workers — workers most complimentary to skilled immigrants gain, while those most substitutable lose. Part of the negative impact on consumption of skilled workers is mitigated as firm profits, and transfers from the government rise over time. The transitional dynamics in Figure 4 show that most of the welfare changes are realized slowly over the longer horizon.

I next turn to analyzing how these welfare effects depend on the state of the economy. In section 1.9, I evaluate how these welfare effects depend on the structure of the labor market by adding search and matching frictions in the baseline model.

1.6.3 Welfare Impacts and the State of the Economy

An important insight from explicitly taking into account the role for firm demand in endogenous skilled immigration is that the demand of foreign labor depends on the realized state Z_t of the economy. Therefore, welfare impacts of an immigration cap change will depend on how firms adjust their hiring in response to the change, which in turn depends on the realized state of the economy. For instance, when the H1-B cap was raised by 80,000 workers in 2001, after it had been binding for the previous three years, the cap did not bind between 2001-2003 (the period for which the cap was raised), as firms did not increase hiring by the full amount of the cap increase. Since the stock of foreign workers rose by less than anticipated, evaluating the impact of the policy change as a labor supply increase (increase in 80,000 workers), would be misleading.

In the context of the model, suppose the immigration cap change is implemented at a time when the economy is transitioning after a negative productivity shock, and the cap is relatively 'less binding' in the sense that the gap between firm demand and the cap is relatively small. Following the cap change, firms will optimally hire more foreign skilled labor, yet they may not increase hiring by the full cap increase. To see this, I calibrate the baseline model to match U.S. labor and immigration data between 2001-2003. In 2001, the cap was raised from 115,000 to 195,000, a 69.5 percent increase. At that point, the economy entered a recessionary phase, and firms did not increase their hiring of foreign workers by 69.5 percent. In fact, the unused cap in 2001, 2002, and 2003, was 31,400, 115,900, and 117,000, respectively.[23] The average additional cap used over the entire period was about 20 percent. I calibrate the model such that the cap change is implemented at a time when the economy is transitioning from a negative productivity shock. The negative shock is calibrated to match the fact that on average, firms increased there hiring of foreign labor by 20 percent due to the additional quota of 69.5 percent.

Figure 1.5 plots the transitional dynamics in response to a 69.5 percent cap change under two cases. The first is the one described above when the economy is transitioning after a negative productivity shock and is called the 'less binding case'. In the second case, the state of the economy is such that the economy is not transitioning after a negative productivity shock and the immigration cap is 'more binding' for firms. This case can be interpreted as the case when a cap change of 69.5 percent would lead to a pure skilled labor supply

[23]Using USCIS historical data.

increase of 69.5 percent because firms increase hiring by the full amount of the cap increase. Therefore, while in the first case, firms increase their hiring of foreign workers by only about 20 percent, in the second case, firms increase the hiring of foreign workers by the full amount of the cap change. Consequently, the stock of foreign skilled labor increases by much less in the first case and the impacts on all endogenous variables are smaller in the 'less binding' case compared to the 'more binding' case. The welfare impacts on both skilled and unskilled workers are also therefore dampened (Table 1.2). The welfare impact in the first case is about one-sixth of that in the second case, for both workers.

Thus the welfare impact would be lower than the welfare impact that would have been evaluated by considering the policy change without taking into account firm hiring responses. The key point is that it may be important to take into account the role of firm demand for foreign skilled workers, and also the timing of the reform, when evaluating the impact of immigration policy changes.

1.7 Social Planner's Solution and Inefficiency Wedges

In this section, I discuss the first-best, efficient allocation chosen by a social planner. I then compare the equilibrium conditions in the baseline decentralized economy (Table 1.1) to those implied by the planner's solution (Table 1.3) as this allows us to identify the distortions in the model economy and to define the inefficiency wedges relative to the efficient allocation. The aim is to analyze whether moving toward an alternate policy with a market-driven allocation of permits (Section 1.8) would close some of the inefficiency wedges and bring the market economy closer to the optimal allocation.

Appendix A presents the planner's problem and the equilibrium conditions implied by the solution to the problem. The social planner maximizes welfare of domestic households and chooses the optimal entry of foreign skilled workers in the domestic labor force, taking the firm size distribution, preferences, technology, and resources available in the economy as given. The only hiring cost that is relevant to the social planner is the technological component of the overall entry cost, f_T. Therefore, in the planner's environment, $g = f_R = 0$.

The appendix also describes the major distortions and derives the inefficiency wedges in the economy. The analysis shows that the market economy features three sources of distortions relative to the planned economy. These distortions lead to two margins of inefficiency wedges that are discussed below.

Job creation margin: Comparing the entry condition of foreign skilled workers under the decentralized solution with the entry condition under the social planner's equilibrium implicitly defines the inefficiency wedge under the market economy's job creation margin for foreign skilled workers.

The inefficiency along the job creation margin results in the wedge $\Sigma_{jc,t}$ given by:

$$\Sigma_{jc,t} = E_t\left[B_{t,t+1}(1-\delta)\left(\tilde{\rho}_{1,t+1}Z_{t+1}\tilde{z}\frac{(\Upsilon_{R,t}+f_T\Upsilon_\theta)}{f_T(\Upsilon_{R,t}+f_T)}+\frac{\Upsilon_{R,t}-\Upsilon_{R,t+1}}{\Upsilon_{R,t}+f_T}\right)\right]$$

First, monopoly power leads to a lower incentive for hiring foreign skilled workers by inducing a lower marginal revenue product of a match (captured by Υ_θ). Second, the presence of immigration policy costs (f_R and g) that differ from the technological component of the hiring cost (f_T) leads to another source of distortion in the market economy. Third, the presence of a binding cap further distorts the costs that firms have to incur. The additional distortion that the cap imposes is due to the fact that when the cap binds and $q_t < 1$ in the decentralized economy, in order to hire one worker, firms need to submit $1/q_t$ applications and hence incur f_R/q_t as regulatory costs. As described in the Appendix, $\Upsilon_{R,t} = f_R + g + \frac{f_R\Upsilon_{q,t}}{1+\Upsilon_{q,t}}$, where $\Upsilon_{q,t} = 1 - q_t$ is the distortion due to the presence of the cap that lowers the probability of being able to hire a foreign worker to less than 1 . Thus, $\Upsilon_{R,t}$ decomposes the distortions in the existing immigration policy into distortions imposed due to immigration policy costs and those due to the cap. In the baseline calibration, around 60 percent of this distortion is due to the presence of a binding cap and 40 percent is due to the costs. If $f_R + g = \Upsilon_{q,t} = \Upsilon_\theta = 0$, then the job creation wedge is equal to 0.

Consumption resource constraint wedge: Sunk regulatory costs imply a diversion of resources from consumption, leading to a consumption-output efficiency wedge given by $\Sigma_{r,t} = \Upsilon_R\tilde{N}_{e,t} - f_T\tilde{N}_{e,t}\Upsilon_{q,t}$. Because of the various procedures involved in the current immigration policy, firms have to incur extra regulatory costs. However, firms have to incur lower technological hiring costs because these are applicable only to workers that firms are able to bring to the firm and the presence of the cap leads to a lower number of such workers in the decentralized economy.

In the baseline calibration, the job creation wedge is 13.1348 and the consumption resource wedge is 0.0045, both in units of the consumption basket. Therefore, the job creation inefficiency wedge contributes to the bulk of the inefficiency in the baseline market economy.

1.8 Market-Driven Allocation of Permits

In this section, I address the following question — what would be the impact of moving toward a market-driven allocation of visas (via auction of a fixed number of permits) for skilled foreign workers, compared to the baseline model with the current skilled immigration policy setup? In particular, would such a policy increase economic welfare and bring the economy's equilibrium closer to the social planner's first-best allocation?

The motivation for the market-driven allocation of permits stems from the advantages of this alternate skilled immigration policy highlighted in Peri (2012).[24] The main idea is that introducing a market-driven system of allocating permits to firms who hire immigrants would introduce a price mechanism to allocate visas efficiently and according to their most productive use. Importantly, the price of permits would be determined by the auction and would quantify the value attributed by the U.S. market to a foreign skilled worker. According to the proposal, the market-driven price of permits would also provide potential flexibility across the business cycle via price feedback and these prices could be a potential signal for raising/lowering total number of permits. For instance, if the price of the permit rises during expansionary times, it would signal a true shortage in the number of permits relative to firm demand for foreign skilled labor. This may be relevant for policy makers as the costs under the current immigration policy setup may distort firm demand of foreign

[24] Peri (2012) focuses on reform of all immigration policies rather than only on skilled immigration policy.

skilled labor, and thus do not always give a true indication of firm demand. Moreover, such a mechanism may generate additional income for the government, which could help compensate domestic households. The key idea in Peri's proposal is that "a simpler, more flexible, and more market-driven system of labor-sponsored permits for immigrants would enhance the economic benefits of employment-based visas".

1.8.1 Model with Market-Driven Allocation of Permits

The preferences, technology, and the economic setup are exactly the same as in the baseline model (Section 1.3). The main difference is that the immigration policy-imposed cost of hiring skilled foreign workers will vary with economic conditions via the optimally varying price of permits. Also, there is no lottery and hence firms get allocated their optimal demand of permits at the market clearing price of permits.

I evaluate the impact of moving from the baseline skilled immigration policy toward an alternate market-driven policy, in a simple framework with no informational asymmetries, and one in which firms bid for permits according to their demand schedule. I initially set the number of permits to be allocated to be the same as the cap imposed under the baseline policy.[25] The timing is as follows: the state of the economy is realized and a fraction δ of foreign skilled workers separate from the domestic labor market. Wages are determined competitively, and firms produce period-t output. The Government announces the period t auction of a fixed mass of permits — each permit would allow firms in Sector 1 to hire a foreign skilled worker that will become productive in period $t+1$. Each firm submits a schedule of permit prices for varying quantities of permits. Since there are no informational asymmetries across firms, they have an incentive to submit no other price and quantity bid other than according to their demand schedule. The government evaluates the permit price at which the total number requested by firms matches the total supply of permits.

[25]According to Peri (2012), permits for the H-1B category (as well as the L-1A, L-1B (intra-company transfers) and TN visas (professionals from NAFTA), all included as one category) should be sold in a quarterly electronic auction and the number of permits could initially be set equal to the number of annual average temporary visas issued over the past ten years.

Firms then pay the government the market clearing price of permits and receive the permits. The government collects the revenue and rebates it back to skilled and unskilled domestic households in a lump-sum and symmetric manner. Firms then hire foreign skilled workers according to the number of permits they hold and also incur the technological hiring costs. There are no secondary market sales for permits.

The optimization problem of firm z for deriving its demand schedule of permits as a function of price of permits is given below. In this derivation, the assumption is that firms anticipate that the number of workers they hire will be equal to the number of permits they own, and they choose their permit demand accordingly.

$$\max_{N^p_{e,t}(z)} E_t \sum_{\tau=t}^{\infty} \beta_{\tau,t} \Big[\rho_\tau(z) Z_\tau z l_{s,\tau}(z) - w_{s,\tau} l_{s,\tau}(z) - \zeta^p_\tau N^p_{e,\tau}(z) - f_T N^p_{e,\tau}(z) \Big]$$

subject to

1. $l_{s,t}(z) = l^s_{h,t}(z) + l^s_{f,t}(z)$

2. $l^s_{f,t+1}(z) = (1-\delta)(l^s_{f,t}(z) + N^p_{e,t}(z))$

The equilibrium condition for the optimal permit demand is given by:

$$\zeta^p_t + f_T = (1-\delta) E_t \{ \beta (C_{s,t+1}/C_{s,t})^{-1} [\rho_{1,t+1}(z) Z_{t+1} z - w_{s,t+1} + \zeta^p_{t+1} + f_T] \} \tag{1.6}$$

Goods market clearing in each period t for each firm is given by $Z_t z l_{s,t}(z) = (\frac{\rho_{1,t}(z)}{\tilde{\rho}_{1,t}})^{-\theta} Y^c_t / \tilde{\rho_{1,t}}$, where Y^c_t is the aggregate demand.
Since wages, and therefore prices in period $t+1$ will be a function of permits held in period t (which determines the foreign labor stock and hence firm output in $t+1$), (1.6) determines the demand schedule for permits. To get the market clearing permit price, the demand schedules of all firms can be aggregated to obtain the following.[26]

$$\zeta^p_t + f_T = (1-\delta) E_t \{ \beta (C_{s,t+1}/C_{s,t})^{-1} [\tilde{\rho}_{1,t+1}(z) Z_{t+1} \tilde{z} - w_{s,t+1} + \zeta^p_{t+1} + f_T] \} \tag{1.7}$$

[26]The tilde variables denote aggregates across firms. Aggregation in this model is similar to the baseline model.

The equilibrium market-clearing permit price that firms pay is such that the aggregate demand for permits is equal to the aggregate supply i.e. $\tilde{N}^p_{e,t} = \bar{N}_e$, where $\bar{N}_e$ is the exogenous number of permits allocated by the government. In Appendix G, I derive the steady-state demand schedule and the equilibrium price of permits. Figure 1.6 plots the steady-state aggregate demand schedule of permits and the equilibrium in the permit market. An increase in aggregate productivity Z raises demand by all firms and therefore shifts the aggregate demand schedule to the right. Given an exogenously fixed number of permits, this raises the equilibrium permit price paid by each firm to the government.

For a given price of permits, the permit demand of each firm (and hence for the economy as a whole) is increasing in productivity, unskilled labor available in the economy, the share of the sector 1 good in consumption, and decreasing in δ (which is a rough measure of how long each permit is allowed to be valid)[27], θ (as this influences profit from hiring each foreign skilled worker), and in the availability of domestic skilled workers.

Moreover, since the permit price is endogenous, an increase in the permit price decreases the optimal demand of permits by each firm, and hence for the economy as a whole. Any factor that increases the demand for permits, including aggregate productivity in the economy, would increase the market clearing price of permits, for a given supply. Thus, as economic conditions vary, the market-clearing price of permits would adjust to reflect varying firm demand of foreign skilled labor.

The rest of the equilibrium conditions are similar to the baseline model. Aggregate accounting requires $\tilde{\rho}_{1,t} Z_t \tilde{z} \tilde{l}_{s,t} + \rho_{2,t} Z_t \bar{l}_u = C_{s,t} + C_{i,t} + C_{u,t} + f_T \bar{N}_e$. Consumption of skilled domestic households is given by $C_{s,t} = w_{s,t} + \tilde{d}_t + T_t/2$, where T_t is the government transfer, which is now equal to $\bar{N}_e \bar{\zeta}^p_t$ (the new revenue from immigration policy). Unskilled domestic households are assumed to receive the rest of the transfers, and immigrants consume their labor income, as before. Average firm profits are given by $\tilde{d}_t = \tilde{\rho}_{1,t} \tilde{y}_{1,t}/\theta - \zeta^p \bar{N}_{e,t} - f_T \bar{N}_{e,t}$.

[27]I take δ to be the same as in the baseline model even though the interpretation is different. If each permit is allowed to be valid for the same time as current skilled immigration visas, than the rate at which foreign skilled workers leave the firm would roughly be the same as the rate at which each permit lasts for the firm.

1.8.2 Welfare Implications of Moving Toward the Market-Driven Allocation of Permits

In this section, I describe the welfare implications for each domestic household, including transitional dynamics, of a perfect foresight change in policy from the current immigration policy setup, toward the market-driven allocation of permits. In order to measure the welfare change, I calibrate the model with the alternate immigration policy by setting the sunk regulatory costs f_R and application costs g to zero. The rest of the calibration is the same as in the baseline case. The equilibrium permit price is determined endogenously.

The welfare change is measured as the percentage change (Δ) in consumption that would leave the household indifferent between the baseline skilled immigration policy and the policy with the market-driven allocation of permits for hiring skilled foreign workers:

$$u\Big[C_i(1+\frac{\Delta_j}{100})\Big] = (1-\beta)\sum_{t=0}^{\infty}\beta^t u(C_{j,t}) \quad \forall\{j \in s,u\}$$

The first impact of the policy change is that government revenue increases by 35.6 percent. This is because the market clearing permit price $\bar{\zeta}_t^p$ that is collected by the government for each of the $\bar{N}_e$ permits is higher than the arbitrarily set application cost g. Since the cap is the same, the revenue collected under this alternate policy will always be higher than the revenue collected under the baseline skilled immigration policy. If this revenue is rebated back to domestic households in a symmetric manner, both households witness a welfare gain as a result of the policy implementation. The welfare gain amounts to 0.1803 percent of annualized steady-state consumption for unskilled workers. For skilled workers, the welfare gain amounts to 0.1770 percent of annualized steady-state consumption.

I next turn to analyzing the inefficiency wedges that would exist in this alternate framework. Since this is a second-best policy relative to the social planner's optimal solution, inefficiency wedges would still exist in this framework. However, since there are welfare gains, this alternate policy would bring the market economy's allocation closer to the social planner's allocation. The inefficiency wedges help identify the mechanisms involved.

In this alternate framework, $\Upsilon_{R,t} = 0$ as this distortion was associated with the baseline immigration policy. However, there is a new distortion associated with the alternate market-driven system – the equilibrium permit price differs from the technological hiring cost in the social planner's framework. This distortion is $\Upsilon_{\zeta,t} = \bar{\zeta}^p$. The new job creation wedge, as derived in the appendix, can be expressed as:

$$\Sigma_{jp,t} = E_t\left[B_{t,t+1}(1-\delta)\left(\rho_{1,t+1}Z_{t+1}\tilde{z}\frac{(\Upsilon_{\zeta^p,t} + f_T\Upsilon_\theta)}{f_T(\Upsilon_{\zeta^p,t} + f_T)} + \frac{\Upsilon_{\zeta^p,t} - \Upsilon_{\zeta^p,t+1}}{\Upsilon_{\zeta^p,t} + f_T}\right)\right] \tag{1.8}$$

If $\Upsilon_{\zeta^p,t} = \Upsilon_\theta = 0$, then the job creation wedge is equal to 0. The resource constraint wedge in this alternate policy is 0 as the only sunk hiring cost that is not rebated back to households is the technological component of the hiring cost, which is also the case under the social planner's problem. Thus the alternate policy closes the consumption resource constraint wedge.

As for the job creation wedge, on comparing the optimal hiring condition in the baseline case with the optimal permit demand under the alternate policy (equation 7), we see that as long as prices, wages, and the technological hiring costs under the two cases are the same, then it must be that $f_R/q_t + g = \bar{\zeta}_t^p$ i.e. $\Upsilon_{R,t} = \Upsilon_{\zeta^p,t}$. Prices and wages in this case depend only on the state variables in the economy i.e. on the realization of aggregate productivity Z_t and on the stock of foreign skilled labor $\tilde{l}_{f,t}^s$. Since the cap under the two policies is the same, the entry and stock of foreign labor is the same in both cases and therefore prices (and wages) in sector 1 are also the same.[28] In this case, the job creation wedges under the two policies are the same i.e. $\Sigma_{jc,t} = \Sigma_{jp,t}$. Therefore, the mechanism through which this alternate policy increases welfare and brings the market economy closer to the planner's allocation is by closing the consumption resource constraint wedge.

In the current framework, closing the job creation wedge, which is the larger of the two inefficiency wedges in the decentralized economy, requires policy makers to increase the cap. However, even in the absence of a cap increase, easing some of the burdensome immigration policy procedures, and moving towards a simpler market-driven mechanism could potentially bring the market economy's allocation closer to the social planner's allocation. An implica-

[28] When the cap does not bind in the baseline model, entry will be lower than the cap. However, in this case, even the optimal permit demand will be lower.

tion of this is that the recent political discussions on tightening the procedures related to skilled immigration policy in the U.S. would have the opposite impact of widening the gap between the market economy's allocation and the social planner's optimal allocation and therefore would increase inefficiency in the economy.

1.9 Model Extension: Search and Matching Framework

In the baseline model, there is no unemployment of domestic skilled workers. Yet, one of the political arguments against increasing skilled immigration is the displacement effect of immigrants on domestic workers. Another argument against immigration is that foreign workers are paid lower wages compared to domestic workers. In this section, I extend the model to include search and matching frictions and non-competitive wage-setting, as such a setup can potentially account for these features. I then re-evaluate the welfare impacts of an immigration cap change.

In the framework with search frictions, firms in the skill-intensive sector now post vacancies and they can be matched with either a skilled foreign worker or to a a skilled domestic worker. While posting vacancies, firms cannot differentiate between domestic and foreign workers.[29] The probability of getting matched to a domestic or foreign worker depends on the relative fraction of each type of worker searching for jobs. However, there is still a policy-imposed cap and additional costs of hiring foreign workers. For each foreign worker that is matched, firms have to pay immigration policy and technological hiring costs as in the baseline model. Also, if the aggregate number of matches with foreign workers (which is now the aggregate demand for foreign workers) exceeds the cap, there is a probability that each application will be selected, similar to before.

Search and Matching in the skill-intensive sector

[29] This is realistic as firms cannot legally differentiate between the two worker types in their job postings. This also follows Chassamboulli and Palivos (2014), Battisti et al. (2014), Kingi (2015), in which domestic and immigrant workers are ex ante identical from a firm's perspective but may have different outcomes depending on their bargaining power, outside options, and separation rate.

Suppose firm z posts $v_t(z)$ vacancies for skilled workers in period t. The cost of posting a vacancy is κ. Given a standard constant returns to scale matching technology with unemployment elasticity ϵ and matching efficiency χ, the probability that the firm will be matched with a skilled worker (domestic or foreign) is given by $\mu_t = \chi(\frac{V_t}{U_t})^{-\epsilon}$, where V_t denotes the aggregate vacancies posted, and $U_t = U_{d,t} + U_{f,t}$ is the aggregate mass of domestic and foreign skilled workers searching for a job. Since the H1-B policy in the U.S. does not allow foreign workers to remain in the U.S. for an extended period if they are unemployed, I interpret $U_{f,t}$ not necessarily as the unemployment of foreign skilled workers in the domestic economy, but instead as the aggregate number of foreign skilled workers who are seeking a job in the domestic labor market, and can be located either in the domestic economy, or abroad.

The market tightness is given by $\frac{V_t}{U_t}$. The probability that the firm is matched to worker type $j \in \{d, f\}$ is $q_{j,t} = \frac{U_{j,t}}{U_{d,t}+U_{f,t}} \chi(\frac{V_t}{U_t})^{-\epsilon}$, where d and f denote domestic and foreign respectively, and $\frac{U_{j,t}}{U_{d,t}+U_{f,t}}$ is the relative share of job searchers of each type. Note that $q_{d,t} + q_{f,t} = \mu_t$. However, firms that match with foreign workers have to pay an additional sunk cost for each foreign worker they apply for, f_R, as well application costs g and technological hiring costs f_T, for foreign workers that they are eventually able to bring to the firm.

The second immigration policy restriction, as before, is the cap on the total number of foreign workers that can be hired each period, $\bar{N}_{e,t}$. Let $N_{e,t}(z) = q_{f,t} v_t(z)$ be the demand of foreign workers (determined by the number of foreign matches) at firm z. Then, the firm will apply for these workers to join the firm and the probability that each foreign worker that was matched would eventually be able to join the firm is $q_t = min[\frac{\bar{N}_{e,t}}{(\int_{z_{min}}^{\infty} N_{e,t}(z) dG(z))}, 1]$, which is endogenously determined. Therefore, if the flow of matches for foreign workers is $q_{f,t} v_t(z)$, the mass of foreign workers that eventually join firm z is $q_t q_{f,t} v_t(z)$. Each firm is of measure 0 and takes q_t as given when making its vacancy decision.

The exogenous separation rate for domestic workers is δ_d, and that of foreign workers is δ_f. As a significant proportion of foreign workers are likely to be temporary workers due to the nature of immigration policy, one can postulate that $\delta_f > \delta_d$ (Battisti et al., 2014). Workers hired this period join the firm in the next period and the separation shock is realized at the beginning of every period. Thus the stock of employed domestic workers at firm z is given by $l_{d,t}(z) = (1 - \delta_d)(l_{d,t-1}(z) + q_{d,t-1}v_{t-1}(z))$, and the stock of employed foreign workers is $l_{f,t}(z) = (1 - \delta_f)(l_{f,t-1}(z) + q_{t-1}q_{f,t-1}v_{t-1}(z))$. The timing is as follows — in each period, first the separations are realized, the aggregate productivity shock is realized, wages are negotiated by a surplus-sharing rule, and firms produce period-t output. Firms then post vacancies and workers are matched. For foreign matches, firms pay the immigration policy costs and submit applications for the workers to join the firm. If the cap binds, only a fraction q_t of the foreign matches are allocated to the firms. Finally, firms pay the technological cost f_T for the workers who are able to join the firm.

There are three households - skilled domestic, unskilled domestic, and skilled foreign. Each household consists of a continuum of workers and the measure of workers that are employed in Sector 1 is determined by the matching process. Let the total measure of domestic skilled workers in the labor force be $\bar{L}_d$ and that of foreign be $\bar{L}_f$ (both fixed to begin with). Then $U_{d,t} = \bar{L}_d - L_{d,t}$ and $U_{f,t} = \bar{L}_f - L_{f,t}$ are the domestic and foreign unemployed/job searchers in each period. $L_{d,t}$ and $L_{f,t}$ are the aggregate domestic and foreign workers that are employed, respectively. Employed and unemployed households of each type pool labor income, as is standard. Thus, the budget constraints are similar to the simple model except that now labor income is earned only by the measure of employed households of each type. Household preferences and optimal consumption choices are exactly the same as in the simple version of the model.

I present details of the optimization problem, the equilibrium conditions, and the wage setting in the Appendix.

The first order condition from firms' optimization problem shows that in equilibrium, the cost of posting a vacancy is equal to the expected discounted surplus from a domestic match plus the expected discounted surplus from a foreign match, both weighed by the probability of each match, net of sunk hiring costs for foreign matches. The surplus from each match is just the additional value generated from a skilled labor net of the real wage paid, plus the continuation value of the match.

From the wage setting equations derived in the appendix, we see that since domestic and foreign workers are perfect substitutes and contribute equally to production, any differences in wages between the two skilled workers has to be because of potential differences in the bargaining power or outside options of the two workers. Evidence shows that immigrants and domestic workers differ according to their outside options (Chassamboulli and Palivos, 2014), and in their separation rates (Battisti et al., 2014).

Welfare Impact of an Immigration Policy Cap Change in the Search and Matching Framework:

In order to get some intuition regarding how an immigration cap change would impact employment of domestic skilled workers and therefore their welfare in this framework, in the appendix, I derive the steady-state relationship between domestic skilled labor employed by firms, L_d, and the immigration policy cap, $\bar{N}_e$ as:

$$L_d = \bar{L}_d \left(\frac{\bar{L}_f \delta_d}{(1-\delta_d)\bar{N}_e} - \frac{\delta_d(1-\delta_f)}{\delta_f(1-\delta_d)} \right) + 1 \Big)^{-1}$$

The equation above shows that as the cap on foreign skilled workers increases, long-run aggregate domestic workers employed, L_d, increases, for a given mass of aggregate domestic and foreign labor in the labor force (i.e. for a given $\bar{L}_d$ and $\bar{L}_f$). Intuitively, the increase in the entry cap increases firms' incentive to post more vacancies as there is a higher probability that a foreign worker that was matched with the firm would eventually be able to join the firm. Another way to see this is from the vacancy posting condition derived in the appendix:

$$\kappa = (1-\delta_d)E_t[B_{t,t+1}\Gamma_{zd,t+1}]q_{d,t} + (1-\delta_f)E_t[B_{t,t+1}\Gamma_{zf,t+1}]q_{f,t}q_t - f_R q_{f,t} - q_{f,t}q_t(f_T + g)$$

Part of the expected benefit from posting a vacancy for firm z is the surplus from a foreign match ($\Gamma_{zf,t}$), as with probability $q_{f,t}$, a firm may be matched with a foreign worker. However, because of the cap on foreign workers, the firm will only be able to retain a fraction q_t of its foreign matches. When the cap increases, the probability of being able to bring the worker to the firm increases as q_t is a positive function of the cap. This increases firms' expected discounted benefit from posting a vacancy and firms end up posting more vacancies. More vacancies posted increases firm matches with domestic skilled workers as well, and therefore, their employment. This effect is captured in Figure 1.7, which plots the transitional dynamics following a 10 percent perfect foresight cap increase in the search and matching framework.

In order to numerically compute the transitional dynamics following a 10 percent cap increase, I calibrate the main parameters of the model using data from the Bureau of Labor Statistics and the Current Population Survey between 2004 - 2014. I choose the matching elasticity ϵ as 0.4 as is standard in the literature (Blanchard and Diamond (1989)), and the bargaining power of both workers, $\eta_d = \eta_f = 0.4$, as the same as ϵ so that the Hosios condition holds. Vacancy posting costs κ are normalized to 1. I normalize the aggregate domestic skilled workers in the labor force ($\bar{L}_d$) to 1 and I calibrate the mass of skilled foreign workers in the labor force ($\bar{L}_f$) to 0.2 in order to match the average ratio of skilled foreign workers to skilled domestic workers in the U.S. labor force. In order to facilitate comparison between the baseline model with no search frictions and this extended model, I take the immigration policy-imposed costs and exogenous return of foreign skilled workers to be the same as in the baseline model. The exogenous separation of domestic skilled workers is set to 0.07 to match the average annual unemployment rate of domestic skilled workers in the U.S. Therefore, foreign skilled workers face a higher separation rate compared to domestic workers which is consistent with Battisti et al. (2014) and Kingi (2015). The outside option of domestic skilled workers is determined endogenously and depends on the job finding probability i. The outside option of foreign workers is set to 0.2 in the baseline calibration. This is about half the outside option of domestic skilled workers which is in line with evidence that immigrants and natives differ according to their outside options and the outside option of immigrants is lower than domestic workers (Chassamboulli and Palivos, 2014). According to the U.S. skilled immigration policy, a foreign skilled worker can only stay for a short duration without being employed and therefore their outside option will always be lower than a domestic workers' outside option. Since I do not model the foreign economy explicitly in this paper, I do not calibrate the outside options that would exist for foreign workers in the foreign economy. However, the main result that a higher cap increases vacancies posted is not sensitive to the outside option and holds even if the outside option of the foreign worker is higher than that of the domestic worker. The intuition is that irrespective of the outside option, an increase in the cap increases the effective surplus from an immigrant worker ($\Gamma_f q_f q$), and therefore increases the total surplus from job creation.

Figure 1.7 shows that following an increase in the immigration cap, firms post more vacancies, which increases not only the foreign skilled labor employed, but also the domestic skilled labor employed. Higher overall job creation has positive spillover effects for domestic matches. Therefore, even though domestic skilled wages fall as in the baseline model, an increase in domestic employment offsets the negative impact on domestic skilled workers and welfare impacts on domestic skilled workers are actually slightly positive (Table 1.2). Higher vacancies posted also increase the outside option of domestic workers and mitigate part of the decline in skilled domestic wages. As the stock of skilled labor employed in sector 1 builds up, output and profit of sector 1 firms increase. Since a larger skilled labor stock employed implies a higher demand for sector 2 output, unskilled wages increase, similar to the baseline model. Therefore, the impact of an immigration cap increase on the welfare of unskilled natives is still positive. In fact, the welfare gain for unskilled domestic households is twice compared to the welfare gain in the baseline model (Table 1.2). The other main difference in this case is that the welfare of skilled native households is slightly positive since their employment increases.

This result confirms the fact that firms' endogenous response to the immigration cap change depends on the structure of the labor market. An immigration cap increase can lead to a welfare gain for domestic skilled workers (through employment gains) if labor markets are imperfectly competitive, even if domestic and foreign workers are perfect substitutes. This is in contrast to the case of a perfectly competitive labor market where the welfare of domestic skilled workers unambiguously falls due to a wage decrease. Therefore, it is important to take into account the structure of the labor market when determining the welfare impact of an increase in skilled immigration on domestic workers.

1.10 Conclusion

This chapter takes a step in the direction of studying the impact of skilled immigration and skilled immigration policy changes in a macroeconomic general equilibrium framework by explicitly focusing on the role of firm demand for foreign skilled labor. The framework I propose — featuring monopolistically competitive firms and a realistic modeling of the current skilled immigration policy setup — facilitates a better understanding of the determinants of firm demand for foreign skilled labor and the aggregate impacts of changes in current skilled immigration policies. This framework leads to some new insights — the realized state of the economy and the structure of the labor market matter, for evaluating the welfare impact of current immigration policy changes. This is because both of these factors influence how firm hiring of skilled workers changes in response to an immigration cap increase. These insights are lost if we evaluate the impact of a cap increase as a pure labor supply change. Also, even if the government does not want to change the cap on foreign workers, an allocation of the same quota of foreign workers via an alternate mechanism — a market-driven allocation of permits for hiring skilled foreign workers, brings the economy closer to the social planner's optimal allocation. However, an increase in the immigration cap is required to close much of the gap between the decentralized economy and the social planner's equilibrium allocation.

The current framework is tractable and offers transparent insights regarding how firms respond to skilled immigration policy changes and how this might depend on macroeconomic and labor market conditions. The model can further be employed to study how immigration policy changes can mitigate the impact of productivity shocks in the economy. However, it does not include several features that would add to the quantitative results — for instance, capital, capital skill complementarity, and disutility of labor supply. It is straightforward to build on this framework and incorporate these elements.

Extensive work remains. Skilled immigration policies may impact domestic firms' decision to hire offshore labor and this needs to be taken into account in order to evaluate the impact of immigration policy changes in the domestic economy. In the next chapter, I extend the framework to include this channel. Moreover, current debates surrounding skilled immigration focus on moving toward a merit-based skilled immigration policy on the lines of Canada. In order to evaluate the impact of this, it is important to include heterogeneity within skill groups. Moreover, it is important to study the implications of firm heterogeneity and the misallocation effect of the current immigration policy across firms in greater detail. I leave this for future work.

1.11 Tables

Table 1.1: Baseline Model Summary

Economic Variable	**Equilibrium Condition**
Sector 1 Output	$Y_{1,t} = Z_t \tilde{z}(1 + \tilde{l}^s_{f,t})$
Sector 2 Output	$Y_{2,t} = Z_t \bar{l}_u$
Price Index	$1 = (\tilde{\rho}_{1,t})^{\alpha}(\rho_{2,t})^{1-\alpha}$
Hiring Condition	$f_{R,t}/q_t + g_t + f_{T,t} = (1-\delta)E_t\{\beta(C_{s,t+1}/C_{s,t})^{-1}[\tilde{\rho}_{1,t+1}Z_{t+1}\tilde{z} - w_{s,t+1} + \frac{f_{R,t+1}}{q_{t+1}} + g_{t+1} + f_{T,t+1}]\}$
Hiring Probability	$q_t = min[\frac{\bar{N}_{e,t}}{\tilde{N}_{e,t}}, 1]$
Foreign Labor Stock	$\tilde{l}^s_{f,t+1} = (1-\delta)(\tilde{l}^s_{f,t} + q_t\tilde{N}_{e,t})$
Sector 1 Profits	$\tilde{d}_t = \tilde{\rho}_{1.t}y_{1.t}/\theta - f_{R,t}\tilde{N}_{e,t} - (c_t + f_{T,t})q_t\tilde{N}_{e,t}$
Skilled Wages	$w_{s,t} = \tilde{\psi}_{1,t}Z_t z$
Sector 1 Prices	$\tilde{\rho}_{1,t} = \frac{\theta}{\theta-1}\tilde{\psi}_{1,t}$
Sector 2 Prices	$\rho_{2,t} = w_{u,t}/Z_t$
Aggregate Demand	$Y^c_t = C_{s,t} + C_{u,t} + C_{i,t} + f_{R,t}\tilde{N}_{e,t} + f_{T,t}q_t\tilde{N}_{e,t}$
Market Clearing	$\rho_{1,t}Y_{1,t}/\alpha = \rho_{2,t}Y_{2,t}/(1-\alpha)$
Consumption by Unskilled	$C_{u,t} = w_{u,t}\bar{l}_u + T_t/2$
Consumption by Domestic Skilled	$C_{s,t} = w_{s,t} + \tilde{d}_t + T_t/2$
Consumption by Immigrants	$C_{i,t} = w_{s,t}\tilde{l}_{f,t}$
Government Budget Constraint	$T_t = R_t$
Immigration Revenue	$R_t = g_t q_t \tilde{N}_{e,t}$

=

Table 1.2: Summary of Welfare Impacts

Experiment	**Skilled Domestic**	**Unskilled Domestic**
10 percent cap increase: Baseline model	-0.0603%	0.0558%
70 percent cap increase: Baseline model (more binding cap)[30]	-0.8231%	0.8427%
70 percent cap increase: Baseline model (less binding cap)[31]	-0.1353%	0.1396%
Policy change: Baseline policy to alternate policy	0.1770%	0.1803%
10 percent cap increase: Search and matching model	0.01%	0.1153%

Note: The welfare change of each household from the policy change is computed as the percentage increase in consumption (including transitional dynamics) that would leave the household indifferent between the initial policy and the new policy.

Table 1.3: Efficient Allocation

Economic Variable	**Equilibrium Condition**
Consumption	$C_{u,t} = C_{s,t}$
Demand for sector 1 output	$Y_{1,t} = \alpha \frac{\varsigma_t}{\nu_t} Y_t^c$
Demand for sector 2 output	$Y_{2,t} = (1-\alpha) \frac{\varsigma_t}{\eta_t} Y_t^c$
Sector 1 output	$Y_{1.t} = Z_t \tilde{z}(1 + L_{f,t}^s)$
Sector 2 output	$Y_{2.t} = Z_t \bar{L}_u$
Aggregate accounting	$C_{u,t} + C_{s,t} + f_{T,t} N_{e,t} = Y_t^c$
Price index	$1 = \left(\frac{\nu_t}{\varsigma_t}\right)^{\alpha} \left(\frac{\eta_t}{\varsigma_t}\right)^{1-\alpha}$
Entry condition of foreign workers	$f_{T,t} = E_t \left[\beta(1-\delta) \frac{C_{s,t}}{C_{s,t+1}} \left(\frac{\nu_{t+1}}{\varsigma_{t+1}} Z_{t+1}\tilde{z} + f_{T,t+1}\right)\right]$
Stock of foreign workers	$L_{f,t+1}^s = (1-\delta)(L_{f,t}^s + N_{e,t})$

Note: $\frac{\nu_t}{\varsigma_t} = \varrho_{1,t}$, and $\frac{\eta_t}{\varsigma_t} = \varrho_{2,t}$ are the relative prices of sector 1 and 2 output in the planner's equilibrium.

1.12 Figures

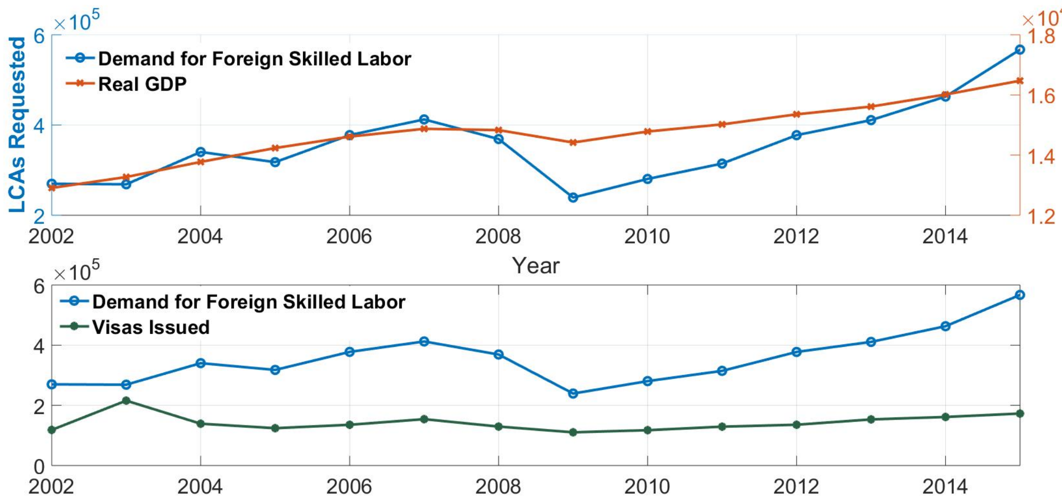

Figure 1.1: Firm demand of H1-B foreign skilled labor over the business cycle vs actual visas issued.

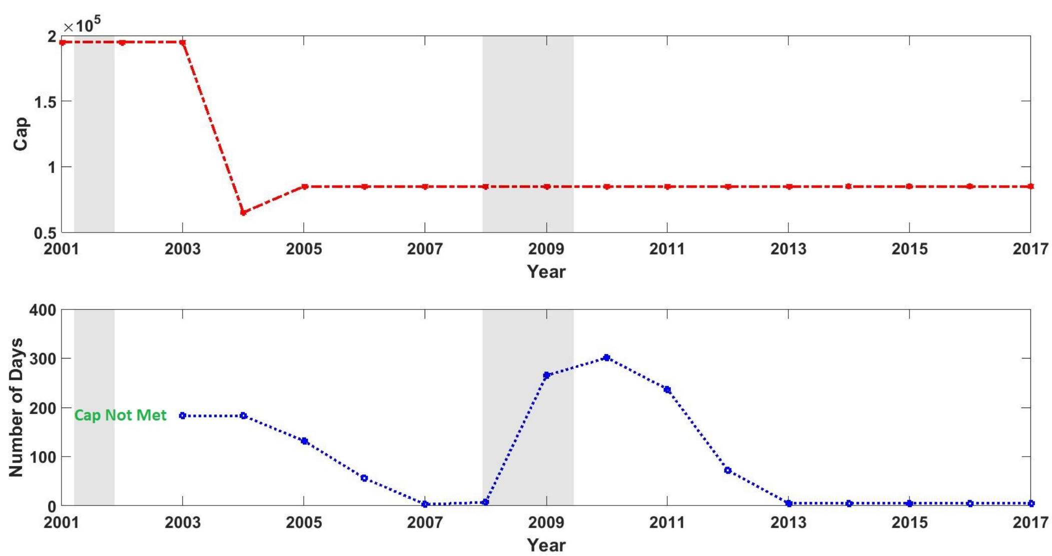

Figure 1.2: H1-B visa cap (top panel) and number of days in which cap was met (bottom panel)

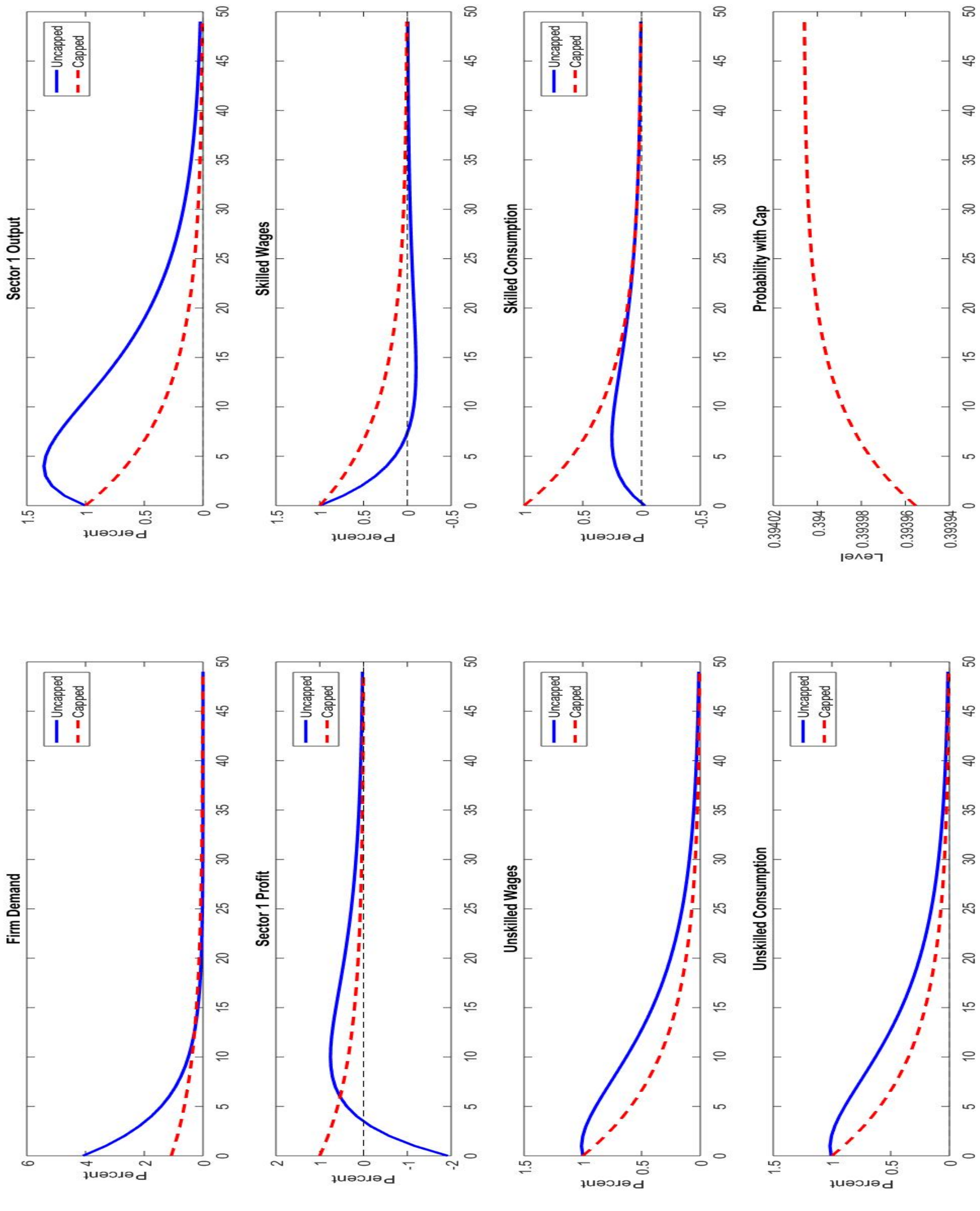

Figure 1.3: Response to a one percent temporary productivity shock in the presence of an occasionally binding constraint (solid blue line) (baseline case) vs the case without an entry cap (dotted red line).

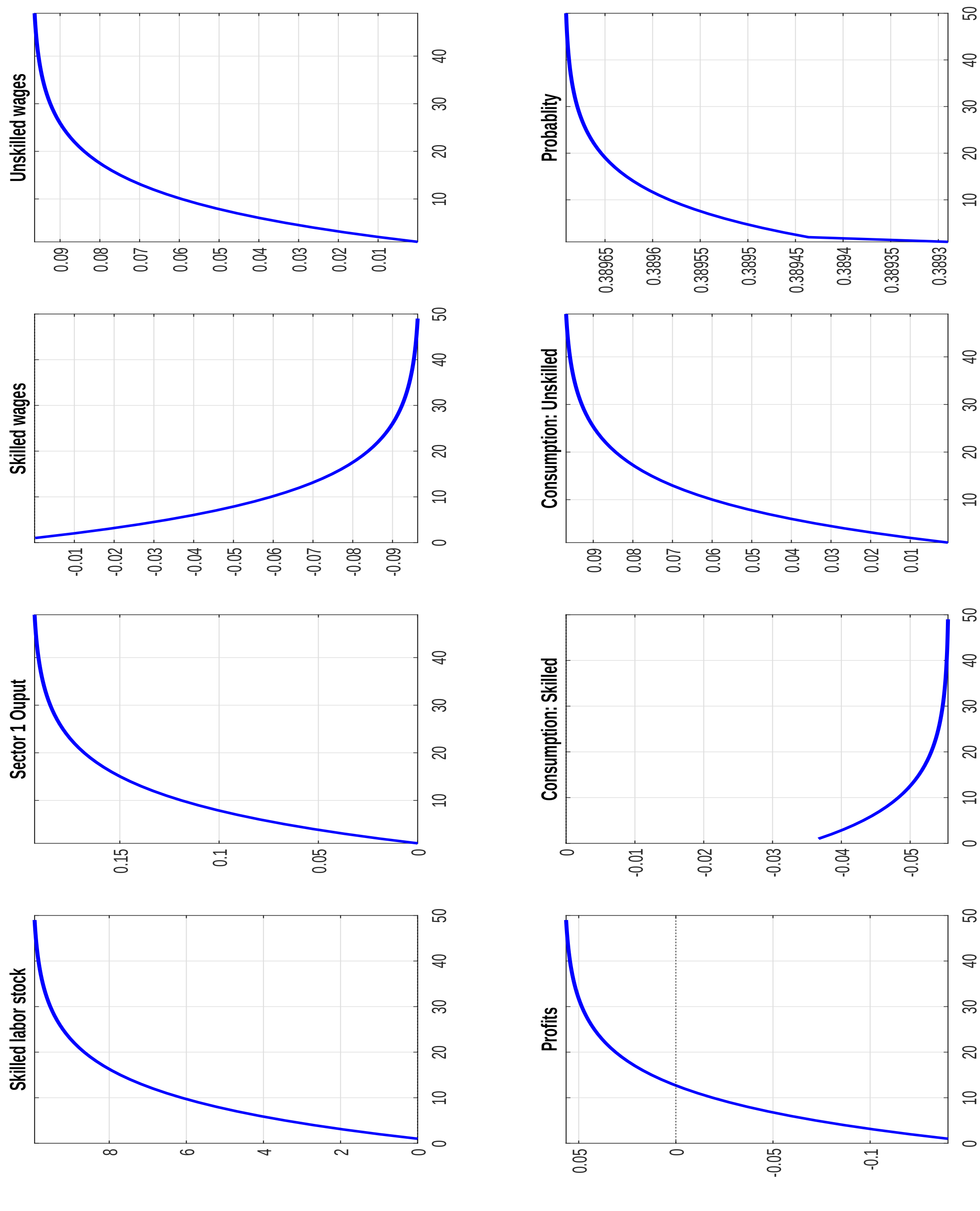

Figure 1.4: Transitional dynamics after a 10 percent skilled immigration cap increase in the baseline model.

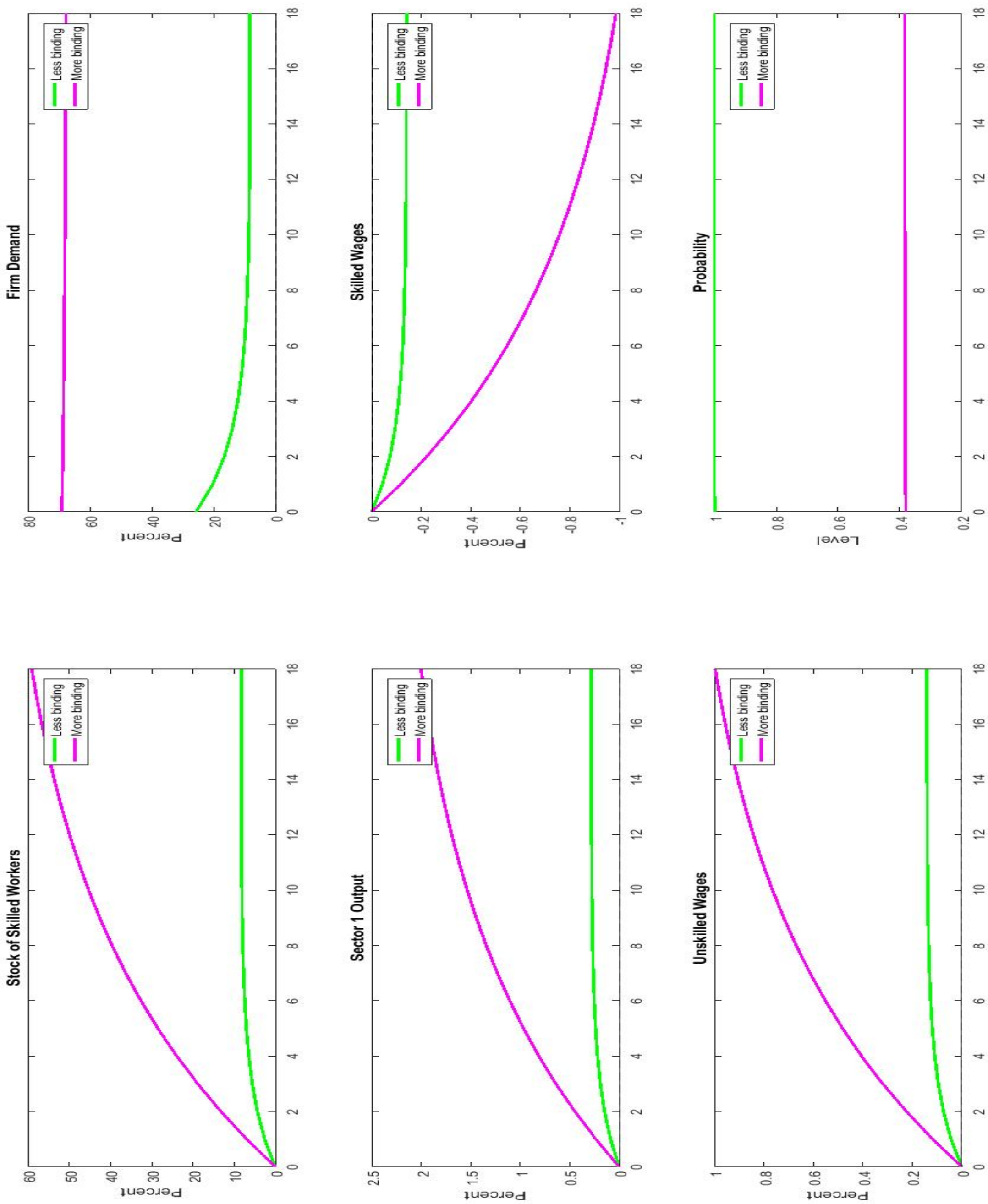

Figure 1.5: Transitional dynamics after a 10 percent skilled immigration cap change in the baseline model when the cap is 'more binding' vs the case when it is 'less binding'.

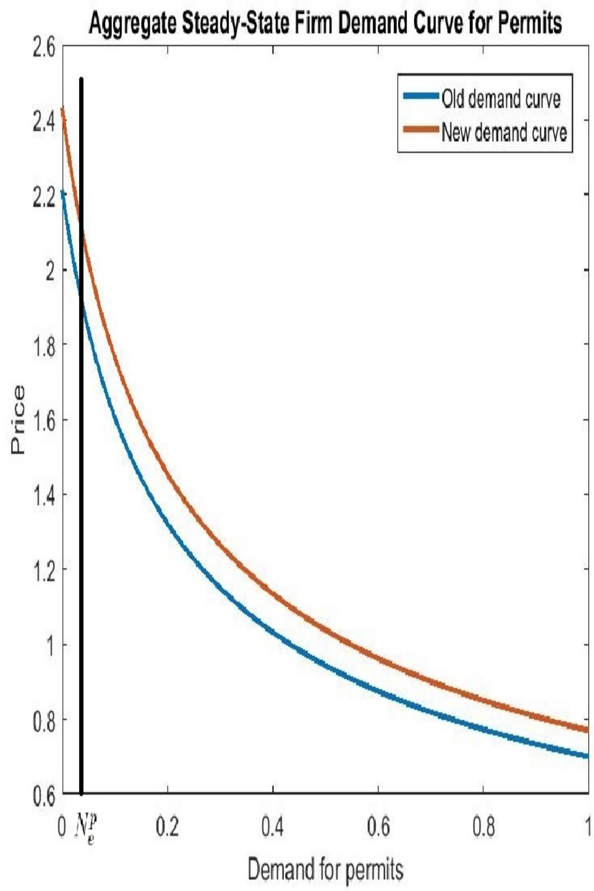

Figure 1.6: Aggregate steady-state demand schedule for permits in the model with market-driven allocation of permits

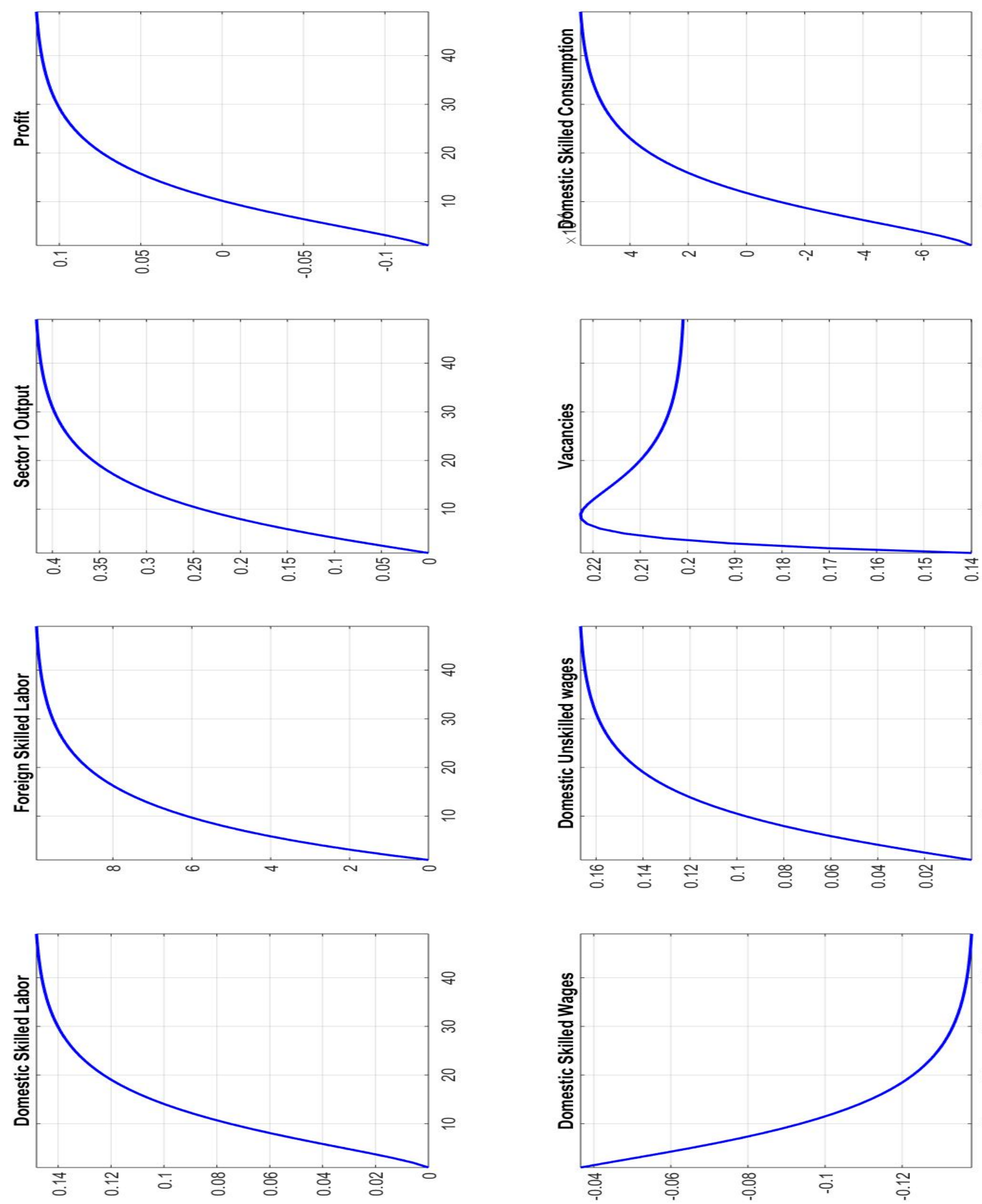

Figure 1.7: Transition dynamics after a 10 percent skilled immigration cap change in the search and matching model.

Chapter 2

SKILLED IMMIGRATION AND OFFSHORING OF SERVICES IN THE U.S.

Mishita Mehra and Raghav Paul

2.1 Introduction

The goal of this paper is to study the interaction between skilled immigration and the offshoring decision of U.S. firms. Specifically, we analyze how skilled immigration policy changes, that influence the flow of skilled immigrant workers, affect offshoring activities of firms in the skilled services sector.

Empirical literature has documented substitutability between immigrants and offshore workers (Ottaviano et al. (2013), Olney and Pozzoli (2018)). While much of the literature has focused on low-skilled immigration and offshoring in the manufacturing sector, our focus is on high-skill immigration. The premise is that skilled immigration policies may impose frictions that restrict the amount of skilled labor firms can hire in the domestic economy. Therefore, firms have an incentive to incur costs in order to hire offshore labor and expand the available skilled labor pool.[1] There is some empirical support for this. Lewin et al. (2009) show that the emerging shortage of high skilled science and engineering talent in the

[1] In fact, firms have indicated this in multiple surveys. For instance, according to a survey by Anderson (2012), for the National Venture Capital Association, 43 percent of the companies said the lack of H-1B visas influenced the company's decisions to place or hire more personnel in facilities located outside the United States. In another survey (Slaughter (2016)), 77 percent of firms responded that "skilled positions unfilled for more than 30 days harms their operations and 71 percent thus say that if it became too difficult to find qualified talent in America, they would consider relocating". According to a GAO (2011) report, in years when firms did not receive approvals for their H-1B petitions, most of the large, multinational firms reported that they were generally able to hire their preferred candidates by sending the candidate to work in an overseas office but they had to incur additional costs to do this.

U.S. drives the need to access talent globally, which partially explains offshoring of product development. They highlight the growing trend for companies to offshore more complex and higher-value-adding activities that require access to highly skilled workers and show that this has been partly influenced by the cutback in the H1-B temporary worker visa in 2003.[2]

Since our focus is skilled immigration, the study is motivated by offshoring in the skill-intensive services sector as the bulk of demand for foreign skilled workers in the U.S. is accounted for by the Professional, Scientific, and Technical Services sector.[3] This sector has also witnessed a significant increase in output used as intermediate inputs, in total exports, and imports (Figure 2.1).[4] The employment in U.S. majority-owned foreign affiliates within this sector has witnessed a substantial increase, especially since 2003 - 04 (Figure 2.2). This increase was concentrated in specific countries like India and China — the share of Asia-Pacific in U.S. majority-owned foreign affiliate employment increased from 24 percent in 2000 to 65 percent in 2015.[5] This indicates that there has been an increase in offshoring in this sector both in terms of employment in foreign affiliates of U.S. firms and also with respect to an increase in imported intermediate inputs. Moreover, skilled immigrant workers and workers hired offshore in the skilled services sector seem to be sourced from similar Asian-Pacific countries like India, which also suggests potential substitutability between these workers.[6]

---

[2]Two thirds of the entry of Foreign skilled workers is via the H1-B visa program (U.S. Department of State). See Appendix A for an overview of the H1-B policy and quota.

[3]73% of Labor Condition Applications filed (a signal of demand for Foreign workers) that are required before H1-B petitions can be filed, were by the Professional, Scientific, and Technical Services sector (LCA database, 2015). Ottaviano et al. (2018) note that even in the U.K., both immigrants and services trade are relatively concentrated in the same sectors — professional, scientific and technical activities.

[4]Between 1997 and 2016, the share of this sector in total intermediate inputs used in the U.S. economy increased from 17 percent to 23 percent, the share in total services imports increased from 13.5 percent to 23.1 percent, and the share in total services exports increased from 16.9 percent to 22.2 percent (BEA Input-Output Make tables).

[5]Within Asia Pacific, India accounted for 65 percent of the employment in majority-owned Foreign affiliates (BEA Direct Investment and Multinational enterprise data).

[6]Yeaple (2013) shows that India is a large outlier for skilled foreign workers in the U.S. via the temporary visa programs.

If skilled immigrant workers and offshore workers are relatively substitutable, then changes in skilled immigration policies would influence the offshoring activities of domestic firms. The main argument for a stricter immigration policy is mitigating the negative impact of skilled immigration on domestic skilled households. Then, in order to fully assess the impact of immigration policy changes on the labor outcomes of domestic workers, it is important to understand potential interactions between skilled immigration policies and offshore production by firms.

Motivated by these facts, we study the impact of skilled immigration policy changes on the offshoring activities of domestic firms and the welfare consequences on heterogeneous (skilled and unskilled) domestic workers in a dynamic general equilibrium framework. To this end, we build a baseline two-country (Home and Foreign) and two-sector (Final and Intermediate) model. In each country, firms in the final goods sector produce output using domestic and imported intermediate goods, and domestic unskilled labor. Monopolistically competitive firms in the intermediate goods sector at Home produce differentiated goods using domestic and immigrant skilled labor, and skilled labor hired offshore. Domestic skilled labor supply is inelastic. Home firms optimally choose the amount of immigrant skilled labor to hire, subject to a policy imposed cap, a sunk hiring cost, and an exogenous probability of return to Foreign. The cap is always binding in the model and firms are allocated a fraction of their immigrant worker demand. The emigration from Foreign is determined by firm labor demand in the Home country.[7] The immigration cap restricts the amount of Foreign skilled labor domestic firms can hire and increases the cost of hiring immigrant workers.[8] However, firms can also hire Foreign skilled workers in an already existing offshore affiliate in Foreign in order to produce the intermediate good. To produce offshore, firms have to pay a per-period

[7]This assumption is realistic due to the significant wage differences between OECD countries like the U.S. and developing countries like India. If hired, there is a strong incentive for a Foreign skilled worker to join the Home labor force. Empirically, Clemens (2013) estimates that there is a six-fold increase in salary for skilled workers who migrate to the US.

[8]For instance, if the demand for immigrant workers is high and the cap is 'more binding' in the sense that firms are allocated a smaller fraction of their demand, firms end up submitting more applications for hiring immigrant workers, therefore incurring higher sunk costs.

fixed cost in order to maintain the relationship with the Foreign affiliate. The model features an increase in offshoring at the intensive margin (increase in labor hired in existing affiliates) rather than an increase in the number of offshore Foreign affiliates (extensive margin). By hiring labor offshore, firms are able to hire more skilled workers and overcome some of the restrictions imposed by skilled immigration policy. Foreign intermediate firms produce output using only Foreign skilled labor — there is no offshoring or immigrant worker hiring by Foreign firms.

We calibrate the main parameters in the Home country that pertain to immigration policy, labor markets, and trade and offshoring costs at Home to match the U.S. economy during the 2004 - 2015 period. We also calibrate parameters related to the Foreign economy's labor markets to match data from India. We then use the model to conduct a policy experiment: a perfect-foresight immigration cap reduction in the Home economy.

The results highlight some key insights that emphasize the importance of taking into account offshoring activities of domestic firms. A reduction in the skilled immigration cap reduces skilled labor available at Home and therefore leads to higher domestic skilled wages. However, if we ignore firms' adjustment towards an increase in the intensive margin of offshoring following a cap reduction, we would evaluate a larger wage gain for domestic skilled workers — in the calibrated model with offshoring, the skilled wages rise (relative to respective steady-states) by 0.1413 percent compared to a 0.1613 percent increase if we do not account for offshoring. Since firms are able to partly substitute immigrant skilled labor with offshore workers (that are now relatively cheaper due to larger skilled labor available in Foreign), the wages of skilled workers increase by less at Home. The welfare impact of an immigration cap reduction on domestic households depends on the distribution of profits across households. Irrespective of the profit distribution, domestic skilled households gain due to a wage increase and unskilled domestic households lose due to wage losses (since the skill-intensive intermediate goods and unskilled labor are complements in final good production). However, the cap reduction hurts firms and reduces their profits even if this is partly offset by the increase in offshoring. Therefore, the profit distribution across households matters for welfare. For instance, if Home skilled households are the firm owners, then the welfare gain (including transitional dynamics) amounts to 0.0104 percent of annualized steady-state consumption. However, if firm profits are distributed towards entrepreneurs and skilled domestic workers earn only wage income, the negative burden of the cap reduction on firm profits falls on the entrepreneurs whose welfare declines by 0.0838 percent and the gain to skilled domestic households amounts to 0.0996 percent of annualized steady-state consumption. Regardless of the two profit distribution scenarios the loss to unskilled workers amounts to 0.0663 percent of annualized steady-state consumption.

In the baseline setup, there are no labor market frictions except for frictions imposed by immigration policy. In order to study the employment effects of immigration policy changes and offshoring, we extend the baseline model to include labor search frictions in the intermediate goods sector. In this framework, Home firms now post vacancies and can be matched with either native or immigrant workers (depending on the relative proportion of job searchers). However, under the current immigration policy, since the cap binds, firms are still able to hire only a fraction of their Foreign matches (given by the probability of an application being selected as in the baseline model). Home firms can also post vacancies in Foreign for hiring offshore workers, and therefore, compete with Foreign intermediate firms for skilled workers. Under search frictions, stricter immigration policy increases the cost of vacancy posting in Home, which causes firms to substitute towards vacancies posted offshore. This leads to a rise in Home skilled unemployment, and while Home skilled wages rise initially, they eventually fall. Since the cap reduction hurts firms and lowers profits, and also reduces skilled wages, the Home skilled household's welfare falls by approximately 0.05 percent. Home unskilled lose by more because of greater increase in offshoring relative to the baseline model.

This paper has two main contributions. First, as Ottaviano et al. (2018) note, much of the literature has omitted an analysis of immigration and services trade (offshoring), and focused mainly on the manufacturing sector. Given the growing importance of skill-intensive services trade, our paper contributes to the literature by analyzing the impact of immigration policy changes and offshoring of firms in the skilled services sector. Moreover, our paper contributes to the current literature by proposing a two-country dynamic general equilibrium model with a realistic skilled immigration policy setup, and accounts for offshoring, both in terms of offshore labor hired in Foreign affiliates and imported intermediate inputs. By analyzing the issue in a general equilibrium model, we can study channels that highlight the importance of taking into account the role of offshoring, profit distributions, and the structure of labor markets, in evaluating welfare impacts of skilled immigration policy changes.

2.2 Related Literature

This paper is related to the literature that studies the impact of immigration and offshoring on native households. Olney (2009) finds that an increase in immigration reduces both the extensive and intensive margins of offshoring. Ottaviano et al. (2013) study how the decline in offshoring and immigration costs affect the employment of native workers. Their paper shows evidence of substitutability between immigrant and offshore workers. Olney and Pozzoli (2018) study the relationship between immigration and offshoring by exploring whether an influx of foreign workers reduces the need for firms to locate production activities abroad. Their paper also shows that an exogenous increase in immigration reduces firm-level offshoring at both the intensive and extensive margin. Our paper is also related to the literature that studies immigration and offshoring in a dynamic general equilibrium model (Mandelman and Zlate (2014)). However, as noted above, much of this literature focuses on offshoring in the manufacturing sector and low-skilled immigration. Ottaviano et al. (2018) is an exception. Their paper explores the impact of immigrants on the imports, exports and productivity of service-producing firms in the U.K. They highlight that immigrants may substitute for imported intermediate inputs (offshore production) and lead to a re-assignment of tasks among offshore and immigrant workers. They find that a 10 percent increase in the bilateral immigrant share reduces intermediate services imports by approximately 1 to 2 percent, therefore suggesting a negative correlation between immigrant and offshore workers in the services sector (mostly concentrated in the professional, scientific, and technical activities) in the U.K.

This research also adds to the emerging literature that examines the implications of high skilled migration. This includes Borjas and Doran (2012), Peri, Shih, and Sparber (2015), and Kerr and Lincoln (2010). Our work is also related to studies that measure the welfare gains from lowering barriers to labor mobility (Urrutia (1998); Klein and Ventura (2007, 2009); Iranzo and Peri (2009); di Giovanni et. al. (2015); Ehrlich and Kim (2015)). The extended model with search and matching frictions is related to recent literature that studies the effects of immigration on the welfare of native individuals in a general equilibrium model featuring search frictions and wage bargaining (Chassamboulli and Palivos (2014), Battisti et al. (2014), Kingi (2017)). We add to the existing literature by not only including a more realistic immigration policy that is relevant to the U.S, but also accounting for the role of firm hiring of offshore labor.

2.3 Baseline Model

The baseline model features a two country (Home and Foreign), two sector (final and intermediate goods) economy that is populated by skilled and unskilled households. A continuum of monopolistically competitive firms produce imperfectly substitutable varieties of final consumption goods in Home and Foreign. These firms produce with Cobb-Douglas technology that combines a basket of domestic and imported varieties of intermediate inputs with domestically available unskilled labor.

Monopolistically competitive intermediate producers in Home produce using domestic, immigrant, and offshore skilled labor. In order to hire immigrant labor, Home firms pay a sunk cost and are subject to a policy imposed cap. To be able to hire offshore skilled labor in Foreign, the Home intermediate firm pays a fixed cost to maintain its relationship with a Foreign affiliate and an iceberg trade cost to bring the output back to Home. Foreign intermediate producers are similar except they produce using only native skilled labor.

2.3.1 Households

The Home economy consists of a continuum of three types of infinitely-lived domestic households that supply units of skilled (native and immigrant) and unskilled labor inelastically. The labor supply of the representative native household is normalized to 1, and that of the representative unskilled household is $\bar{l_u}$. Each skilled and unskilled representative household has the same preferences over a basket of goods produced in Home. The lifetime utility of the skilled and unskilled households is given by:

$$\max_{C_{j,t}} E_t \sum_{k=t}^{\infty} \beta^{k-t} \Big(lnC_{j,k} \Big) \quad \forall j \in \{s, f, u\}$$

where $C_{j,t} = \int_{\upsilon \in \Upsilon} (c_{d,t}(\upsilon)^{\frac{\theta-1}{\theta}} d\upsilon)^{\frac{\theta}{\theta-1}}$ is the consumption basket of each household. Here $\theta > 1$ is the households' symmetric elasticity of substitution across varieties (υ) of consumption goods. Thus, the associated consumption-based price index in units of Home consumption is $1 = \int_{\upsilon \in \Upsilon} (\rho_{d,t}(\upsilon)^{1-\theta} d\upsilon)^{\frac{1}{1-\theta}}$. The demand for variety υ is given by $\left(\frac{\rho_{d,t}(\upsilon)}{\rho_{d,t}}\right)^{-\theta} C_{j,t}$. The budget constraint for the native skilled household is $w_{s,t} + d_t = C_{s,t}$, where d_t is profit income from intermediate and final goods producers in Home in units of Home consumption. $w_{s,t}$ is the real wage paid to skilled labor, which is determined in the competitive labor market for skilled workers.[9] Native skilled households are assumed to be the firm owners in the baseline model. Immigrant skilled and domestic unskilled households consume the sum of their respective labor incomes, $C_{f,t} = w_{s,t} l_{f,t}$, and $C_{u,t} = w_{u,t} \bar{l_u}$. $w_{u,t}$ is the real wage paid to unskilled labor, and is also determined competitively in a separate unskilled labor market.

Foreign households face a similar problem. All skilled households in Foreign pool income. $l_{o,t}$ is the Foreign labor employed in the offshore affiliate, $f_{o,t}$ is the Foreign labor employed by the Home intermediate firm to cover the fixed cost of offshoring, and $N_d^* l_{s,t}^*$ is the total Foreign labor employed by the Foreign intermediate firm, where N_d^* is the mass of Foreign

[9]Foreign and domestic skilled workers are paid the same wage in the baseline model. This is consistent with the overall evidence on relative earnings of native born as a percent of foreign born for workers with a bachelors degree or higher (Figure 2.3). Moreover, when filing a Labor Condition Application, firms attest that they will pay the worker the prevailing compensation for that occupation.

intermediate firms. All skilled Foreign households are paid the same wage $w^*_{s,t}$ and total firm profit in the Foreign economy is d^*_t. Therefore, the budget constraint of the representative skilled household in Foreign is: $C^*_{s,t} = w^*_{s,t}(l_{o,t} + f_{o,t} + N^*_d l^*_{s,t}) + d^*_t$. The budget constraint of unskilled households in Foreign is $C^*_{u,t} = w^*_{u,t}\bar{l}^*_u$.

2.3.2 Production

Intermediate Good Producers

There are a continuum of monopolistically competitive firms, each producing a differentiated variety $\omega \in \Omega$. There is no endogenous entry or exit, and we normalize the constant mass of firms to 1. Production requires skilled (native or immigrant) labor. Aggregate total factor productivity at Home is Z_t which is exogenous and follows an AR(1) process. Part of the intermediate good can be produced using labor hired offshore ($l_{o,t}$) and the aggregate productivity of offshore labor is subject to total factor productivity in Foreign (Z^*_t). Each firm supplies output $y_{m,t}(\omega) = Z_t(l_{d,t}(\omega) + al_{f,t}(\omega)) + Z^*_t l_{o,t}(\omega)/\tau$. The domestic supply of skilled labor in Home is inelastic and normalized to 1. $l_{f,t}(\omega)$ is the stock of immigrant skilled labor employed. Even though domestic, immigrant, and offshore workers are substitutes in production, we account for potential labor productivity differences between immigrant and offshore Foreign workers — a is the relative productivity of immigrant workers.

Domestic firms face certain immigration policy restrictions when hiring immigrant workers: Firms have to pay hiring costs, and there is a policy-imposed cap on the number of Foreign workers that can be hired each period. The sunk hiring costs $f_{R,t}$ must be paid for each Foreign skilled worker the firm applies for. If each firm chooses to submit applications for $N_{e,t}(\omega)$ workers, then the total cost the firm will incur for hiring immigrants, in units of Home consumption, is $f_R N_{e,t}(\omega)$.

The entry cap for Foreign skilled workers is exogenously set at $\bar{N}_{e,t}$. Since each firm submits applications for $N_{e,t}(\omega)$ Foreign skilled workers, the probability of each application being selected is $\mu_t = \frac{\bar{N}_{e,t}}{\int_{\omega\in\Omega}(N_{e,t}(\omega)d\omega)}$. So if each firm submits $N_{e,t}(\omega)$ applications, it will get

$\mu_t N_{e,t}(\omega)$ workers. Firms are of measure 0 and take μ_t as given in their hiring decision.

Additionally, firms can hire Foreign skilled labor at an offshore affiliate. To do this, the firm must pay a per-period fixed cost $f_{o,t}$ in units of Foreign skilled labor[10]. Thus, if period t offshore labor hired is $l_{o,t}$, then the total cost incurred by the firm is $Q_t w^*_{s,t} l_{o,t}(\omega) + Q_t f_{o,t} w^*_{s,t}/Z^*_t$. Here Q_t is the real exchange rate defined as the units of the Home consumption basket needed to purchase one unit of the Foreign consumption basket.

The timing is as follows. A fraction δ of Foreign skilled workers currently employed by domestic firms (including newly hired workers from the previous period) are separated from firms at the beginning of the period. The state Z_t of the economy is realized and wages are determined. Firms pay the fixed offshoring cost and choose offshore labor $l_{o,t}$, taking the Foreign skilled wages $w^*_{s,t}$ as given.[11] Firms produce period-t output with the period t stock of immigrant labor. Firms then maximize the expected discounted profits and optimally choose the number of Foreign skilled workers to hire (or submit applications for), after taking into account the immigration policy restrictions. The realized state of the economy and the corresponding firm demand for Foreign workers determine the fraction μ_t of applications approved. Thus $\mu_t N_{e,t}$ are the workers that firms are able to bring to the firm for production. There is a time to build lag and those workers that survive the separation shock are added to the stock of next period's skilled labor.

Thus, the stock of Foreign skilled labor at firm producing variety ω in period $t+1$ is given by:

$$l_{f,t+1}(\omega) = (1-\delta)(l_{f,t}(\omega) + \mu_t N_{e,t}(\omega)) \tag{2.1}$$

Exogenously separated immigrant workers return back to Foreign and get added to the Foreign skilled labor supply. Expressed in units of the consumption basket, the inter-temporal profit function of firm producing variety ω is given by:

---

[10]This can be interpreted as labor or managers hired to maintain operations in the offshore affiliate

[11]In the model, all firms are symmetric and therefore all firms end up offshoring. We calibrate the model such that firm profits are always positive after paying the fixed offshoring cost.

$$E_t \sum_{k=t}^{\infty} \beta_{k,t} \Big[\rho_{1,k}(\omega) y_{1,k}(\omega) + Q_k \rho_{x,k}(\omega) y_{x,k}(\omega) - w_{s,k}(l_{f,k}(\omega) + l_{d,k}(\omega)) - Q_k w^*_{s,k} l_{o,k}(\omega) - f_{R,k} N_{e,k}(\omega) - f_{o,k} w^*_{s,k} Q_k / Z^*_k \Big]$$

The inter-temporal discount factor that the firm applies to its profits is $\beta_{k,t} \equiv \beta(u'(C_{s,k})/u'(C_{s,t}))$ since domestic skilled households are assumed to be the firm owners.

Optimal Hiring of Skilled Foreign Workers:

As long as fixed offshoring costs ensure positive profits, firms hire offshore labor till the marginal cost of hiring labor offshore is equalized with that of hiring domestically available skilled labor:

$$w^*_{s,t} Q_t \tau / Z^*_t = w_{s,t} / Z_t$$

Additionally, each period, firms hire and submit applications for skilled immigrant workers such that the expected discounted benefit generated from an additional skilled immigrant worker is equal to the expected cost of hiring immigrant workers:

$$\frac{f_R}{\mu_t} = (1-\delta) E_t \Big\{ \beta_{t,t+1} \Big[a w_{s,t+1} - Q_{t+1} \tau w^*_{s,t+1} Z_{t+1} / Z^*_{t+1} + \frac{f_R}{\mu_{t+1}} \Big] \Big\} \tag{2.2}$$

The expected cost of hiring immigrant workers is f_R/μ_t. Since firms have to pay f_R for each immigrant worker that they apply for, and μ_t is the probability of the application being selected, firms effectively pay f_R/μ_t to hire each immigrant worker. The right hand side of (3.2) gives the expected benefit of hiring immigrant workers — the value of output produced by each worker net of wages paid, plus the future cost saving of hiring workers. Here we express the expected benefit as a function of domestic and Foreign skilled wages. Hiring immigrant labor is like an investment decision for firms and the stock of immigrant workers is governed by an Euler equation, the forward iteration of which gives (2.2).

Intermediate goods producing firms serve domestic and Foreign input demand. The goods market clearing for each firm is given by $y_{m,t}(\omega) = y_{1,t}(\omega) + \tau y_{x,t}(\omega)$, where $y_{1,t}(\omega)$ is the demand by domestic final good producers and $y_{x,t}(\omega)$ is the demand by Foreign final good producers (given in 3.3). The presence of the iceberg trade cost $\tau > 1$ implies that in order to export $y_{x,t}(\omega)$ units of output, firms need to produce $\tau y_{x,t}(\omega)$. The elasticity of substitution across different intermediate varieties is ϕ. Profit maximization implies that the price set by firm ω for the domestic final good producer is $\rho_{1,t}(\omega) = \frac{\phi}{\phi-1}(w_{s,t}/Z_t)$ and the export price for the Foreign final good producer is $\rho_{x,t}(\omega) = Q_t^{-1}\tau\rho_{1,t}(\omega)$, where the export price is in units of Foreign consumption. Firm profits in period t are given by $d_{m,t}(\omega) = \rho_{1,t}(\omega)y_{1,t}(\omega) + Q_t\rho_{x,t}(\omega)y_{x,t}(\omega) - w_{s,t}l_{s,t}(\omega) - w_{s,t}l_{f,t}(\omega) - Q_t w^*_{s,t}l_{o,t}(\omega) - f_R q_t N_{e,t}(\omega) - f_o(w^*_{s,t}/Z^*_t)Q_t$.

Foreign Intermediate Firms

We normalize the constant mass of Foreign intermediate producers to N^*_d. Each Foreign intermediate firm ω produces output using native skilled workers — the technology is given by $y^*_{m,t}(\omega) = Z^*_t l^*_{s,t}$. They supply output to Home and Foreign final good producing firms i.e. $y^*_{m,t}(\omega) = y^*_{1,t}(\omega) + \tau y^*_{x,t}(\omega)$. Except for the hiring decision of immigrant and offshore workers, Foreign firms face a similar problem as Home firms and set prices for their domestic final good firms as $\rho^*_{1,t}(\omega) = \frac{\phi}{\phi-1}(w^*_{s,t}/{Z_t}^*)$ and for Home final good firms as $\rho^*_{x,t}(\omega) = Q_t\tau\rho^*_{1,t}(\omega)$. Firm profits are given by $d^*_{m,t}(\omega) = \rho^*_{1,t}(\omega)y^*_{1,t}(\omega) + Q_t^{-1}\rho^*_{x,t}(\omega)y^*_{x,t}(\omega) - w^*_{s,t}l^*_{s,t}(\omega)$.

2.3.3 Consumption Good Producers

The Home consumption basket is comprised of imperfectly substitutable varieties $\upsilon \in \Upsilon$ produced by a constant mass 1 of monopolistically competitive Home final good producers. The production technology of each firm is given by $y_{d,t}(\upsilon) = Z_t(m_t(\upsilon))^{\alpha}(l_{u,t}(\upsilon))^{1-\alpha}$, where $m_t = \left[\int_0^1 (y_{1,t}(\omega)^{\frac{\phi-1}{\phi}} d\omega) + \int_0^{N^*_d} (y^*_{x,t}(\omega)^{\frac{\phi-1}{\phi}} d\omega)\right]^{\frac{\phi}{\phi-1}}$ is a basket of domestic (y_1) and imported (y^*_x) intermediate inputs. $l_{u,t}$ is the unskilled labor employed. In minimizing costs, each firm chooses its optimal demand of the intermediate composite $m_t = (\alpha(\frac{\theta-1}{\theta})Y^c_t)/\rho_{m,t}$ and unskilled labor $l_{u,t} = ((1-\alpha)(\frac{\theta-1}{\theta})Y^c_t)/w_{u,t}$, where Y^c_t is the Home aggregate demand (defined in 2.4). The demand for Home intermediate input is $y_{1,t}(\omega) = \left(\frac{\rho_{1,t}(\omega)}{\rho_{m,t}}\right)^{-\phi} m_t$, where $\rho_{m,t}$ is the price index of the domestic and Foreign intermediate input composite used in the production of Home final good. The demand for Foreign intermediate input is $y_{x,t}(\omega) = \left(\frac{\rho_{x,t}(\omega)}{\rho^*_{m,t}}\right)^{-\phi} m^*_t$, where $\rho^*_{m,t}$ is the price index of the domestic and Foreign intermediate input composite used in the production of Foreign final good.

Each firm producing variety υ sets their price $\rho_{d,t}(\upsilon) = \frac{\theta}{\theta-1}(\frac{\rho_{m,t}}{\alpha})^{\alpha}(\frac{w_{u,t}}{1-\alpha})^{1-\alpha}$ and their per-period profit is $d_{c,t} = \rho_{d,t}y_{d,t} - \rho_{1,t}y_{1,t} - N^*_d\rho^*_{x,t}y^*_{x,t} - w_{u,t}l_{u,t}$. $w_{u,t}$ is the unskilled wage Since consumption goods are not traded, the final good producers serve domestic demand such that $y_{d,t}(\upsilon) = \rho_{d,t}(\upsilon)^{-\theta}Y^c_t$.

A constant mass, normalized to 1, of consumption good producers in Foreign face an identical problem and we use * to denote the corresponding Foreign variables.

2.3.4 Aggregate Accounting and Equilibrium

Since firms in each sector are identical to their domestic counterparts, the aggregation over varieties is straightforward. Aggregate intermediate sector output is $y_{m,t} = Z_t(l_{d,t} + al_{f,t}) + Z^*_t l_{o,t}/\tau$ and the associated price index is $(\rho^*_{m,t})^{1-\phi} = N^*_d(\rho^*_{1,t})^{1-\phi} + (\rho_{x,t})^{1-\phi}$.

Aggregate consumption by households in Home is $C_{s,t} + C_{u,t} + C_{f,t}$. Home labor market clearing requires $l_{d,t} = 1$ and $l_{u,t} = \bar{l}_u$. The aggregate demand at Home is $Y^c_t = w_{s,t}(1 + l_{f,t}) + w_{u,t}\bar{l}_u + d_t + f_R N_{e,t}$.[12] Home profits are defined as $d_t = d_{1,t} + d_{c,t}$.

Similarly in Foreign, aggregate intermediate output is $N^*_d y^*_{m,t} = Z^*_t l^*_{s,t}$ and the associated price index is $(\rho^*_{m,t})^{1-\phi} = (\rho_{x,t})^{1-\phi} + N^*_d(\rho^*_{1,t})^{1-\phi}$.

Aggregate consumption by households in Foreign is $C^*_{s,t} + C^*_{u,t}$. Foreign labor market clearing requires $\bar{L}^*_s = l_{o,t} + f_{o,t} + l_{f,t} + N^*_d l^*_{s,t}$ and $l^*_{u,t} = \bar{l}^*_u$, where $\bar{L}^*_s$ is the total exogenous supply of skilled workers in Foreign.[13] Aggregate accounting in Foreign requires $Y^{c*}_t = w^*_{s,t}(l_{o,t} + f_{o,t} + N^*_d l^*_{s,t}) + w^*_{u,t}\bar{l}^*_u + d^*_{c,t} + N^*_d d^*_{1,t}$. Finally, any trade imbalance must be offset

[12] The R.H.S is the aggregate consumption by domestic households plus the sunk cost of hiring immigrant workers which is in units of Home consumption.

[13] Immigrant workers employed in Home are part of this supply and any changes in Home immigration policy affect the skilled labor supply in Foreign.

by payments incurred for offshore production : $Q_t\rho_{x,t}y_{x,t} - N_d^*\rho_{x,t}^*y_{x,t}^* = Q_t w_{s,t}^* l_{o,t} + Q_t f_o w_{s,t}^*$.

2.4 Steady-State Intuition

Since our focus is on analyzing how changes in skilled immigration policies influence the offshoring decision of firms, this section gives some intuition regarding the relationship between the steady-state levels of offshoring and the policy-imposed, skilled immigration cap in Home. Using the goods market clearing conditions for the intermediate goods sector in Home and Foreign, the steady state law of motion for immigrants, and the skilled labor market clearing equation in Foreign, we can get:

$$l_o = \frac{\tau N_d^*}{Z^*(1+N_d^*)}\left[\left(\tau\left(\frac{\rho_x}{\rho_m^*}\right)^{-\phi} - \left(\frac{\rho_1^*}{\rho_m^*}\right)^{-\phi}\frac{1}{\tau}\right)m^* - \frac{(1-\delta)\bar{N}_e}{\delta}\left(aZ + \frac{Z^*}{N_d^*\tau}\right) + (\bar{L}_s^* - f_o)\frac{Z^*}{N_d^*\tau} - Zl_d\right] \tag{2.3}$$

We can further use the equilibrium price index equations in Home and Foreign to get — $\left(\frac{\rho_1^*}{\rho_m^*}\right)^{-\phi} = \left(\frac{1}{\tau^{2(1-\phi)}+N_d^*}\right)^{\frac{\phi}{1-\phi}}$ and $\left(\frac{\rho_x}{\rho_m^*}\right)^{-\phi} = \left(\frac{1}{1+N_d^*\tau^{2(\phi-1)}}\right)^{\frac{\phi}{1-\phi}}$

(2.3) shows that there is a negative relationship between the immigration policy cap and the offshore labor hired — a lower immigration cap (lower $\bar{N}_e$) increases offshore labor hired (l_o increases). A lower immigration cap reduces the skilled labor available at Home and increases the skilled labor supply in Foreign. Therefore, there is an upward pressure on skilled wages at Home and a downward pressure on skilled wages in Foreign — both effects would tend to increase the offshore labor hired by Home firms. Moreover, higher labor available in Foreign increases demand for the final consumption good in Foreign. This increases the demand for the skilled intermediate composite good (m^*) used by Foreign firms. The higher export demand for the Home intermediate good (which depends on the relative price (ρ_x/ρ_m^*)), also positively influences the level of offshore labor hired.

2.5 Calibration

In order to study the dynamics numerically, we calibrate the parameters of the model under the assumption that the steady state Home economy mimics the U.S. and Foreign mimics India during the 2004-2015 period. The immigration policy cap was binding during this period. We interpret each period as a year to accommodate the annual allocation of the H-1B visa cap. We calibrate the parameters that pertain to immigration to match average annual U.S. data from the Current Population Survey (CPS), and the United States Citizenship and Immigration Service (USCIS), between 2004 to 2014. Foreign labor supply parameters are calibrated to match education-wise labor available using data from the Indian Census.

The immigration cap $\bar{N}_e$ is set to 0.0022 in order to match the average cap imposed by actual policy (85,000) as a proportion of the normalized average domestic skilled labor in the U.S. Domestic unskilled labor supply is calibrated to 1.84 (given the normalization of domestic skilled labor supply to 1) to match the share of domestic workers in the U.S.with less than a bachelor's degree of 34 percent. We rely on existing literature for some parameters. We set $\beta = 0.96$ which implies an annual real interest rate of 4 percent. Following Ghironi and Melitz (2004), we set the elasticities of substitution across product varieties equal to 3.8. The exogenous return shock to Foreign is set to $\delta = 0.1$, in order to match the annual return migration rate of 10 percent (Center for Immigration Studies, 2011).

We jointly calibrate $\{\alpha, N_d^*, f_R, \tau, f_o\}$ to minimize the squared residuals between model moments and targets in Table 2.2. Data on the share of exports and imports in skilled service sector GDP (the average share of Professional, Scientific, and Technical services output that is exported and imported) is calculated from the Bureau of Economic Analysis Input-Output Use Tables (2004-2015). The resulting parameter values are highlighted in Table 2.3.

The calibration implies that $\delta_f > \delta_d$, which is consistent with the literature (Battisti et al., 2014) and also in line with the fact that a significant proportion of immigrant workers are likely to be temporary workers due to the nature of immigration policy, and therefore, their separation rate is likely to be higher.

2.6 Transition Dynamics and Welfare Results in the Baseline Model

In this section, we solve the calibrated model numerically to study dynamics in response to a perfect foresight change in immigration policy. In particular, we study the response to a 10 percent reduction in the immigration policy cap. We then calculate the welfare effects, on domestic households, of the cap reduction. We also analyze how these welfare impacts vary depending on the presence of offshoring and distribution of firm profits across households.

2.6.1 Dynamic Response to Permanent Cap Reduction

We study the responses (deviation from the steady state) to a deterministic, 10 percent cap reduction. Figures 2.4 and 2.5 give the dynamic responses in the baseline model. From Figure 2.4, we see that a tighter immigration policy leads to a decline in the fraction of immigrant workers that firms can employ in Home. This reduction in the stock of domestically available skilled labor leads to a rise in Home skilled wages which causes domestic firms to substitute towards Foreign labor through an increase in offshoring. However, rising domestic costs, along with lesser consumption demand due to a smaller immigrant population, leads to a decline in demand for Home intermediate output. Thus, while a reduction in the cap causes a decline in the sunk costs firms pay for hiring immigrant workers, the decline in revenue from decreased consumption and intermediate goods sales leads to a fall in profits. Another way to see this is that that the increase in firm offshoring is less than the decline in immigrant labor hired and therefore the total output produced by the intermediate sector in Home is lower, leading to lower profits. Additionally, Home unskilled wages decline due to a decreased demand for unskilled labor by consumption good producers as demand for their output declines. In the Foreign economy, a larger available supply of skilled labor leads to lower skilled wages. A higher labor supply also implies a larger demand for the Foreign consumption good, which leads to a higher demand for Home and Foreign intermediate inputs.

Figures 2.6 and 2.7 compare the responses of the cap reduction in the baseline model (with offshoring) with an alternate case in which we do not have offshoring.[14] Figure 2.6 shows that if we do not account for firms' adjustment towards higher offshoring after an immigration cap reduction, we would get a larger decrease in Home intermediate output and a greater increase in skilled wages at Home. Moreover, since shutting down offshoring cuts off the outflow of offshoring related wages, the consumption good expenditure in Home falls by less (also seen as higher Home skilled wages) and thus unskilled wages fall by less. These wage effects directly feed into welfare impacts on domestic households. Therefore, it is important to take into account the role of offshoring when evaluating the impact of immigration policy changes on welfare of domestic households.

2.6.2 Welfare Analysis

We calculate welfare impacts after a 10 percent, perfect foresight reduction in the immigration cap. The long-run welfare gain or loss of each type of native worker from the immigration policy tightening is computed as the percentage change (Δ) in initial steady-state consumption that would leave the households indifferent between the initial policy and the new policy with the lower cap, when the new policy is implemented at time $t = 0$. Transitional dynamics have been included in the welfare computations. Thus, Δ solves:

$$u\left[C_j\left(1+\frac{\Delta}{100}\right)\right] = (1-\beta)\sum_{t}^{\infty}\beta^t u(C_{j,t}) \;\; \forall j \in \{s,u\}$$

First we consider the impact of the cap reduction in the baseline model. In Section 2.7.2 we compare the welfare results with an extended model with search and matching frictions. From Table 2.4, we note that under the benchmark case where native skilled households get profits, tighter immigration policy leads to a 0.01 percent rise in native skilled welfare due to a rise in Home skilled wages that outweighs the decline in profits. Home unskilled households are hurt as their welfare falls by approximately 0.07 percent due to the decline in

[14] In order to shut down offshoring, yet preserve steady state values close to the model benchmark, we re-calibrate f_o to ensure $l_o = 0$, while keeping all other parameters the same.

Home consumption demand that leads to a decrease in demand for unskilled labor and thus unskilled wages. Second, we note that the distribution of profits is crucial for the outcomes of the native skilled.

In order to more carefully analyze the role of profit distribution in the welfare implications of an immigration cap reduction, we introduce a new type of household, the entrepreneurs. The entrepreneurs own the firms and thus their budget constraint is $C_{e,t} = d_t$, and the new Home skilled households budget constraint is $C_{s,t} = w_{s,t}$. Therefore, the new stochastic discount factor for the firms is $\beta_{k,t} \equiv \beta(u'(C_{e,k})/u'(C_{e,t}))$. Welfare results following a 10 percent immigration cap reduction are detailed in Table 2.4 below. The results confirm our intuition. Under competitive labor markets, while home skilled labor benefits from the resulting skilled labor shortage, home firms are hurt. Intermediate profits decline due to rising wage costs that increase prices and reduce demand for their output. Increased offshoring by intermediate producers leads to outflow of wage income from Home. This reduces demand for the consumption good, thereby hurting consumption good producers who also face increasing intermediate good costs. Thus, entrepreneurs lose as a result of the cap reduction.

Through this analysis, we intended to emphasize the importance of accounting for offshoring decisions of U.S. firms when evaluating the impact of changes in immigration policy. Thus, we consider a third scenario where we shut down offshoring in the benchmark profit distribution case. We expect that if we do not account for offshoring, while firms are likely to be hurt more by the cap, Home skilled households are likely to gain more through increased domestic labor demand and a greater rise in wages. The welfare results confirm this as we see that the Home skilled gain more and unskilled lose less after a cap reduction, when we do not account for offshoring. To delve deeper into the mechanisms, we analyze the responses to the cap reduction in this scenario in Figures 2.6 and 2.7. From Figure 2.7, we see that if the firm does not have the option to increase offshore employment, it does not reduce demand for immigrant labor as much, which causes the probability to fall by more. The lack of the offshoring channel causes more pressure on the skilled labor market which causes a greater rise in skilled wages and decline in intermediate profits. However, a key channel of impact on the unskilled workers through offshoring is that increased offshoring leads to a greater outflow of wage earnings to Foreign and thus a lower expenditure on Home consumption. Thus, when we shut down offshoring, the unskilled lose by less as their wages fall by less. Our results indicate that analyzing the impact of immigration policy changes without accounting for firm adjustment via offshoring may over exaggerate the welfare benefit to skilled, and underestimate the loss to unskilled workers. Additionally, when entrepreneurs earn profits and home skilled earn only labor income, the benefit to home skilled labor and cost to entrepreneurs is greater in the absence of offshoring as home skilled wages rise by more and profits fall by more.

In the benchmark model, Home skilled benefit primarily due to the rise in wages and we do not account for potential changes in employment. In order to analyze the employment effects on native workers, we introduce labor market search frictions and discuss welfare impacts of immigration policy changes in this framework.

2.7 Model with Labor Market Frictions

In the framework with search frictions, Home firms in the skill-intensive intermediate goods sector post vacancies at Home and they can be matched with either a skilled immigrant worker or with a skilled domestic worker. Home firms also post vacancies in the Foreign economy for hiring offshore workers, thus competing with vacancies posted by Foreign intermediate sector firms in the Foreign economy.

While posting vacancies at Home, firms cannot differentiate between domestic and immigrant workers.[15] The probability of getting matched to a domestic or foreign worker depends on the relative fraction of each type of worker searching for jobs. However, there is still a policy-imposed cap and additional costs of hiring immigrant workers. For each immigrant

[15]This is realistic as firms cannot legally differentiate between the two worker types in their job postings. This also follows Chassamboulli and Palivos (2014), Battisti et al. (2014), Kingi (2017), in which domestic and immigrant workers are ex ante identical from a firm's perspective but may have different outcomes depending on their bargaining power, outside options, and separation rate.

worker that is matched, firms have to pay an immigration policy cost as in the baseline model.

Search and Matching in the skill-intensive sector

Suppose domestic firm ω posts $v_t(\omega)$ vacancies for skilled workers at Home in period t. The cost of posting a vacancy is κ. Given a standard constant returns to scale matching technology with unemployment elasticity ϵ and matching efficiency χ, the probability that the firm will be matched with a skilled worker (domestic or foreign) is given by $\chi(\frac{v_t}{U_t})^{-\epsilon}$, where v_t denotes the aggregate vacancies posted, and $U_t = U_{d,t} + U_{f,t}$ is the aggregate mass of domestic and immigrant skilled workers searching for a job.

The market tightness is given by $\frac{v_t}{U_t}$. The probability that the firm is matched to worker type $j \in \{d, f\}$ is $q_{j,t} = \frac{U_{j,t}}{U_{d,t}+U_{f,t}}\chi(\frac{v_t}{U_t})^{-\epsilon}$, where d and f denote domestic and foreign respectively, and $\frac{U_{j,t}}{U_{d,t}+U_{f,t}}$ is the relative share of job searchers of each type. However, firms that match with foreign workers have to pay an additional sunk cost for each foreign worker they apply for, f_R.

The second immigration policy restriction, as before, is the cap on the total number of foreign workers that can be hired each period, $\bar{N}_{e,t}$. Let $q_{f,t}v_t$ be the total number of matches with skilled immigrant workers. Then, the probability that each foreign worker that was matched would eventually be able to join the firm is $\mu_t = \frac{\bar{N}_{e,t}}{q_{f,t}v_t}$. Therefore, if the flow of matches for foreign workers is $q_{f,t}v_t$, the mass of foreign workers that eventually get added to the stock of immigrant workers is $\mu_t q_{f,t} v_t$.

The exogenous separation rate for domestic workers is δ_d, and that of foreign workers is δ_f. Workers hired this period join the firm in the next period and the separation shock is realized at the beginning of every period. Thus the stock of employed domestic workers at Home is given by $l_{d,t+1} = (1-\delta_d)(l_{d,t} + q_{d,t}v_t)$, and the stock of employed foreign workers is $l_{f,t+1} = (1-\delta_f)(l_{f,t} + \mu_t q_{f,t} v_t)$.

The first order condition from firms' optimization problem gives that in equilibrium, the cost of posting a vacancy is equal to the expected discounted surplus from a domestic match plus the expected discounted surplus from a foreign match, both weighed by the probability of each match, net of sunk hiring costs for foreign matches.

$$\kappa = (1-\delta_d)\Gamma_{d,t} q_{d,t} + (1-\delta_f)\Gamma_{f,t} q_{f,t}\mu_t - f_R q_{f,t}$$

The surplus from each match is just the additional value generated from an additional skilled labor net of the real wage paid, plus the continuation value of the match:

$$\Gamma_{d,t} = E_t \beta_{t,t+1} \left[\Psi_{t+1} Z_{t+1} - w_{d,t+1} + (1-\delta_d)\Gamma_{d,t+1}\right]$$

$$\Gamma_{f,t} = E_t \beta_{t,t+1} \left[a\Psi_{t+1} Z_{t+1} - w_{f,t+1} + (1-\delta_f)\Gamma_{f,t+1}\right]$$

$\Gamma_{d,t}$ (surplus from domestic match) is the Lagrange Multiplier (LM) on the stock of domestic workers employed and $\Gamma_{f,t}$ (surplus from immigrant match) is the LM on stock of immigrant workers employed. Ψ_t is the real marginal cost of production and $w_{d,t}$ and $w_{f,t}$ are the skilled wages paid to domestic and immigrant workers at Home.

Additionally, firms post vacancies (after incurring a cost κ_o^*) in Foreign to employ workers in the offshore affiliate. The corresponding hiring and employment equations are:

$$\frac{\kappa_o^*}{q_t^*} = \beta_{t,t+1}(1-\delta^*)\left[\frac{\Psi_{t+1} Z_{t+1}^*}{\tau} - Q_{t+1} w_{o,t+1}^* + \frac{\kappa_o^*}{q_{t+1}^*}\right]$$

$$l_{o,t+1} = (1-\delta^*)(l_{o,t} + q_t^* v_{o,t}^*)$$

where δ^* is the exogenous separation of skilled workers in Foreign and q_t^* is the probability that the firm matches with a skilled worker in Foreign. This probability is influenced by the total vacancies posted in Foreign — vacancies posted by Home intermediate ($v_{o,t}^*$) and by Foreign intermediate in Foreign (v_t^*):

$$q_t^* = \chi\left(\frac{v_{o,t}^* + v_t^*}{U_t^*}\right)^{-\epsilon}$$

The hiring condition by Foreign intermediate firms and the corresponding law of motion for workers employed is given by:

$$\frac{\kappa^*}{q_t^*} = E_t \beta_{t,t+1}(1-\delta^*)\left[\Psi_{t+1}^* Z_{t+1}^* - w_{s,t+1}^* + \frac{\kappa^*}{q_{t+1}^*}\right]$$

$$l^*_{s,t+1} = (1-\delta^*)(l^*_{s,t} + q^*_t v^*_t)$$

Wages: Nash Bargaining

Home intermediate firms face a surplus sharing rule given by $\eta_i S^F_{i,t}(\omega) = (1-\eta_i) S^W_{i,t}(\omega) \quad \forall i \in \{d, f, o\}$ where η_i is the bargaining power of worker $i \in \{\text{domestic, immigrant, offshore}\}$. $\eta_o = \eta^*$ (i.e. the bargaining power of skilled workers hired in the offshore affiliate is the same as the bargaining power (η^*) of all Foreign skilled workers). S^F is the firm's surplus and S^W is the worker's surplus from the match. The surplus sharing rule implies that the domestic, immigrant, and offshore skilled wages ($w_{d,t}$, $w_{f,t}$, $w_{o,t}$) are given by:

$$w_{d,t} = \eta_d(\Psi_t Z_t) + (1-\eta_d)\varpi_{d,t}$$

$$w_{f,t} = \eta_f(a\Psi_t Z_t) + (1-\eta_f)\varpi_{f,t}$$

$$w^*_{o,t} = \eta^* Q_t^{-1}\left(\frac{\Psi_t Z^*_t}{\tau}\right) + (1-\eta^*)\varpi^*_{s,t}$$

where $\varpi_{d,t}$, $\varpi_{f,t}$, $\varpi^*_{s,t}$ are the outside options of the workers. Under the assumption of no unemployment benefits in the baseline case, the only outside option of workers is the expected surplus from searching for a job in the next period (taking into account the probability that the potential match will survive).

The job finding probabilities (weighed by the proportion of workers searching for jobs) of skilled domestic workers ($\iota_{d,t}$ is given by:

$$\iota_{d,t} = \frac{U_{d,t}}{U_{d,t}+U_{f,t}}\chi_t\left(\frac{v_t}{U_{d,t}+U_{f,t}}\right)^{1-\epsilon}$$

The outside option of immigrant workers is finding a job in Foreign (either with the offshore affiliate or with the Foreign intermediate) with probability $\iota^*_t = \chi\left(\frac{v^*_{o,t}+v^*_t}{U^*_t}\right)^{1-\epsilon}$

Prices, profits, and other equilibrium conditions are similar to the baseline model.[16]

[16]Except that vacancy posting costs are deducted from the intermediate firms' profits in both countries.

Let the total measure of domestic skilled workers in the labor force be $\bar{L}_d$ and that of immigrant households be $\bar{L}_f$.[17] Then $U_{d,t} = \bar{L}_d - l_{d,t}$ and $U_{f,t} = \bar{L}_f - l_{f,t}$ are the domestic and Foreign unemployed (job searchers) in each period. Employed and unemployed households of each type pool labor income, as is standard. Thus, the budget constraints are similar to the baseline model except that now labor income is earned only by the measure of employed households of each type. Household preferences and optimal consumption choices are exactly the same as before.

Given that foreign workers are immigrants in the Home labor force, the skilled labor market clearing in Foreign requires $\bar{L_s}^* = N_d^* l_{s,t}^* + l_{o,t} + f_o + l_{f,t} + U_t^*$. Foreign firms face a similar surplus sharing rule as Home firms and skilled wages paid are determined as: $w_{s,t}^* = \eta^*(\Psi_t^* Z_t^*) + (1 - \eta^*)\varpi_{s,t}^*$.

2.7.1 Calibration

The addition of labor market frictions requires us to set parameters that govern the labor market. We choose the matching elasticity ϵ as 0.4 as is standard in the literature (Blanchard and Diamond (1989)), and the bargaining power of both workers, $\eta_d = \eta_f = 0.4$, as the same as ϵ so that the Hosios condition holds. Vacancy posting costs at Home, κ, are normalized to 1. We choose δ_d and δ_f to match average quarterly unemployment rate of Home skilled of 2.9 percent over 2004-2015 and the quarterly rate of immigrant unemployment as 4.2 percent. We then annualize the resulting values of the respective exogenous separations. We then jointly calibrate the remaining parameters $\{\kappa^*, \kappa_o^*, \delta^*, \chi\}$ by targeting the annual rate of Foreign skilled unemployment as 11 percent, the ratio of immigrant to domestic skilled wages in Home as 1.005, and the Foreign skill premium as 4.99. Data on average annual unemployment rates and wages of domestic and foreign born workers are computed from monthly Current Population Survey data over 2004-2015. Table 2.5 summarizes the calibrated parameter values.

[17] At any point in time, we keep the total pool of immigrants in the Home labor force as fixed to begin with.

2.7.2 Welfare

A 10 percent cap reduction under the search and matching framework causes the cost of posting vacancies in the Home country to rise due to the fall in fraction of matched immigrant workers the firm is able to "bring" to itself. This explains the initial decline in vacancies posted. Lower skilled labor at Home also increases the marginal revenue product of skilled workers and therefore the surplus from skilled workers — this leads to an increase in vacancies posted at Home. The higher surplus also increases the expected benefit of workers of finding jobs and therefore increases their outside options. The higher outside option leads to an increase in wages of domestic skilled workers but as the outside option falls, wages fall. As the job finding probability of domestic skilled workers falls, this eventually leads to a rise in their unemployment rate. Due to higher outside option and higher costs of Home vacancy postings, Home intermediate firms substitute towards vacancies posted offshore. (This causes Home skilled unemployment to rise. Additionally, since the fall in probability μ causes a rise in immigrant workers searching for jobs that is larger than the rise in U_d, firms are more likely to get matched with immigrant workers. This decline in skilled wages and worker separation causes Home vacancies to rise, however, they do not rise by enough to counter the falling probability q_d as the stock l_d falls. In comparing welfare results with competitive labor markets, the rise in Home skilled unemployment and eventual decline in Home skilled wages leads to a decline in welfare of Home skilled. Further, Home skilled profits fall on impact rather than rise as under competitive labor markets, since the firm needs to take on additional costs of vacancy postings when the immigration cap is reduced. Eventually these profits rise due to the reduction in the wage bill, however, the outflow of offshoring related payments, and reduced immigrant population reduces the profits of consumption good producers.

Again we consider the case when home skilled households are separated into entrepreneurs and labor. From the results in Table 2.6, we clearly see that home skilled labor is hurt by the cap reduction, and this loss in welfare is due to rising home skilled unemployment that leads to falling skilled wages. Additionally, entrepreneurs lose by more than under competitive labor markets as they are faced with greater labor shortages, and rising vacancy posting costs.

2.8 Conclusion

In this paper, we introduce a two-country dynamic general equilibrium model with skilled immigration, offshore labor hiring, and trade in skill-intensive intermediate inputs. We employ the calibrated model to study the interaction between skilled immigration policy changes in the U.S. and offshore labor hiring in the skilled services sector. In the model, a lower skilled immigration cap increases offshoring at the intensive margin. We show that it is important to take into account firm adjustment in offshoring following immigration policy changes. In particular, if we did not account for an adjustment in offshoring, we would overestimate the wage benefits for native skilled workers from reducing skilled immigration. Therefore, it is important to account for the role of offshoring. Yet, much of the current literature has ignored this channel when evaluating the impact of skilled immigration policy changes.

By studying the interaction between skilled immigration policy changes and offshoring in a dynamic general equilibrium model, we are able to highlight other channels that influence the impacts of immigration policy changes —for instance, the distribution of firm profits and the presence of labor market frictions. However, the model is a first step in studying the interaction between skilled immigration policies and offshoring in the skilled services sector. It abstracts from the role of firm heterogeneity, the extensive margin of offshoring, and the role of other temporary work visas for skilled workers (for instance, L1 visas are important for multinational firms). Moreover, the search and matching model extension currently does not feature Foreign households' decision to migrate to Home and search for jobs. All these are important channels and we leave this for future work.

2.9 Tables

Table 2.1: A Priori Parameters

A Priori Parameters	Value	Target
Discount Factor	$\beta = 0.96$	
Elasticity of Substitution	$\phi = \theta = 3.8$	
Return migration	$\delta = 0.1$	Average return migration
Cap	$\bar{N}_e = 0.0022$	Cap/Domestic Skilled Labor
Domestic unskilled labor	$\bar{l}_u = 1.84$	Proportion of U.S. unskilled labor
Foreign skilled labor	$\bar{L}_s^* = 1.2$	India's skilled labor/U.S. skilled labor
Foreign unskilled labor	$\bar{l}_u^* = 4.84$	Proportion of Indian unskilled

Table 2.2: Targeted Moments

Target	Data	Model
Share of exports in skilled service sector GDP	0.12	0.16
Share of imports in skilled service sector GDP	0.09	0.07
Average fraction of immigrant applications approved	0.40	0.40
Skill Premium	1.85	1.20

Table 2.3: Calibrated Parameters

Calibrated Parameters	Value
Skill Intensity	$\alpha = 0.40$
Mass of Foreign Intermediate Firms	$N_d^* = 0.3765$
Sunk Immigration Cost	$f_R = 0.1274$
Iceberg Trade Cost	$\tau = 1.1078$
Fixed Offshoring Cost	$f_o = 0.4836$

Table 2.4: Welfare Impact of 10 Percent Immigration Cap Reduction

Profit Earners (Scenario)	Home, Skilled	Home, Unskilled	Home, Entrepreneurs
Home Skilled (Offshoring)	0.0104	-0.0663	
Entrepreneurs (Offshoring)	0.0996	-0.0663	-0.0838
Home Skilled (No Offshoring)	0.0183	-0.0602	
Entrepreneurs (No Offshoring)	0.1138	-0.0602	-0.0860

Note: Values reported above are in percent of initial steady-state consumption.

Table 2.5: Calibrated Parameters Under Labor Market Frictions

Calibrated Parameters	Value
Foreign Vacancy Posting Cost	$\kappa^* = 1.4908$
Offshore Vacancy Posting Cost	$\kappa_o^* = 0.2000$
Domestic Exogenous Job Separation	$\delta_d = 0.0378$
Immigrant Exogenous Job Separation	$\delta_f = 0.0725$
Foreign Exogenous Job Separation	$\delta^* = 0.0719$
Matching Function Efficiency	$\chi = 0.6913$

Table 2.6: Welfare Impact of a 10 Percent Immigration Cap Reduction: Competitive versus Frictional Labor Markets

Competitive Labor Markets

Profit Earners	Skilled	Unskilled	Entrepreneurs
Home Skilled	0.0104	-0.0663	
Entrepreneurs	0.0996	-0.0663	-0.0838

Frictional Labor Markets

Profit Earners	Skilled	Unskilled	Entrepreneurs
Home Skilled	-0.0544	-0.1038	
Entrepreneurs	-0.0298	-0.1041	-0.0653

Note: Values reported above are in percent of initial steady-state consumption.

2.10 Figures

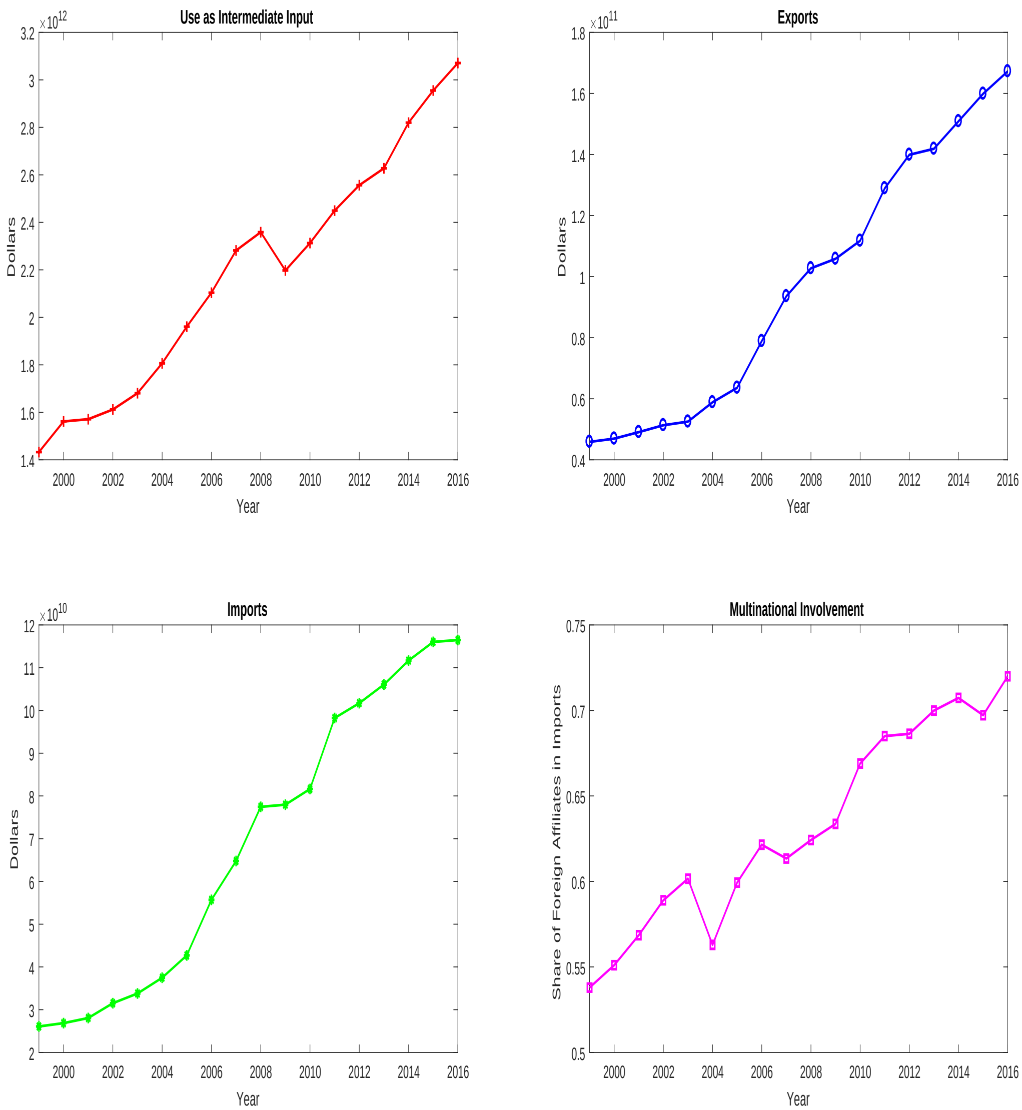

Figure 2.1: Rising Importance of Skilled Service Sector for U.S.

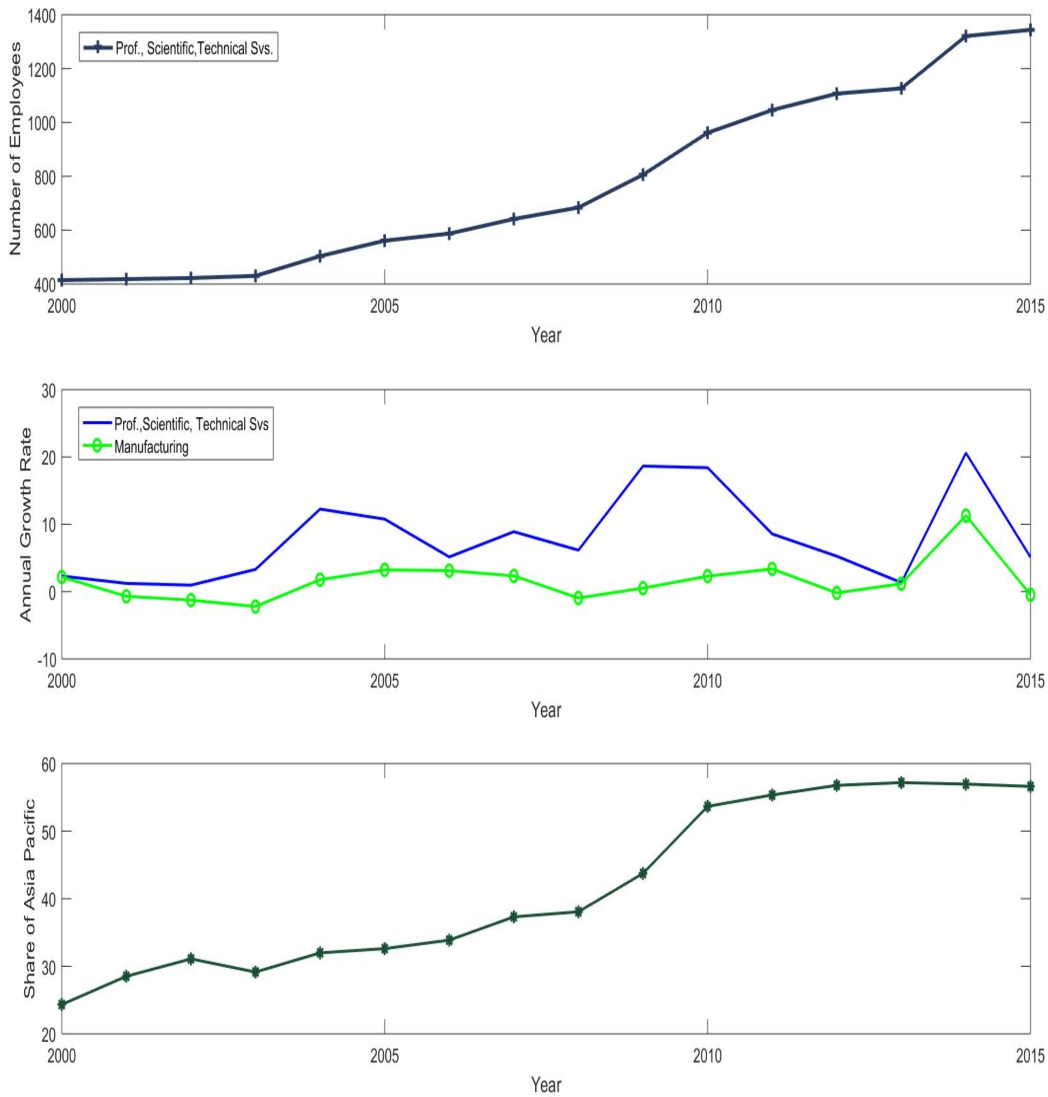

Figure 2.2: Employment at Foreign Affiliates in Professional, Scientific, and Technical Services

Note: Number of Employees are in thousands for the first panel, and the annual growth rates and share of Asia-Pacific are in percentages in the second and third panels, respectively.

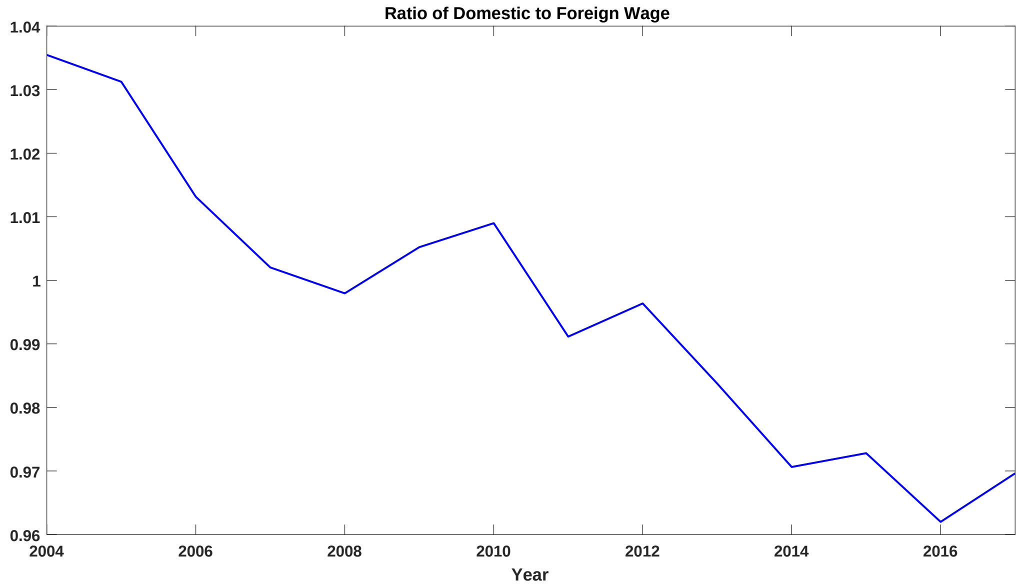

Figure 2.3: Earnings of Native Born as Percent of Foreign Born: Bachelor's Degree and Higher, 25 Years and Over

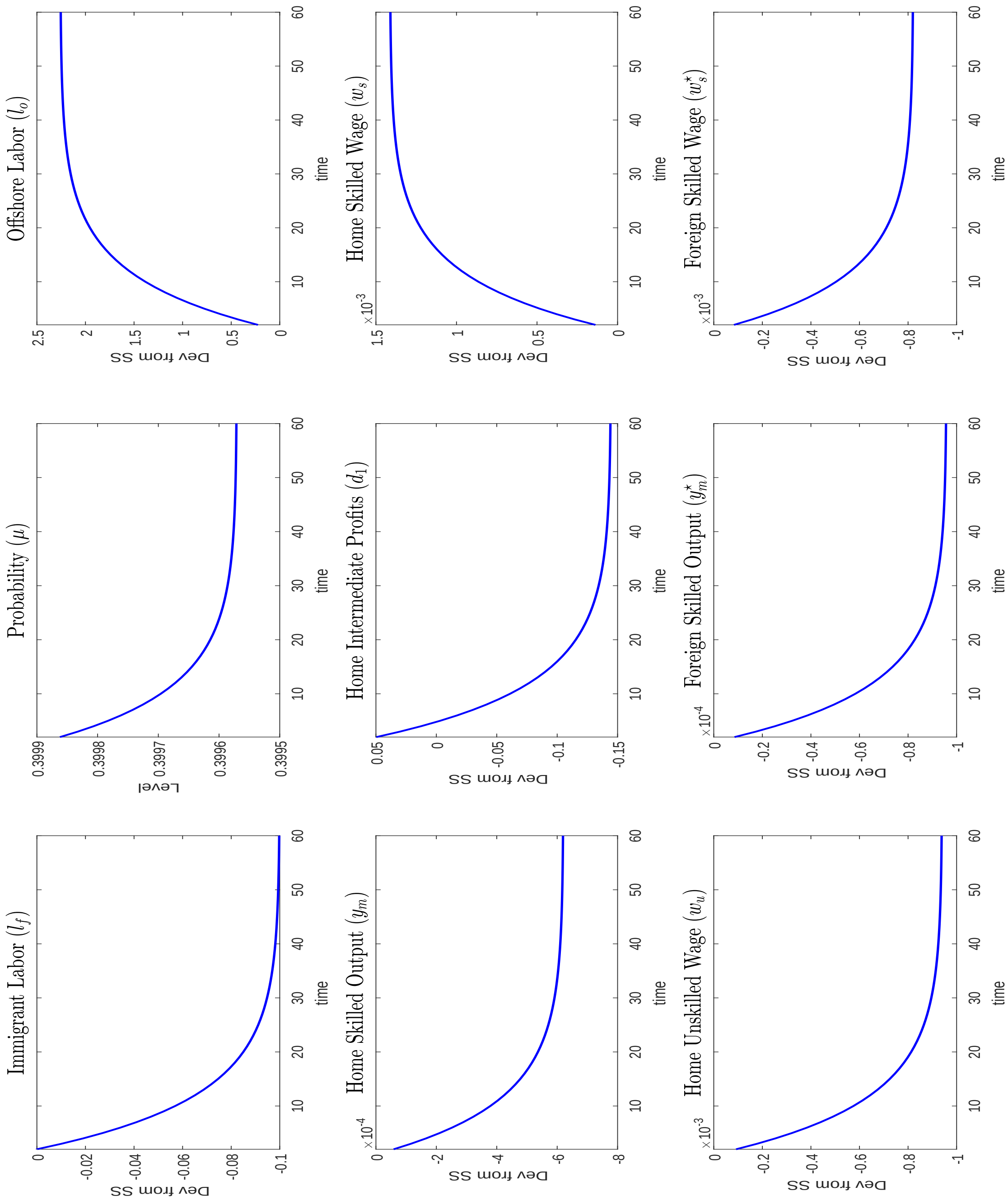

Figure 2.4: Response to a 10 Percent Immigration Cap Reduction in Baseline Model

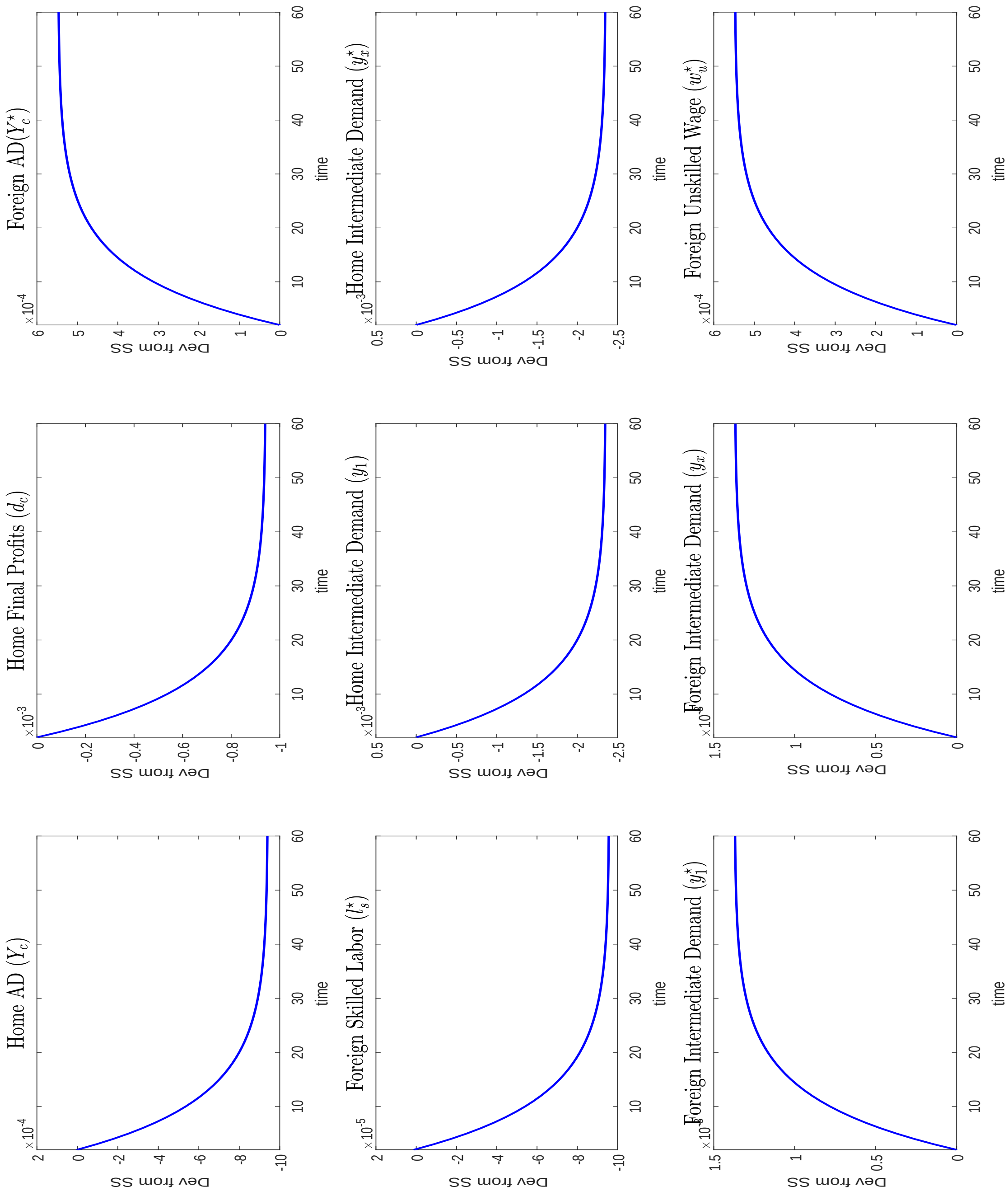

Figure 2.5: Response to a 10 Percent Immigration Cap Reduction in Baseline Model

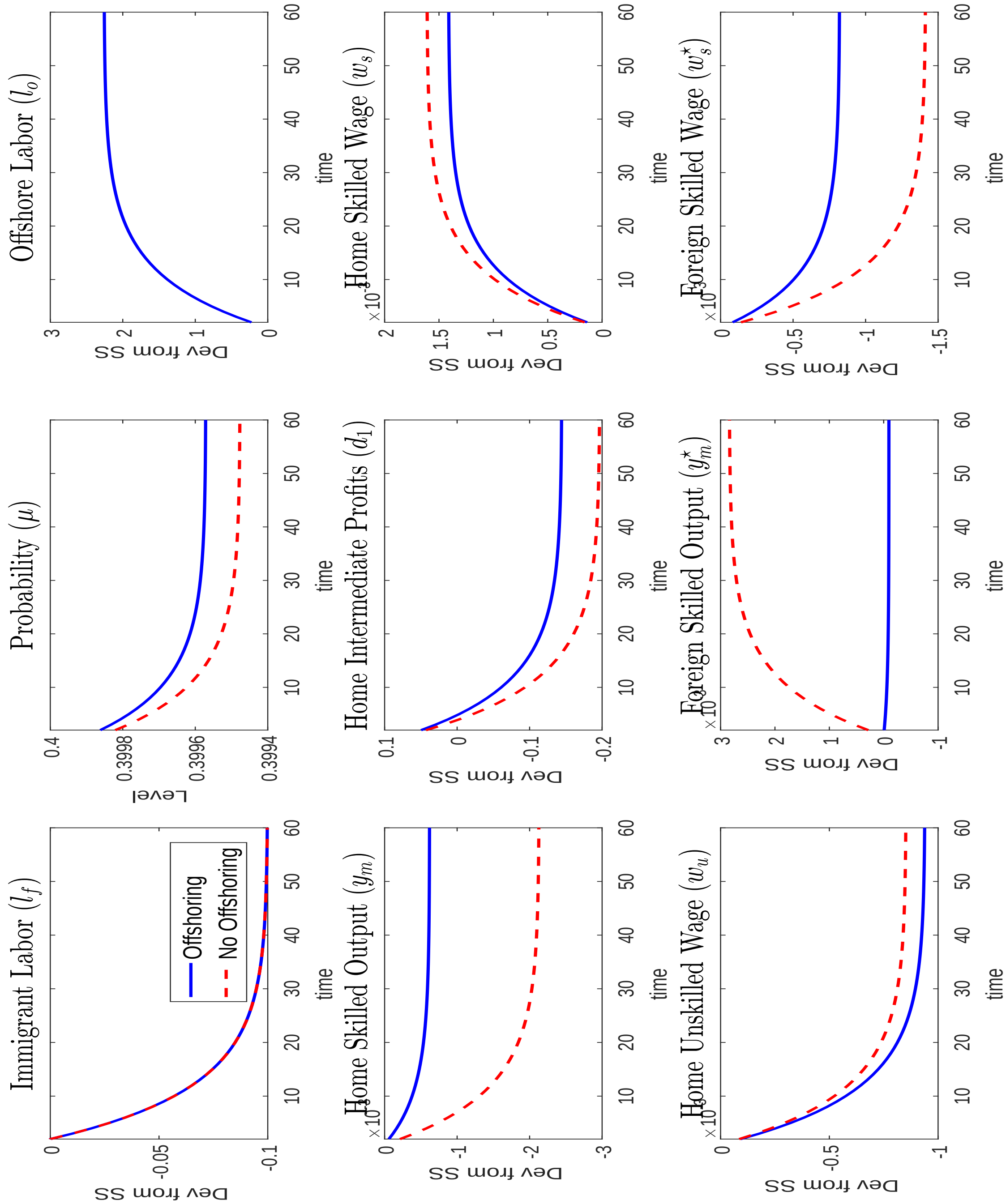

Figure 2.6: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus No Offshoring

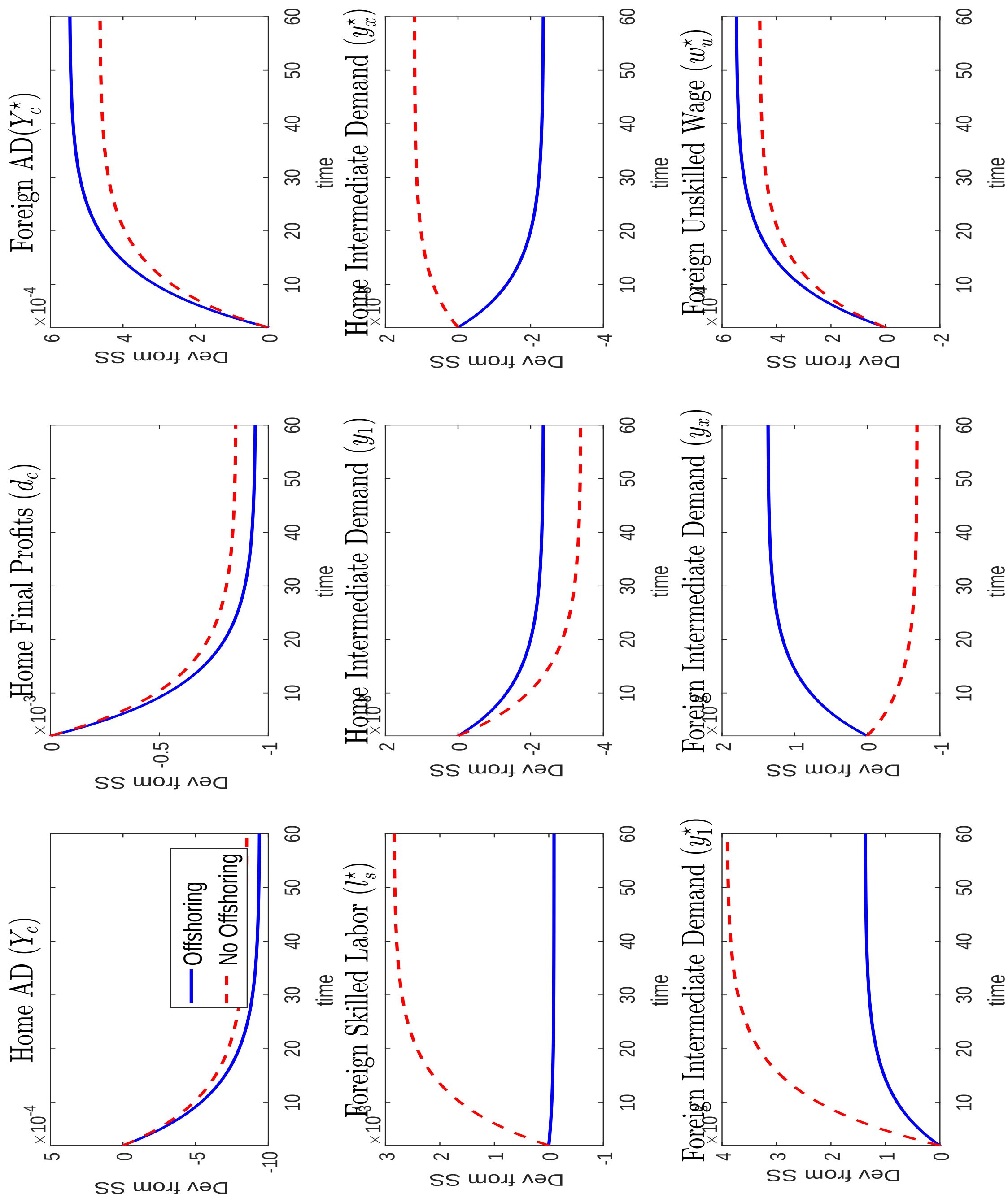

Figure 2.7: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus No Offshoring

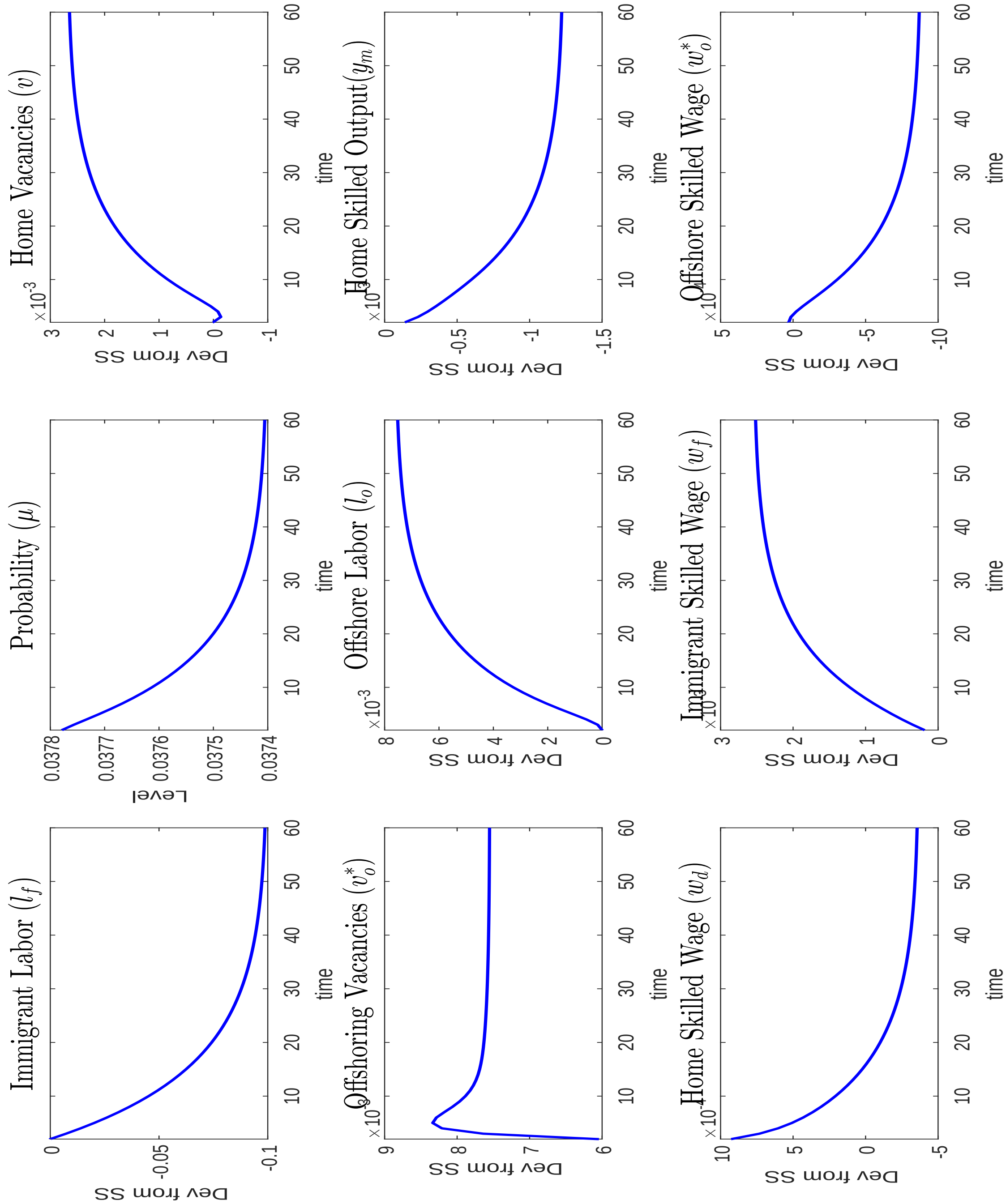

Figure 2.8: Response to a 10 Percent Immigration Cap Reduction with Labor Market Frictions

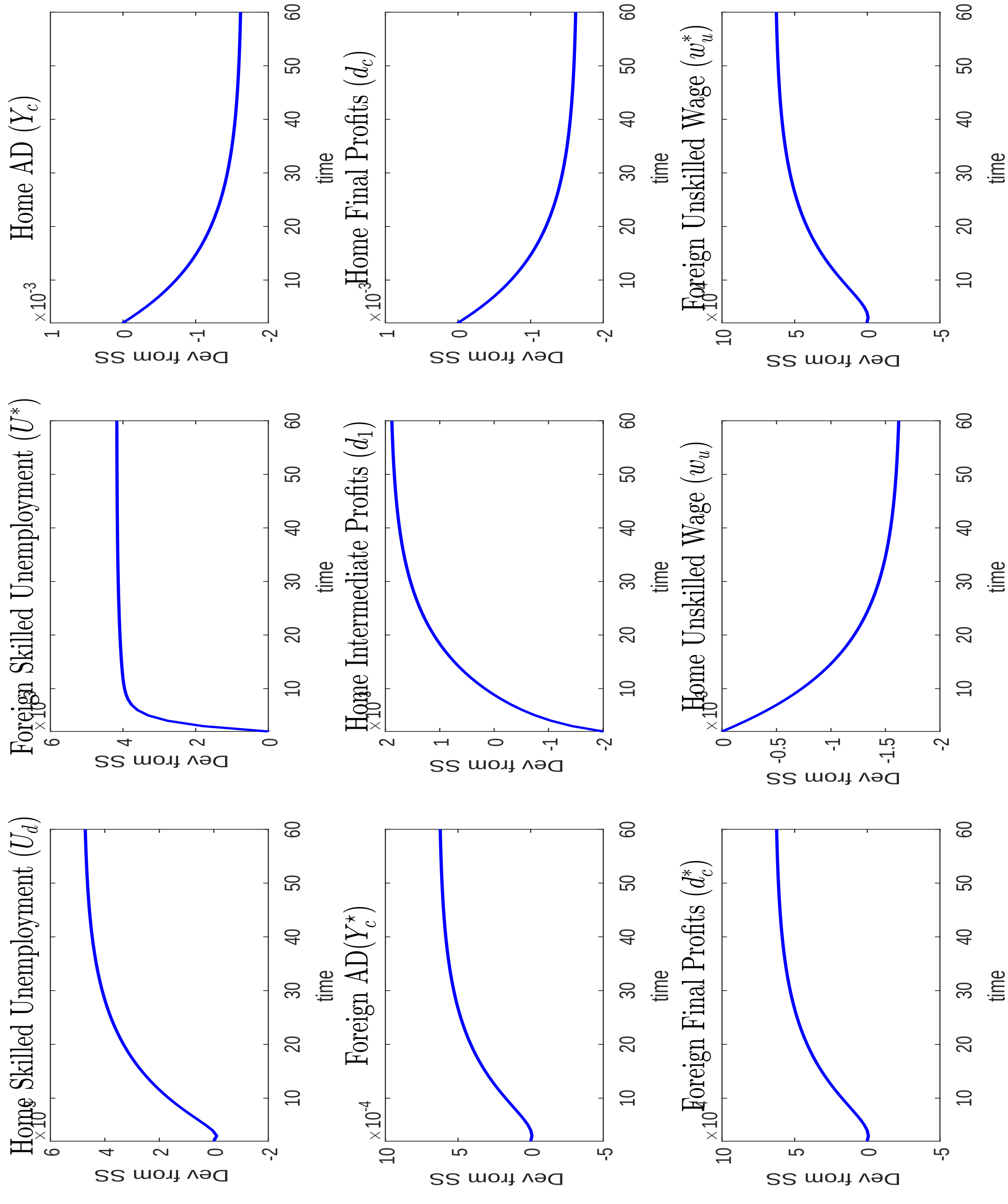

Figure 2.9: Response to a 10 Percent Immigration Cap Reduction with Labor Market Frictions

Chapter 3

AN ESTIMATED MODEL OF HIGH-SKILLED MIGRATION WITH SEARCH AND MATCHING FRICTIONS

Federico Mandelman and Mishita Mehra

3.1 Introduction

This chapter takes a step in estimating a search and matching model with skilled immigration. Labor market parameters such as the bargaining share of workers play an important role in equilibrium efficiency (Hosios (1990)). However, it is difficult to pin down some of these parameters, which creates potential problems for calibration (Lubik (2009)). This may be of particular relevance for models with skilled immigration as native and foreign-born workers may have different bargaining powers. These parameters are not only important for quantifying inefficiency in the economy, but may also influence how the economy responds to economic fluctuations and to policy changes.

Motivated by this, we present a search and matching model with skilled immigration.[1] In the model, monopolistically competitive firms in the skill-intensive sector post vacancies and can be matched to either a skilled foreign worker or to a skilled domestic worker. The probability of getting matched to either worker depends on relative fraction of each worker type searching for jobs. However, there is a policy-imposed cap and additional cost of hiring foreign workers. We treat the model as a data generation process for a set of aggregate variables and estimate some of the model parameters using Bayesian methods using U.S. quarterly data from 1995 to 2017.

[1] This is similar to the model extension presented in chapter 1. The major differences are homogenous production technology in the skill-intensive sector, an immigration policy cap that always binds, and endogenous outside options of foreign workers.

The main labor market parameters that we estimate to begin with are the elasticity of the matching function and the bargaining shares of skilled foreign and skilled native workers. Preliminary results highlight that the bargaining power of domestic skilled workers is higher than the bargaining power of foreign skilled workers. Moreover, the bargaining power of both type of workers is different from the elasticity of the matching function, implying a departure from the Hosios condition in this framework. Preliminary analysis also shows that these results are generally robust across different sets of observables and shock processes.

In the future, we plan to employ these estimated parameters to analyze the implication of skilled immigration policy reform.

3.2 Model

3.2.1 Households

The domestic economy consists of a continuum of three types of infinitely-lived households that supply units of skilled and unskilled labor inelastically. Each skilled and unskilled representative household has the same preferences over a basket of goods produced at Home. The lifetime utility of skilled domestic (d), skilled immigrant (f), and unskilled domestic (u) households is given by:

$$\max_{C_{j,t}} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \Big(lnC_{j,\tau} \Big) \quad \forall j \in \{d, f, u\} \tag{3.1}$$

where $C_{j.t} = (\frac{c_{1,t}}{\alpha})^{\alpha}(\frac{c_{2,t}}{1-\alpha})^{1-\alpha}$ is the consumption basket of each household. $c_{1,t}$ is the basket of sector 1 goods consumed, and $c_{2,t}$ is the sector 2 good consumed. $\alpha \in (0, 1]$ is the weight of sector 1 goods in consumption. The consumption-based price index is $P_t = (p_{1,t})^{\alpha}(p_{2,t})^{1-\alpha}$, where $p_{1,t}$ and $p_{2,t}$ are the price indices of sector 1 and sector 2 goods, respectively. The price indices in units of the consumption basket are $\rho_{1,t} = p_{1,t}/P_t$ and $\rho_{2,t} = p_{2,t}/P_t$. Therefore, the consumption-based price index can also be expressed as $1 = (\rho_{1,t})^{\alpha}(\rho_{2,t})^{1-\alpha}$ in units of the consumption basket. The basket of sector 1 goods is given by $c_{1,t} = \int_{\omega \in \Omega} (c_{1,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega)^{\frac{\theta}{\theta-1}}$, where $\theta > 1$ is households' symmetric elasticity of substitution across sector 1 goods. Thus, the price index of sector 1 output is $p_{1,t} = \int_{\omega\in\Omega}(p_{1,t}(\omega)^{1-\theta}d\omega)^{\frac{1}{1-\theta}}$ where $p_{1,t}(\omega)$ is the price of the good ω. The demand for each good in sector 1 by household type $j \in \{s,u\}$ is given by $\alpha(\frac{p_{1,t}(\omega)}{p_{1.t}})^{-\theta}\frac{P_t}{p_{1,t}}C_{j,t}$ or $\alpha(\frac{\rho_{1,t}(\omega)}{\rho_{1.t}})^{-\theta}\frac{1}{\rho_{1,t}}C_{j,t}$.

The demand for the sector 2 good by household j is given by $(1-\alpha)\frac{P_t}{p_{2,t}}C_{j,t} = (1-\alpha)\frac{1}{\rho_{2,t}}C_{j,t}$, where $\rho_{2,t}$ is the price of sector 2 output in units of the consumption basket. The labor supply of the representative unskilled household is normalized to $\bar{l}_u$. Unskilled households consume their labor income i.e. $C_{u,t} = w_{u,t}l_{u,t}$, where $w_{u,t}$ is the real wage paid to unskilled labor, and is determined competitively in a separate labor market for unskilled labor. Skilled domestic households pool income and their consumption is given by $C_{d,t} = w_{d,t}l_{d,t} + d_t$, where d_t is the profit income of sector 1 firms in units of the consumption basket (skilled domestic households are the skill-intensive sector's firm owners in the baseline model). $w_{d,t}$ is the real wage paid to skilled domestic labor, which is determined in the labor market via Nash bargaining. The mass of employed domestic skilled workers ($l_{d,t}$) is determined in the labor market via the matching process. The total mass of domestic skilled households in the labor force is given by $\bar{L}_{d,t}$, where $\bar{L}_{d,t} = \varepsilon_t^{ld}\bar{l}_d$, where ε_t^{ld} is a shock to the domestic skilled labor force and follows an AR(1) process in logs. The mass of unemployed domestic skilled workers is given by $u_{d,t} = \bar{L}_{d,t} - l_{d,t}$. The mass of employed and unemployed immigrant skilled workers is determined similarly and is given by $l_{f,t}$ and $u_{f,t} = \bar{L}_{f,t} - l_{f,t}$, where $\bar{L}_{f,t} = \varepsilon_t^{lf}\bar{l}_f$, and ε_t^{lf} also follows an AR(1) process in logs. Consumption of skilled immigrants is given by $C_{f,t} = w_{f,t}l_{f,t}$, where $w_{f,t}$ is wages of skilled immigrant workers, also determined via Nash bargaining in the labor market for skilled workers.

3.2.2 Labor Market in the Skill-Intensive Sector

There is a constant mass of firms in the skill-intensive sector that produce output using domestic and foreign skilled labor. Each monopolistically competitive firm produces differentiated varieties (indexed by ω) using an identical technology given by $y_{1,t}(\omega) = Z_t(l_{f,t}(\omega) + l_{d,t}(\omega))$, where $l_{d,t}$ and $l_{f,t}$ are the domestic and foreign skilled workers employed by the firm, respectively. Z_t is the aggregate productivity that follows at AR(1) process in logs. In order to hire skilled workers, firms post vacancies (at cost κ) for hiring skilled workers and they can be matched with either domestic or immigrant skilled workers, depending on the relative proportion of job searchers of each type. The matching function is given by $m(v_t, u_t) = \chi_t u_t^{\epsilon} v_t^{1-\epsilon}$, where ϵ is the matching function elasticity, χ_t is the matching function efficiency, $u_t = u_{d,t} + u_{f,t}$ is the total mass of job searchers (including immigrant $u_{f,t}$ and domestic $u_{d,t}$), and v_t is the total vacancies posted by firms. The matching function efficiency χ_t is given by $\chi_t = \chi \varepsilon_t^{\chi}$, where ε_t^{χ} is a shock to the matching efficiency. The probability of matching with a skilled worker (domestic or foreign) is given by $\mu_t = \chi_t (\frac{v_t}{u_t})^{-\epsilon}$. The probability of matching with a domestic skilled worker is given by $q_{d,t} = \frac{u_{d,t}}{u_{d,t}+u_{f,t}} \chi_t (\frac{v_t}{u_{d,t}+u_{f,t}})^{-\epsilon}$ and the probability of matching with a foreign skilled worker is $q_{f,t} = \frac{u_{f,t}}{u_{d,t}+u_{f,t}} \chi_t (\frac{v_t}{u_{d,t}+u_{f,t}})^{-\epsilon}$. However, there is an immigration policy imposed cap on the total number of foreign skilled matches that a firm can 'bring to the firm'. The probability of an application for an immigrant skilled worker being selected is given by

$$q_t = \frac{\bar{N}_{e,t}}{q_{f,t} v_t} \tag{3.2}$$

where $\bar{N}_{e,t}$ is the cap on foreign workers and $q_{f,t} v_t$ is the total number of matches with foreign workers. The cap is always binding in this framework. Moreover, for all foreign matches, firms have to pay a sunk cost f_r (to capture restrictive administrative procedures imposed by skilled immigration policy). Since firms are able to retain only a fraction of their foreign matches, the stock of foreign workers evolves according to $l_{f,t}(\omega) = (1 - \delta_f)(l_{f,t-1}(\omega) + v_{t-1}(\omega) q_{f,t-1} q_{t-1})$. The stock of domestic workers employed is given by $l_{d,t}(\omega) = (1 - \delta_d)(l_{d,t-1}(\omega) + v_{t-1}(\omega) q_{d,t-1})$.

Firm's Profit Maximization Problem:

Each firm's profit maximization is given by

$$\max_{\left\{(\rho_{1,t}(\omega), v_t(\omega), l_{f,t}(\omega), l_{d,t}(\omega)\right\}_{t=0}^{\infty}} E_t \sum_{\tau=t}^{\infty} \beta_{\tau,t} \Big[\rho_{1,\tau}(\omega) y_{1,\tau}(\omega) - w_{d,\tau}(\omega) l_{d,\tau}(\omega) - w_{f,\tau}(\omega) l_{f,\tau}(\omega) - \kappa v_\tau(\omega) - q_{f,\tau}(\omega) v_\tau(\omega) f_r \Big]$$

subject to following constraints:

1. Production Technology:

$$y_{1,t}(\omega) = Z_t(l_{f,t}(\omega) + l_{d,t}(\omega)) \tag{3.3}$$

2. Stock of domestic workers:

$$l_{d,t}(\omega) = (1 - \delta_d)(l_{d,t-1}(\omega) + v_{t-1}(\omega)q_{d,t-1}) \tag{3.4}$$

3. Stock of foreign workers:

$$l_{f,t}(\omega) = (1 - \delta_f)(l_{f,t-1}(\omega) + v_{t-1}(\omega)q_{f,t-1}q_{t-1}) \tag{3.5}$$

4. Demand:

$$y_{1,t}(\omega) = (\frac{\rho_{1,t}(\omega)}{\rho_{1,t}})^{-\theta} Y_t^c / \rho_{1,t} \tag{3.6}$$

$\beta_{t,t+1}$ is the stochastic discount factor which is the stochastic discount factor of domestic skilled households as they are the firm owners in the baseline setup. The hiring condition is given by (from the F.O.C. with respect to v_t):

$$\kappa = (1 - \delta_d)E_t[\beta_{t,t+1}\Gamma_{d,t+1}(\omega)]q_{d,t} + (1 - \delta_f)E_t[\beta_{t,t+1}\Gamma_{f,t+1}(\omega)]q_{f,t}q_t - f_r q_{f,t} \tag{3.7}$$

where $\Gamma_{d,t}$ is the Lagrange Multiplier (LM) on (3.4) and $\Gamma_{f,t}$ is the LM on (3.5) and these are also the surplus from the respective matches. The F.O.C w.r.t $l_{d,t}$ and $l_{f,t}$ give

$$\Gamma_{d,t}(\omega) = \Xi_t(\omega)Z_t - w_{d,t}(\omega) + (1 - \delta_d)E_t[\beta_{t,t+1}\Gamma_{d,t+1}(\omega)] \tag{3.8}$$

$$\Gamma_{f,t}(\omega) = \Xi_t(\omega)Z_t - w_{f,t}(\omega) + (1 - \delta_f)E_t[\beta_{t,t+1}\Gamma_{d,t+1}(\omega)] \tag{3.9}$$

Ξ_t is the LM on (3.3) and is the real marginal cost of production. (3.8) and (3.9) state that the surplus from the matches is just the value of output generated by each match net of wages plus the continuation value of the match.

Wages: Nash Bargaining

Wages are determined by a surplus sharing rule given by $\eta_i S_{i,t}^F(\omega) = (1 - \eta_i) S_{i,t}^W(\omega) \quad \forall i \in$

$\{d, f\}$, where η_i is the bargaining power of worker $i \in \{\text{domestic}, \text{foreign}\}$. S^F is the firm's surplus and S^W is the worker's surplus from the match. Workers' surplus is given by wage minus outside option plus the continuation value of match:

$$\begin{aligned} S^W_{d,t}(\omega) &= w_{d,t}(\omega) - \varpi_{d,t} + (1-\delta_d)E_t\beta_{t,t+1}S^W_{d,t+1}(\omega) \\ S^W_{f,t}(\omega) &= w_{f,t}(\omega) - \varpi_{f,t} + (1-\delta_f)E_t\beta^f_{t,t+1}S^W_{f,t+1}(\omega) \end{aligned}$$

$\beta^f_{t,t+1}$ is the stochastic discount factor of foreign skilled households which may differ from that of domestic households and firms as foreign households are not firm owners in the baseline setup. $\varpi_{i,t}$ is worker i's outside option described below. Since there are no firing costs, firm surplus is given by $S^F_{i,t} = \Gamma_{i,t}$ Since all firms are symmetric, we drop the index ω below. Using expressions for $\Gamma_{i,t}$, $S^W_{i,t}$, and the surplus sharing rule, we can get the solution for domestic and foreign skilled wages as:

$$w_{d,t} = \eta_d(\Xi_t Z_t) + (1-\eta_d)\varpi_{d,t} \tag{3.10}$$

$$w_{f,t} = \eta_f(\Xi_t Z_t) + (1-\eta_f)\varpi_{f,t} + (1-\delta_f)E_t[\Gamma_{f,t+1}(\beta_{t,t+1} - \beta^f_{t,t+1})] \tag{3.11}$$

where the last term in (3.11) comes from different stochastic discount factors of firms and foreign households Under the assumption of no unemployment benefits in the baseline case, the only outside option of workers is the expected surplus from searching for a job in the next period (taking into account the probability that the potential match will survive). Therefore the outside options are given by:

$$\varpi_{d,t} = E_t[\beta_{t,t+1} i_{d,t+1}(1-\delta_d)S^W_{d,t+1}]$$

$$\varpi_{f,t} = E_t[\beta_{t,t+1} i_{f,t+1}(1-\delta_f)S^W_{f,t+1}]$$

where $i_{d,t}$ and $i_{f,t}$ are the job finding probabilities of a skilled domestic and foreign worker, respectively, and are given by:

$$i_{d,t} = \frac{u_{d,t}}{u_{d,t} + u_{f,t}}\chi_t(\frac{v_t}{u_{d,t} + u_{f,t}})^{1-\epsilon}$$

$$i_{f,t} = \frac{u_{f,t}}{u_{d,t} + u_{f,t}} \chi_t (\frac{v_t}{u_{d,t} + u_{f,t}})^{1-\epsilon} \tag{3.12}$$

The job finding probabilities of workers are also weighed by the proportion of workers searching for jobs. The job finding probability of skilled worker (either domestic or foreign) is given by $i_t = \chi_t(\frac{v_t}{u_{d,t}+u_{f,t}})^{1-\epsilon}$. Using $S^W_{i,t} = \frac{\eta_i}{(1-\eta_i)} S^F_{i,t}$ (from surplus sharing rule) and using $S^F_{i,t} = \Gamma_{i,t}$, we can write outside option of workers as:

$$\varpi_{d,t} = E_t[\beta_{t,t+1} i_{d,t+1}(1-\delta_d)\frac{\eta_d}{(1-\eta_d)}\Gamma_{d,t+1}] \tag{3.13}$$

$$\varpi_{f,t} = E_t[\beta_{t,t+1} i_{f,t+1}(1-\delta_f)\frac{\eta_f}{(1-\eta_f)}\Gamma_{f,t+1}] \tag{3.14}$$

Profit maximization by firms implies that prices are a markup over marginal cost: $\rho_{1,t} = \frac{\theta}{\theta-1}\Xi_t$ Period t profits of firms in the skill-intensive sector is given by $d_t = \rho_{1,t} y_{1,t} - w_{d,t} l_{d,t} - w_{f,t} l_{f,t} - \kappa v_t - f_r q_{f,t} v_t$

The Unskilled Sector

Production technology for perfectly competitive firms using unskilled labor is given by $y_{2,t} = Z_t l_{u,t}$. Prices of symmetric firms in units of the consumption basket is the real marginal cost of production: $\rho_{2,t} = w_{u,t}/Z_t$.

Aggregate Accounting in the Home Economy

Aggregate accounting implies that aggregate output is equal to the aggregate demand in units of the consumption basket: $\rho_{1,t} y_{1,t} + \rho_{2,t} y_{2,t} = Y^c_t$, where $Y^c_t = C_{u,t} + C_{s,t} + C_{f,t} + \kappa v_t + f_r q_{f,t} v_t$. Since all firms are symmetric, the goods market clearing for skilled sector output is given by $y_{1,t} = \alpha Y^c_t/\rho_{1,t}$ and for unskilled sector output is given by $y_{2,t} = (1-\alpha)Y^c_t/\rho_{2,t}$. The decentralized equilibrium allocation is determined as a solution of 30 equations in 30 variables: $\rho_{1,t}$, $\rho_{2,t}$, $C_{f,t}$, $C_{d,t}$, $C_{u,t}$, $w_{d,t}$, $w_{f,t}$, $w_{u,t}$, d_t, $l_{f,t}$, $l_{d,t}$, $u_{d,t}$, $u_{f,t}$, q_t, $q_{d,t}$, $q_{f,t}$, $y_{1,t}$, v_t, $\Gamma_{d,t}$, $\Gamma_{f,t}$, Ξ_t, $\varpi_{d,t}$, $\varpi_{f,t}$, $y_{2,t}$, $i_{d,t}$, $i_{f,t}$, Z_t, χ_t, $\bar{L}_{d,t}$, $\bar{L}_{f,t}$, where the last four are exogenous shock processes.

3.3 Bayesian Estimation

We estimate the model presented above using Bayesian estimation techniques that uses a general equilibrium approach and fits the solved DSGE model to a vector of aggregate time series (see Fernandez-Villaverde and Rubio-Ramirez (2004) for additional details).[2] The model is estimated over the sample period from 1995:1 through 2017:4.

3.3.1 Data

The number of data series used in the estimation cannot exceed the number of structural shocks in the model. Since we have four exogenous shock processes, we use four U.S. quarterly data series for the baseline estimation: output, unemployment of domestic skilled workers, employment of domestic skilled workers, and unemployment of foreign-born skilled workers for the sample period 1995:1 through 2017:4. For robustness checks, we also consider alternate series on wages of domestic skilled workers, wages of foreign skilled workers, and the job finding rate of skilled workers. Output is defined as seasonally adjusted real gross domestic product in chained 2009 dollars from the Federal Reserve Bank of St. Louis. Quarterly data from 1995 to 2017 for employment and unemployment of domestic and foreign workers is computed from the monthly Current Population Survey (CPS) data. Average quarterly domestic and foreign wages are computed using weekly wage data of skilled foreign and native-born workers in private non-farm employment from the CPS. The wage data is deflated using the CPI deflater to convert it in real units. We seasonally adjust each data series using the X-12 ARIMA method. The job finding for skilled workers is computed using de-seasonalized monthly CPS data data as in Shimer (2005). Each de-seasonalized data series is expressed in natural logs, then detrended using a linear trendand then first-differenced to obtain growth rates. The detrended data series (in growth rate) used in the baseline estimation is plotted

[2]The main idea is to first estimate the mode of the posterior distribution by maximizing the log posterior function, which combines the prior information on the parameters with the likelihood of the data. In a second step, the Metropolis-Hastings algorithm is used to get a complete picture of the posterior distribution and to evaluate the marginal likelihood of the model.

in Figure 3.2. All seasonally adjusted non-detrended data used in estimation and calibration is plotted in Figures 3.3 - 3.12.

3.3.2 Calibration

Some parameters are kept fixed in the estimation. The discount rate β is set to 0.99, as is standard in the literature. We set the elasticity of substitution across product varieties to $\theta = 3.8$ (Bernard, Eaton, Jensen, and Kortum (2003)). We normalize the vacancy posting cost κ to 1. The share of sector 1 goods in consumption is set at $\alpha = 0.5$ to match the average share of unskilled income in total aggregate income over the period 1995 to 2017.[3] The domestic skilled labor force $\bar{L}_d$ is normalized to 1 and given this normalization, the domestic unskilled labor supply is calibrated to $\bar{L}_u = 2.22$ to match the average share of domestic workers over this time period with less than a bachelor's degree of 31 percent. The immigration cap $\bar{N}_e$ is set to 0.00021 in order to match the average (quarterly) cap imposed by actual policy over the 1995 to 2017 period as a proportion of the normalized average domestic skilled labor in the economy. The total foreign skilled workers in the U.S. labor force is set to $\bar{L}_f = 0.1875$ to match the average skilled foreign labor in the U.S as a proportion of the average skilled domestic labor. The separation rates δ_d and δ_f are set to 0.036 and 0.06 to match the average quarterly separation rates computed using monthly CPS data as in Shimer (2005). The sunk cost of immigration and the efficiency of the matching function are jointly calibrated at $f_R = 0.12$ and $\chi = 0.68$ to target the average job finding probability of skilled workers ($i = 0.71$) and the average ratio of native skilled wages to foreign skilled wages ($w_d/w_f = 1.01$).

3.3.3 Prior Distribution

Table 3.1 presents the calibrated parameters and the mean and standard deviations of the prior distributions of the parameters $\{\eta_d, \eta_f, \epsilon, \phi_z, \phi_d, \phi_f, \phi_c\}$ and shock processes $\{\sigma_e, \sigma_{ld}, \sigma_{lf}, \sigma_\chi\}\}$

[3]This follows from sector two's good market clearing: $Z\bar{l}_u = (1-\alpha)Y^c/\rho_2$, which implies that $w_u\bar{l}_uY^c = (1-\alpha)$.

to be estimated, along with their respective densities. The shapes of the densities are selected to match the domain of the structural parameters, and we deduce the prior mean and distribution from previous studies. The prior mean for the elasticity of the matching function ϵ is set to 0.5, which is the commonly used value in the literature (Petrongolo and Pissarides (2001)). We allow for a relatively large interval as these values are not uncontroversial (Lubik (2009)). Following most calibration exercises that set the bargaining share of workers to be the same as the elasticity of the matching function (so that the Hosios condition is met), we set the prior mean of both bargaining shares as 0.5. However, since these parameters are of key interest to us as they have potential implications for efficiency and for the impact of policy changes, we choose a relatively loose prior for these parameters in order to gain information from the data. Following Lubik (2009), we use a uniform distribution prior with a relatively wide coverage interval for the bargaining share of workers. We do not have much prior information about the magnitude of shocks. The prior for the standard errors of the stochastic components $\{e, \sigma_{ld}, \sigma_{lf}, \sigma_{\chi}\}$ is assumed to follow Inverse Gamma distributions with (a degree of freedom 2) as such a distribution delivers positive values with a relatively large domain. The prior distribution of the autoregressive parameters of the shocks follows a Beta distribution that covers the range between 0 and 1.

3.4 Preliminary Estimation Results (Posterior Distributions)

Figure 1 shows the prior and posterior density of the parameters. The plots show that the marginal posteriors and the priors differ, which signals that the data are relatively informative about the values of the estimated parameters. Table 2 reports the posterior mean and 90% probability interval of the structural parameters. The posterior mean of the bargaining share of domestic and foreign workers are different and the bargaining power of domestic skilled workers is higher than the bargaining power of foreign skilled workers. Moreover, the bargaining share of both type of workers is different from the elasticity of the matching function, implying departures from the Hosios condition in this framework. Preliminary analysis also shows that these results are generally robust across alternate data series used as observations — wages of foreign-born workers, wages of domestic-born workers, and job finding rate of skilled workers.

3.5 Conclusion and Future Work

This chapter presents a very preliminary estimation of a search and matching model with skilled immigration. The estimation results show that the bargaining power of domestic skilled workers exceeds that of foreign skilled workers, and both workers' bargaining shares are in general different from the elasticity of the matching function. This is generally robust across different sets of observables. The next steps are to analyze and refine the model fit and to employ the estimated parameters to evaluate immigration policy reform. Immigrants impose a cost to the domestic economy but also create benefits via additional output produced. During an expansionary period, the value of an additional skilled immigrant will be higher and therefore, the optimal number of skilled immigrants should be higher. Similarly, during economic downturns, the optimal number of immigrants would be lower. We plan to use the estimated parameters to evaluate the impact of immigration policy reform along these lines.

3.6 Tables

Table 3.1: Prior Distribution

Parameter	**Density**	**Mean**	**Std Dev**
β	Fixed	0.99	-
θ	Fixed	3.8	-
κ	Fixed	1	-
α	Fixed	0.5	-
$\bar{L}_d$	Fixed	1	-
$\bar{L}_u$	Fixed	2.22	-
$\bar{L}_f$	Fixed	0.1875	-
$\bar{N}_e$	Fixed	0.00021	-
δ_d	Fixed	0.036	-
δ_f	Fixed	0.06	-
f_R	Fixed	0.12	-
χ	Fixed	0.68	-
ϵ	Inv Gamma	0.5	0.15
η_f	Uniform	0.5	0.15
η_d	Uniform	0.5	0.15
ϕ_z	Beta	0.75	0.15
ϕ_f	Beta	0.75	0.15
ϕ_d	Beta	0.75	0.15
ϕ_c	Beta	0.75	0.15
σ_e	Inv Gamma	0.01	inf
σ_{ld}	Inv Gamma	0.01	inf
σ_{lf}	Inv Gamma	0.01	inf
σ_χ	Inv Gamma	0.01	inf

Table 3.2: Summary Statistics for the Prior and Posterior Distribution of Parameter Estimates

Parameter	**Density**	**Mean**	**Std Dev**	**Posterior Mean**	**10%**	**90%**
ϵ	Inv Gamma	0.5	0.15	0.4871	0.4169	0.5555
η_f	Uniform	0.5	0.15	0.3047	0.2657	0.3412
η_d	Uniform	0.5	0.15	0.7334	0.6976	0.7598
ϕ_z	Beta	0.75	0.15	0.9793	0.9623	0.9981
ϕ_f	Beta	0.75	0.15	0.7657	0.6664	0.8359
ϕ_d	Beta	0.75	0.15	0.7913	0.7365	0.8554
ϕ_c	Beta	0.75	0.15	0.4454	0.3738	0.5187
σ_e	Inv Gamma	0.01	inf	0.0030	0.0026	0.0033
σ_{ld}	Inv Gamma	0.01	inf	0.0058	0.0049	0.0067
σ_{lf}	Inv Gamma	0.01	inf	0.0784	0.0687	0.0881
σ_χ	Inv Gamma	0.01	inf	0.0830	0.0708	0.0965

3.7 Figures

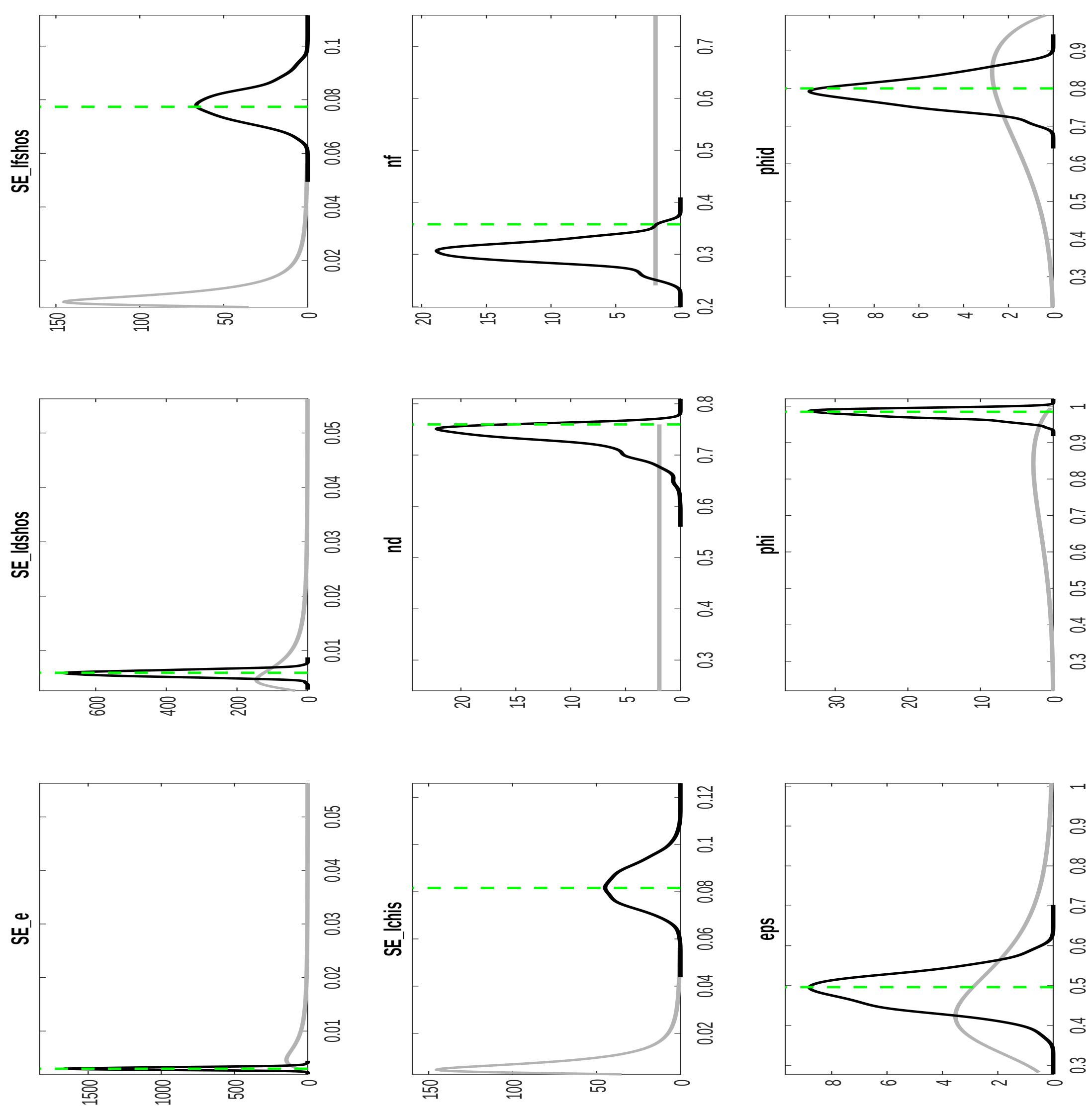

Figure 3.1: Prior vs Posterior Distribution

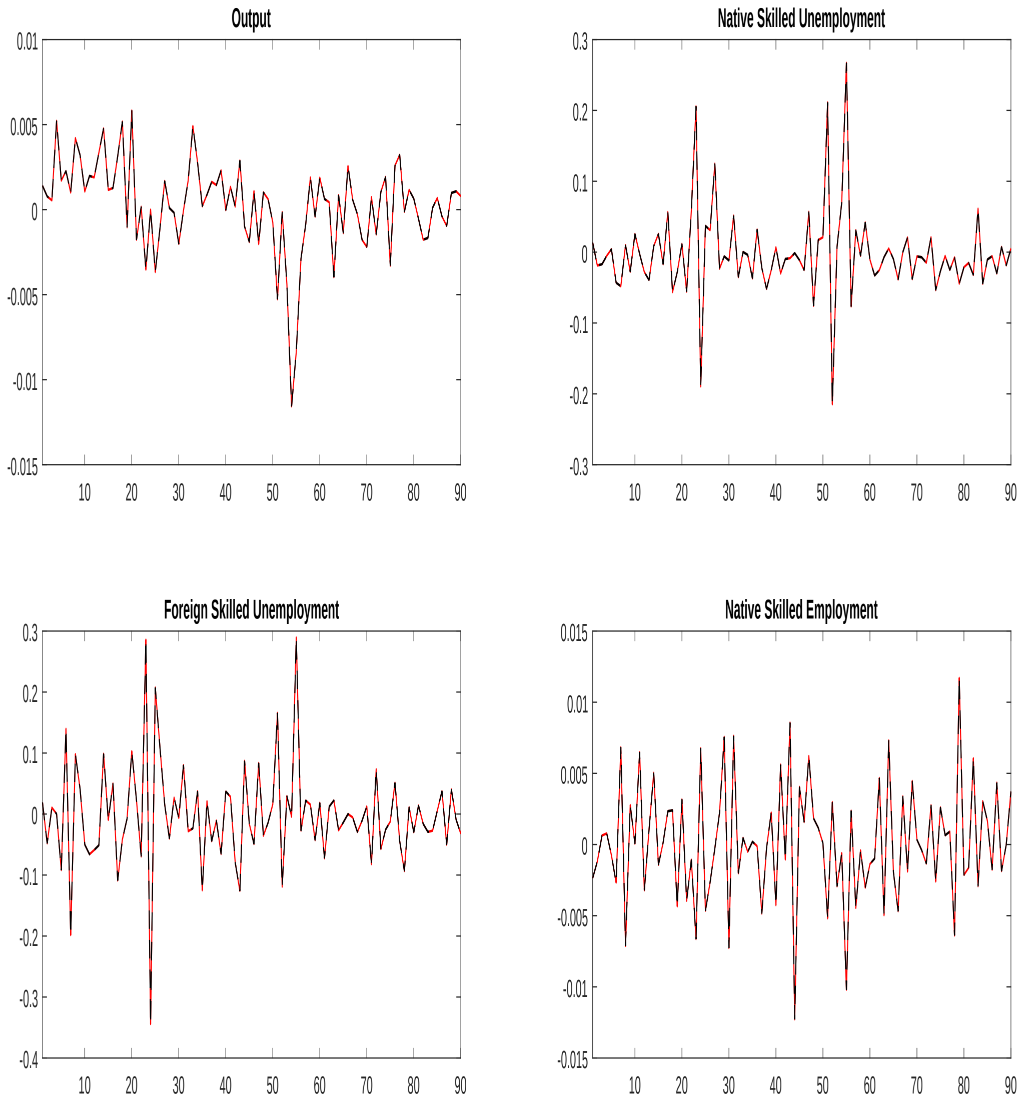

Figure 3.2: Detrended data (in Growth) used in Baseline Estimation

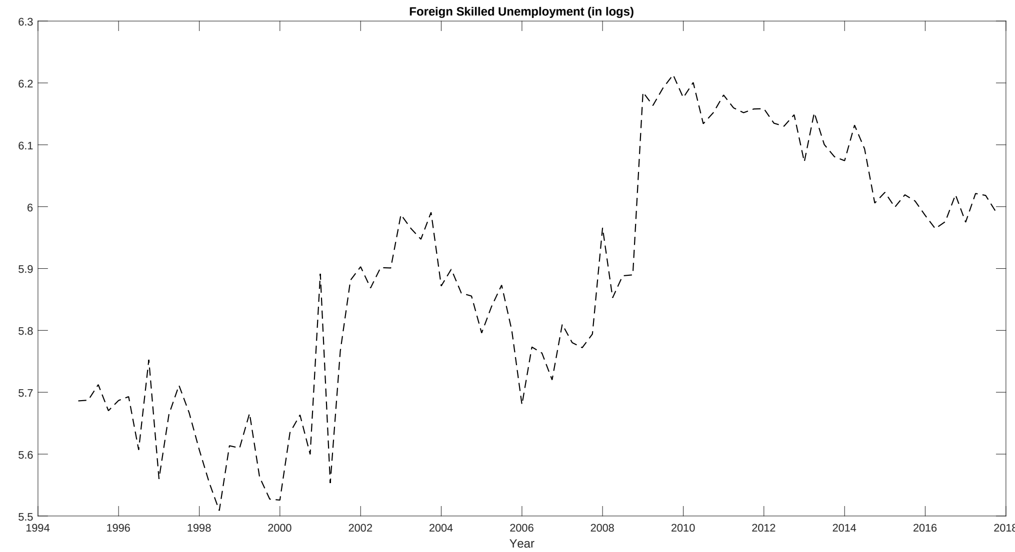

Figure 3.3: Seasonally Adjusted Log of Unemployed Skilled Immigrants

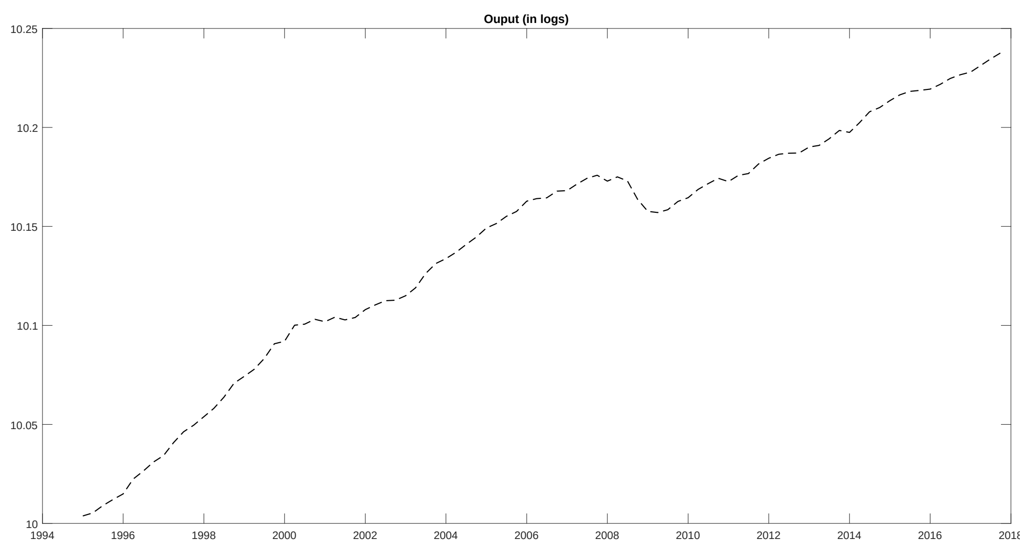

Figure 3.4: Seasonally Adjusted Log Real GDP

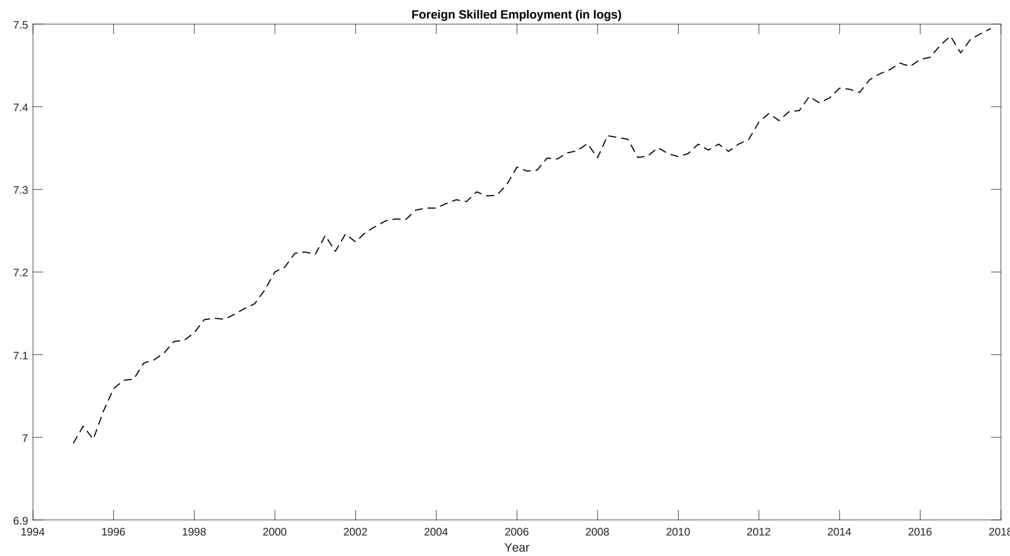

Figure 3.5: Seasonally Adjusted Log of Employed Skilled Immigrants

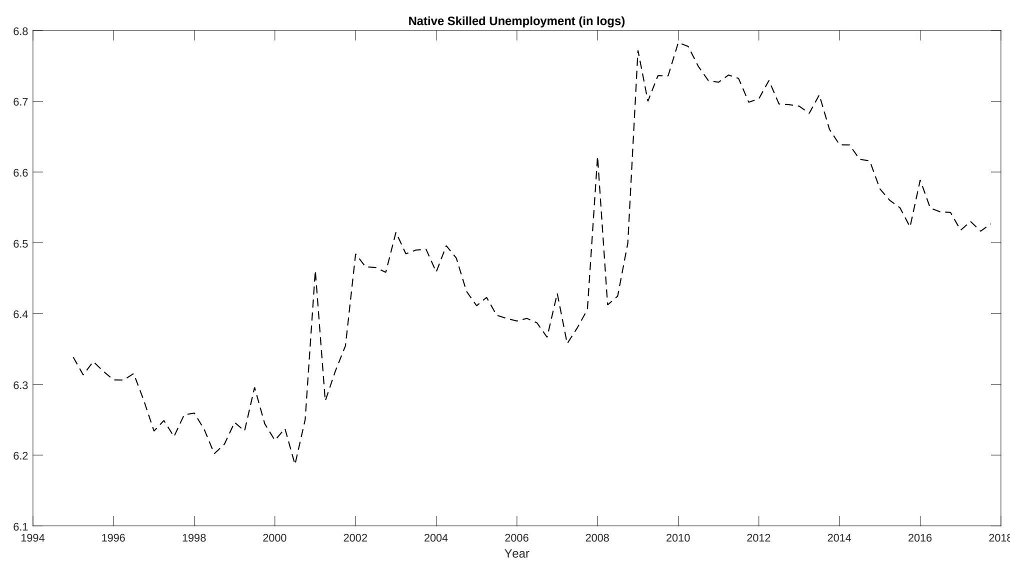

Figure 3.6: Seasonally Adjusted Log of Unemployed Skilled Natives

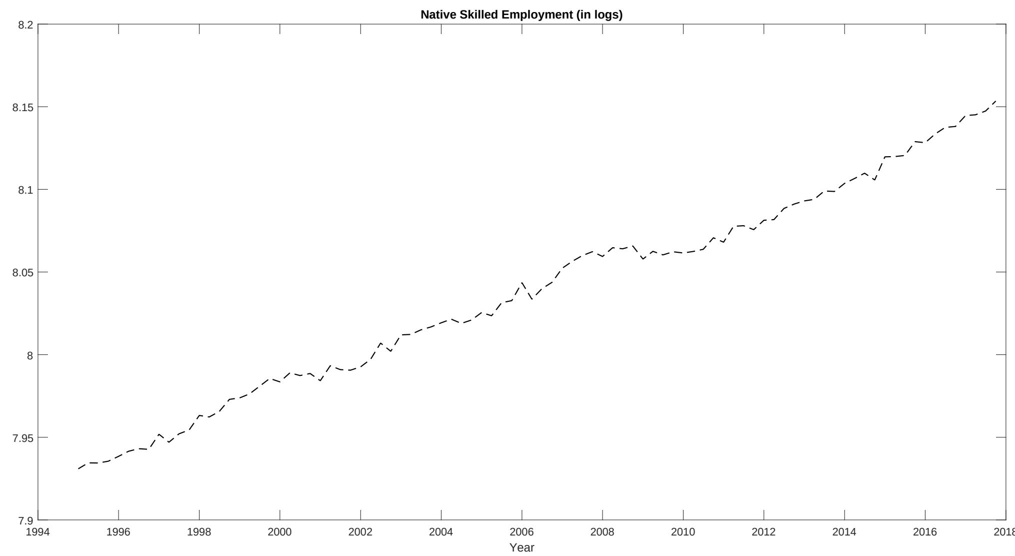

Figure 3.7: Seasonally Adjusted Log of Employed Skilled Natives

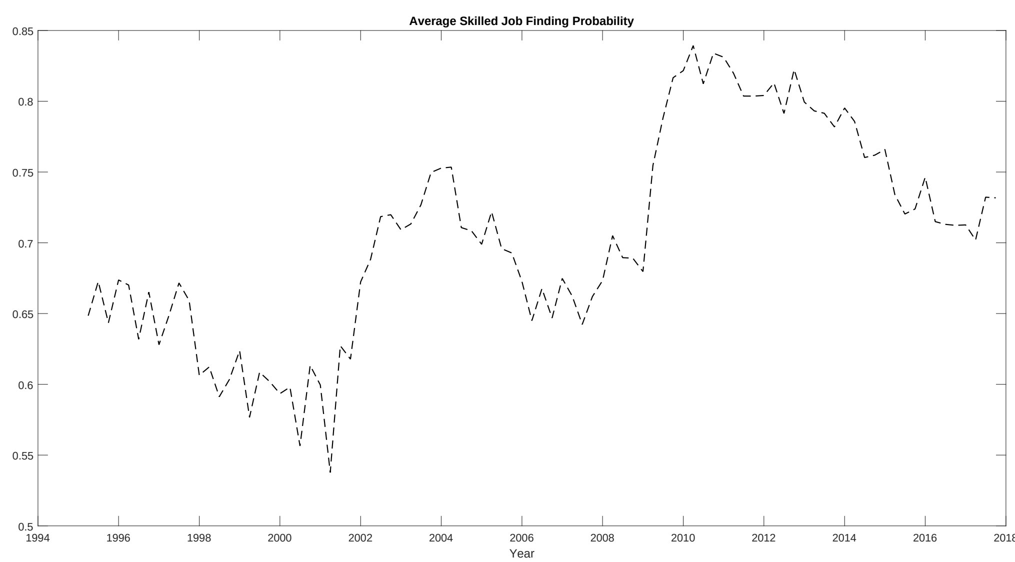

Figure 3.8: Job Finding Probability of Skilled Workers

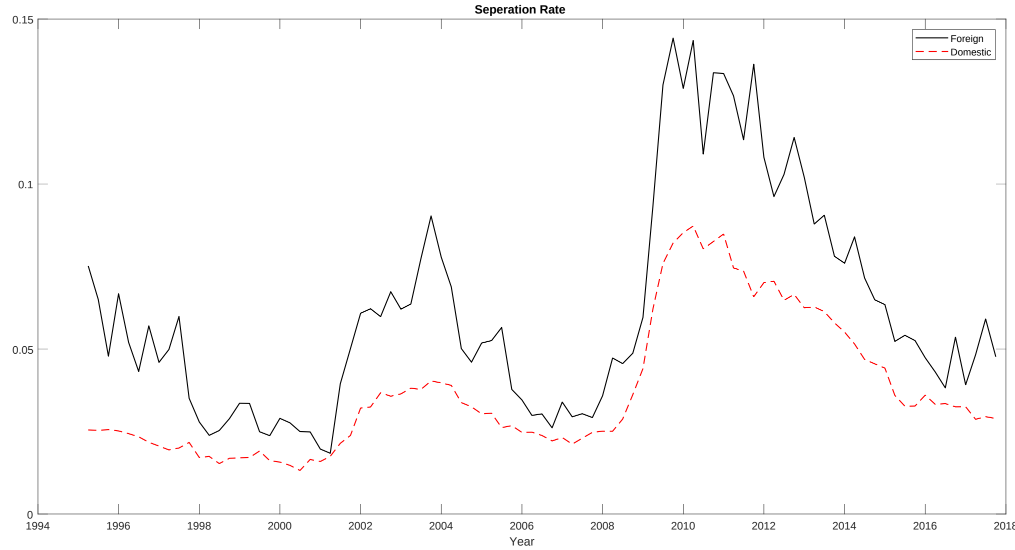

Figure 3.9: Separation Rates

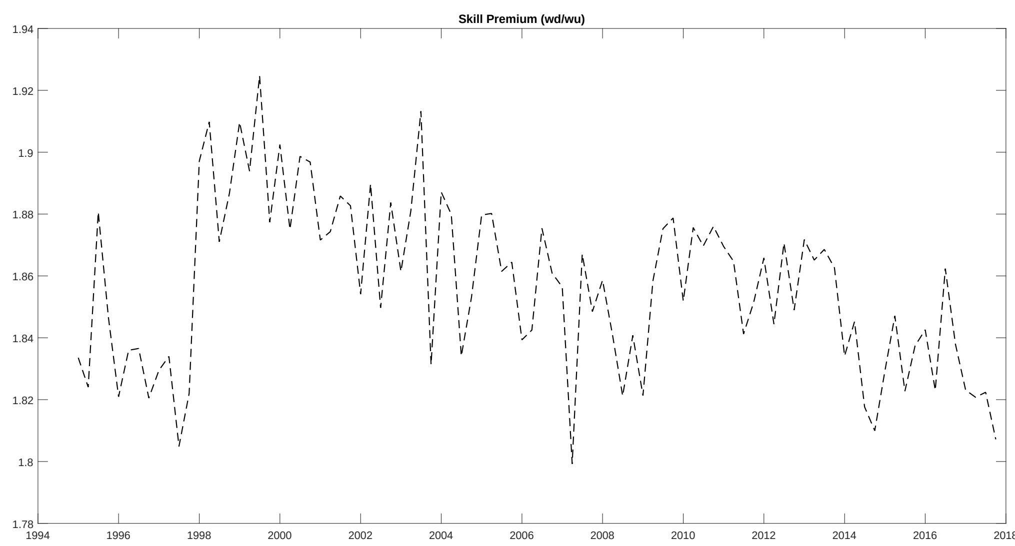

Figure 3.10: Skill Premium

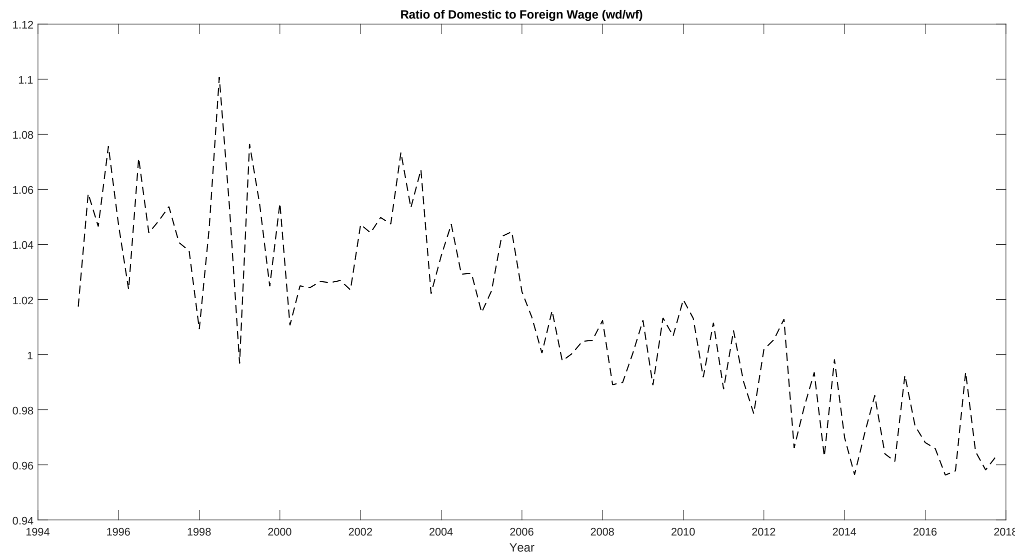

Figure 3.11: Ratio of Native to Foreign Skilled Wages

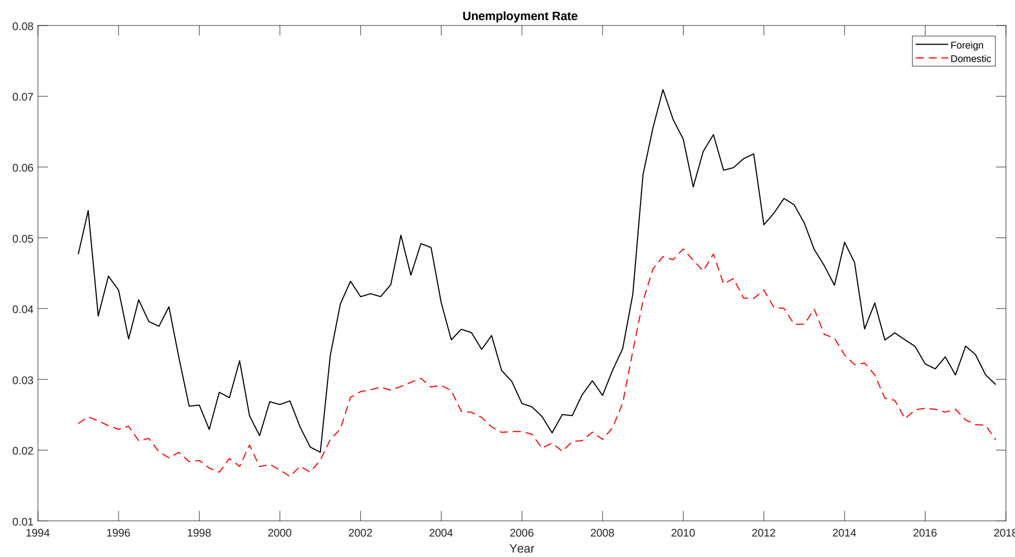

Figure 3.12: Unemployment Rate of Native vs Foreign Born

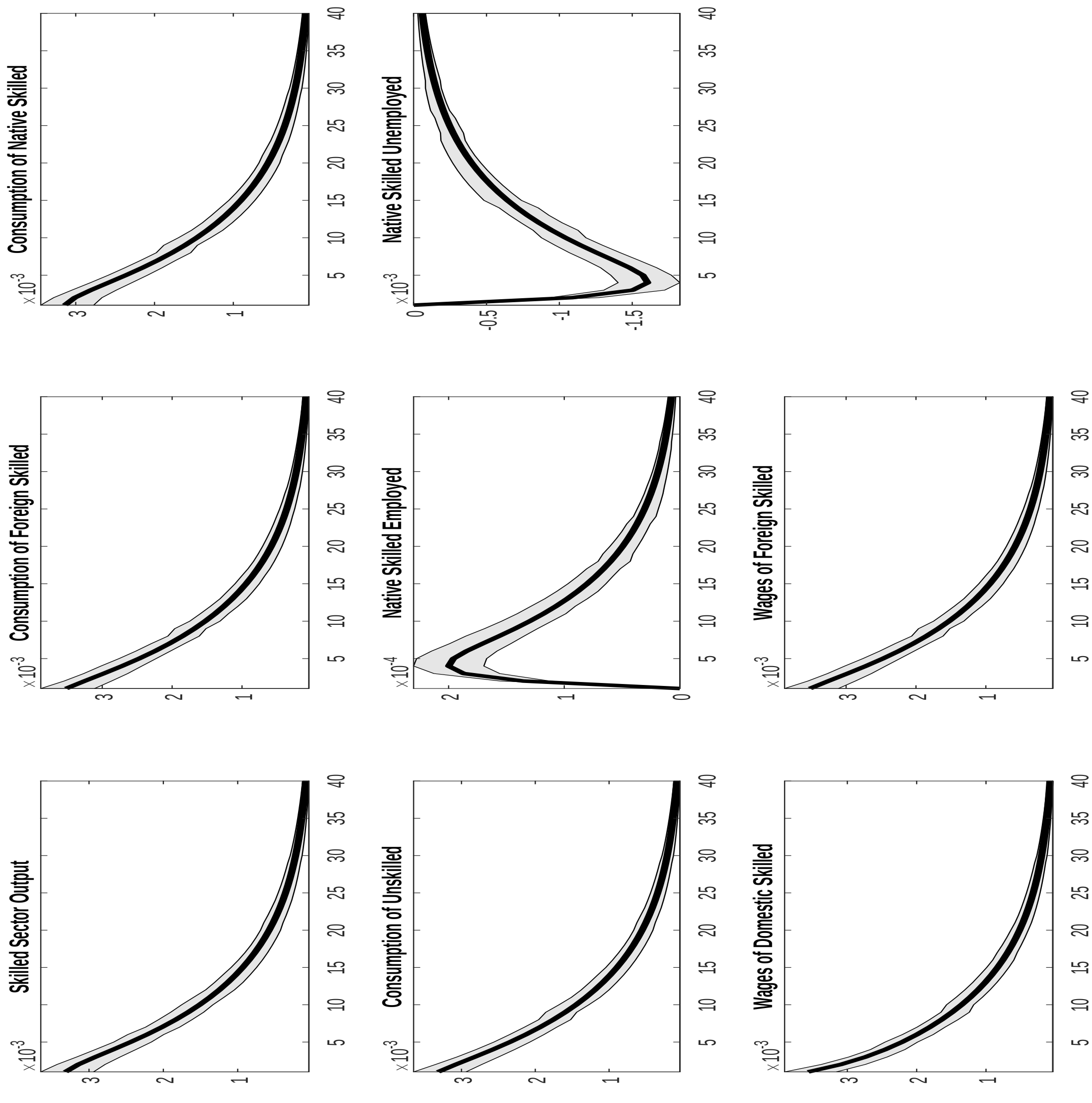

Figure 3.13: Response to a 1 Std Dev Shock in Productivity

BIBLIOGRAPHY

[1] Anderson, Stuart. How Immigrant Entrepreneurs Continue to Contribute to the U.S. Economy. Technical report, National Venture Capital Association, January 2012.

[2] David H Autor, Lawrence F Katz, and Melissa S Kearney. Trends in U.S. Wage Inequality: Revising the Revisionists. *The Review of Economics and Statistics*, 90(2):300–323, 2008.

[3] David K Backus, Patrick J Kehoe, and Finn E Kydland. International Real Business Cycles. *Journal of political Economy*, pages 745–775, 1992.

[4] Michele Battisti, Gabriel Felbermayr, Giovanni Peri, and Panu Poutvaara. Immigration, Search, and Redistribution: A Quantitative Assessment of Native Welfare. Technical report, National Bureau of Economic Research, 2014.

[5] Olivier Jean Blanchard and Peter A Diamond. The Aggregate Matching Function. Technical report, National Bureau of Economic Research, 1989.

[6] George J Borjas. Economic Theory and International Migration. *International migration review*, pages 457–485, 1989.

[7] George J Borjas. The Labor Demand Curve is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market. Technical report, National Bureau of Economic Research, 2003.

[8] George J Borjas and Kirk B Doran. The collapse of the Soviet Union and the Productivity of American Mathematicians. Technical report, National Bureau of Economic Research, 2012.

[9] George J. Borjas and Kirk B. Doran. The Collapse of the Soviet Union and the Productivity of American Mathematicians. Working Paper 17800, National Bureau of Economic Research, February 2012.

[10] George J Borjas, Jeffrey Grogger, and Gordon H Hanson. Imperfect Substitution Between Immigrants and Natives: A Reappraisal. Technical report, National Bureau of Economic Research, 2008.

[11] John Bound, Breno Braga, Joseph M Golden, and Gaurav Khanna. Recruitment of Foreigners in the Market for Computer Scientists in the United States. *Journal of Labor Economics*, 33(S1 Part 2):S187–S223, 2015.

[12] John Bound, Gaurav Khanna, and Nicolas Morales. Understanding the Economic Impact of the H-1B Program on the U.S. In *High-Skilled Migration to the United States and its Economic Consequences*. University of Chicago Press, 2017.

[13] Matteo Cacciatore. International Trade and Macroeconomic Dynamics with Labor Market Frictions. *Journal of International Economics*, 93(1):17–30, 2014.

[14] David Card. Immigration and Inequality. *American Economic Review*, 99(2):1–21, 2009.

[15] Andri Chassamboulli and Theodore Palivos. A Search-Equilibrium Approach to the Effects of Immigration on Labor Market Outcomes. *International Economic Review*, 55(1):111–129, 2014.

[16] Michael A Clemens. The Effect of International Migration on Productivity: Evidence from Randomized Allocation of U.S. Visas to Software Workers at an Indian Firm. 2012.

[17] Michael A. Clemens. Why Do Programmers Earn More in Houston Than Hyderabad? Evidence from Randomized Processing of US Visas. *American Economic Review*, 103(3):198–202, May 2013.

[18] H David and David Dorn. The Growth of Low-Skill Service Jobs and the Polarization of the U.S Labor Market. *The American Economic Review*, 103(5):1553–1597, 2013.

[19] Julian di Giovanni, Andrei A. Levchenko, and Francesc Ortega. A Global View Of Cross-Border Migration. *Journal of the European Economic Association*, 13(1):168–202, February 2015.

[20] Kirk Doran, Alexander Gelber, and Adam Isen. The Effects of High-Skilled Immigration Policy on Firms: Evidence from H-1B Visa Lotteries. Working Paper 20668, National Bureau of Economic Research, November 2014.

[21] Kirk Doran, Alexander Gelber, and Adam Isen. The Effects of High-Skilled Immigration Policy on Firms: Evidence from Visa Lotteries. 2016.

[22] Isaac Ehrlich and Jinyoung Kim. Immigration, Human Capital Formation and Endogenous Economic Growth. Technical report, National Bureau of Economic Research, 2015.

[23] Jesús Fernández-Villaverde and Juan Francisco Rubio-Ramırez. Comparing Dynamic Equilibrium Models to Data: a Bayesian Approach. *Journal of Econometrics*, 123(1):153–187, 2004.

[24] Fabio Ghironi and Marc J Melitz. International Trade and Macroeconomic Dynamics with Heterogeneous Firms. Technical report, National Bureau of Economic Research, 2004.

[25] Julian Giovanni, Andrei A Levchenko, and Francesc Ortega. A Global View of Cross-Border Migration. *Journal of the European Economic Association*, 13(1):168–202, 2015.

[26] Government Accountability Office. H-1B Visa Program: Reforms are Needed to Minimize the Risks and Cost of Current Program. Report to Congressional Committees GAO-11-26, United States Government Accountability Office, January 2011.

[27] Luca Guerrieri and Matteo Iacoviello. Occbin: A toolkit for Solving Dynamic Models with Occasionally Binding Constraints easily. *Journal of Monetary Economics*, 70:22–38, 2015.

[28] Gordon H. Hanson, William R. Kerr, and Sarah Turner. *High-Skilled Migration to the United States and its Economic Consequences*. University of Chicago Press, 2018.

[29] Gihoon Hong and John McLaren. Are Immigrants a Shot in the Arm for the Local Economy? Technical report, National Bureau of Economic Research, 2015.

[30] Susana Iranzo and Giovanni Peri. Migration and Trade: Theory with an Application to the Eastern–Western European Integration. *Journal of International Economics*, 79(1):1–19, 2009.

[31] Sari Pekkala Kerr and William R Kerr. Global collaborative Patents. Technical report, National Bureau of Economic Research, 2015.

[32] Sari Pekkala Kerr, William R Kerr, and William F Lincoln. Skilled Immigration and the Employment Structures of U.S. Firms. Technical report, National Bureau of Economic Research, 2013.

[33] Sari Pekkala Kerr, William R Kerr, and William F Lincoln. Firms and the Economics of Skilled Immigration. In *Innovation Policy and the Economy, Volume 15*. University of Chicago Press, 2014.

[34] William R Kerr and William F Lincoln. The Supply Side of Innovation: H-1B Visa Reforms and U.S. Ethnic Invention. Technical report, National Bureau of Economic Research, 2010.

[35] William R. Kerr and William F. Lincoln. The Supply Side of Innovation: H-1B Visa Reforms and US Ethnic Invention. Working Paper 15768, National Bureau of Economic Research, February 2010.

[36] Hautahi Rawiri Kingi. Essays in Immigration and Taxation. 2017.

[37] Paul Klein and Gustavo Ventura. TFP Differences and the Aggregate Effects of Labor Mobility in the Long Run. *The B.E. Journal of Macroeconomics*, 7(1):1–38, May 2007.

[38] Paul Klein and Gustavo Ventura. Productivity Differences and the Dynamic Effects of Labor Movements. *Journal of Monetary Economics*, 56(8):1059–1073, 2009.

[39] Per Krusell and Anthony A Smith, Jr. Income and Wealth Heterogeneity in the Macroeconomy. *Journal of political Economy*, 106(5):867–896, 1998.

[40] Arie Y Lewin, Silvia Massini, and Carine Peeters. Why are Companies Offshoring Innovation? The Emerging Global Race for Talent. *Journal of International Business Studies*, 40(6):901–925, Aug 2009.

[41] Thomas Lubik. Estimating a Search and Matching Model of the Aggregate Labor Market. 2009.

[42] Federico S Mandelman and Andrei Zlate. Immigration, Remittances and Business Cycles. *Journal of Monetary Economics*, 59(2):196–213, 2012.

[43] Marc J Melitz. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica*, 71(6):1695–1725, 2003.

[44] Enrico Moretti and Per Thulin. Local multipliers and human capital in the us and sweden. 2012.

[45] William Olney. Does Immigration Substitute for Offshoring? Working Paper, University of Colorado, 2009.

[46] William Olney and Dario Pozzoli. The Impact of Immigration on Firm-Level Offshoring. Discussion Paper Series 11480, Institute of Labor Economics, 2018.

[47] Gianmarco I. P. Ottaviano, Giovanni Peri, and Greg C. Wright. Immigration, Offshoring, and American Jobs. *American Economic Review*, 103(5):1925–59, August 2013.

[48] Gianmarco IP Ottaviano and Giovanni Peri. Rethinking the Effect of Immigration on Wages. *Journal of the European Economic Association*, 10(1):152–197, 2012.

[49] Gianmarco IP Ottaviano, Giovanni Peri, and Greg C Wright. Immigration, Trade and Productivity in Services: Evidence from U.K. Firms. Technical report, National Bureau of Economic Research, 2015.

[50] Gianmarco I.P. Ottaviano, Giovanni Peri, and Greg C. Wright. Immigration, Trade and Productivity in Services: Evidence from U.K. firms. *Journal of International Economics*, 112:88 – 108, 2018.

[51] Giovanni Peri. Rationalizing U.S. Immigration Policy: Reforms for Simplicity, Fairness, and Economic Growth. *The Hamilton Project (May 2012)*, page 5, 2012.

[52] Giovanni Peri, Kevin Shih, and Chad Sparber. Stem Workers, H1B Visas and Productivity in U.S. Cities. *London: Norface Migration*, 2013.

[53] Giovanni Peri, Kevin Shih, and Chad Sparber. Foreign and Native Skilled Worke: What Can We Learn from H-1B Lotteries? Technical report, National Bureau of Economic Research, 2015.

[54] Giovanni Peri, Kevin Y Shih, and Chad Sparber. Foreign STEM Workers and Native Wages and Employment in U.S. Cities. Technical report, National Bureau of Economic Research, 2014.

[55] Giovanni Peri and Chad Sparber. Task Specialization, Immigration, and Wages. *American Economic Journal: Applied Economics*, 1(3):135–169, 2009.

[56] Robert Shimer. The Cyclical Behavior of Equilibrium Unemployment and Vacancies. *American economic review*, 95(1):25–49, 2005.

[57] Slaughter, Matthew J. The Increasing Cost to American Companies of Hiring Skilled Immigrant Workers. Technical report, AC Alliance, March 2016.

[58] Carlos Urrutia. On the Self-Selection of Immigrants. *Manuscript, Universidad Carlos III de Madrid*, 1998.

[59] Michael E Waugh. Firm Dynamics and Immigration: The Case of High-Skilled Immigration. Technical report, National Bureau of Economic Research, 2017.

[60] Rui Xu. High-Skilled Migration and Global Innovation, 2015.

[61] Stephen Ross Yeaple. The Innovation Activities of Multinational Enterprises and the Demand for Skilled Worker, Non-Immigrant Visas. In *Talent Flows in the Global Economy*. University of Chicago Press, 2016.

[62] Stephen Ross Yeaple. *The Innovation Activities of Multinational Enterprises and the Demand for Skilled-Worker, Nonimmigrant Visas*, pages 41–69. In [28], May 2017.

[63] Robert E. Yuskavage, Erich H. Strassner, and Gabriel W. Medeiros. Outsourcing and Imported Services in BEA's Industry Accounts. Technical report, National Bureau of Economic Research, 2006.

[64] Andrei Zlate and Federico Mandelman. Offshoring, Low-Skilled Immigration and Labor Market Polarization. In *2013 Meeting Papers*, number 1073. Society for Economic Dynamics, 2013.

Appendix A

A.1 Figures

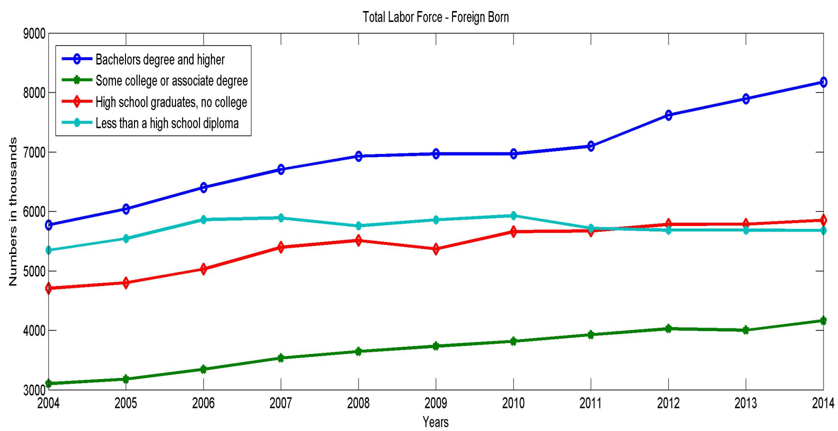

Figure A.1: Educational attainment of foreign-born workers

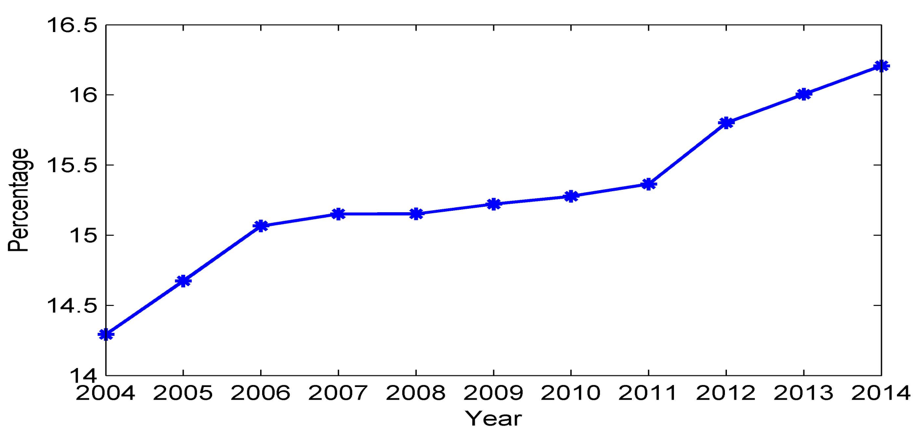

Figure A.2: Proportion of foreign born in the U.S. skilled labor force

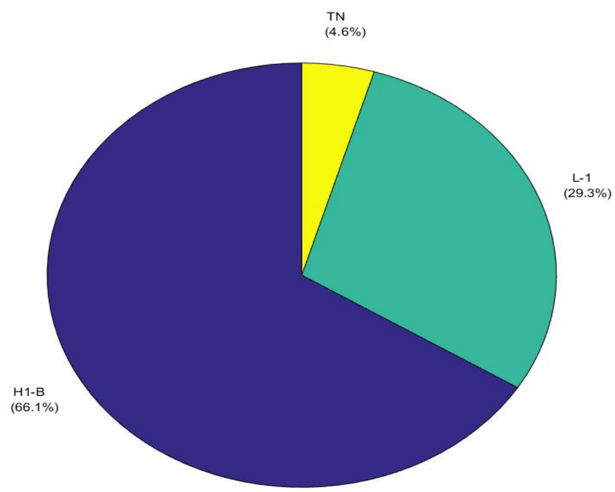

Figure A.3: Entry of foreign skilled workers by visa category

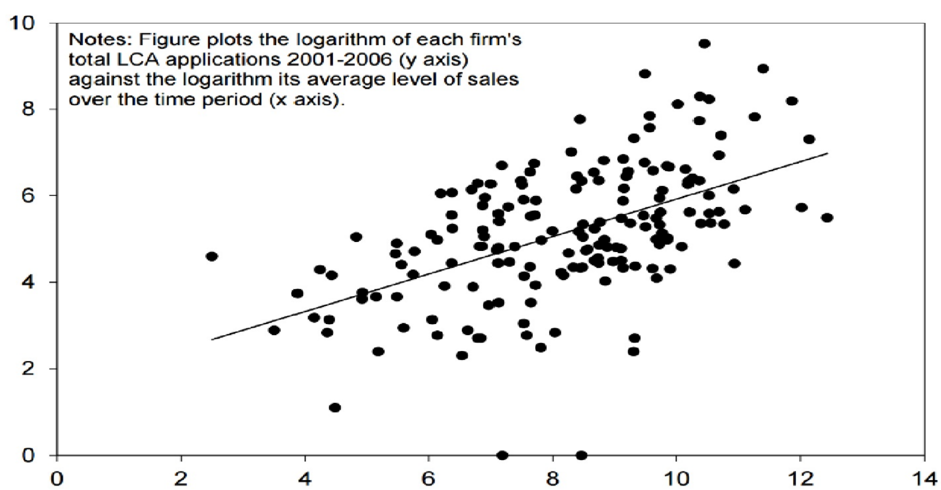

Figure A.4: Firm sales and Labor Condition Applications (LCA)

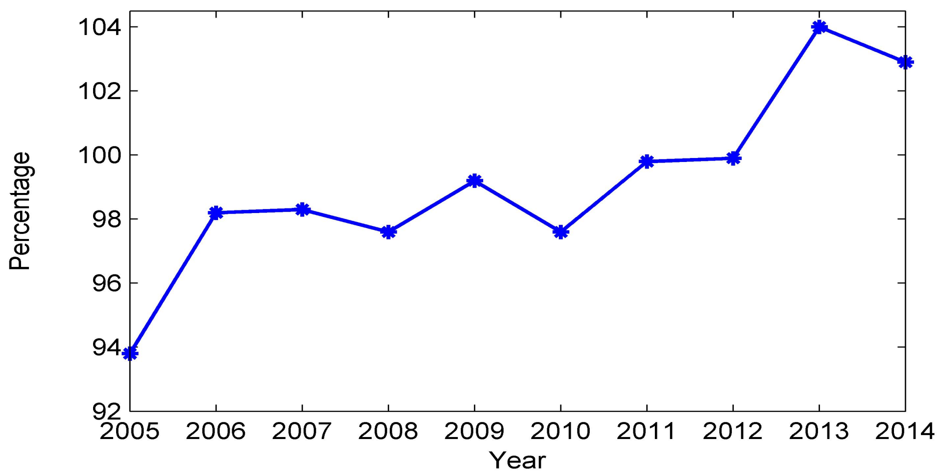

Figure A.5: Earnings of foreign born as percent of native born: Bachelor's degree and higher, 25 years and over

A.2 H1-B Program: Institutional Framework and Background

Since the implementation of the H1-B visa program in 1990, it has been the main method of entry into the U.S. workforce for foreign college educated professionals. Table 6 shows that H1-B visa holders constituted 66 percent of all skilled foreign entrants in 2014. A significant proportion of H1-B recipients (over 70 percent) are from emerging economies — India and China. The other major visa categories for foreign skilled workers are L-1 (for transfer of employees across multinational firms) and TN (visas for Canadian and Mexican NAFTA professional workers). The proportion of entrants from the latter two visa categories has been increasing since 2001, but the H1-B visa program still remains the dominant entry mode. Thus, most studies that analyze the impact of skilled foreign workers in the U.S. focus on the H1-B visa program. Though the H-1B visa is a temporary visa as it is issued for three years (and can be renewed for another three years), it is a dual intent visa as it can lead to permanent residency if the employer is willing to sponsor the worker for a green card.

Table A.1: Major Entry Routes for Foreign Skilled Workers (2014)

Visa Category	Proportion of Total
H1-B	66.1 %
L-1	29.3 %
TN	4.6 %

Source: U.S. Department of State

The H1-B program has been subject to an annual quota on new visa issuances. The initial visa cap was 65,000 which was subsequently increased to 115,000 in 1999 and 2000, after the cap was met in 1997. The cap was further increased to 195,000 for 2011 through 2003. In 2001, cap exemptions were introduced for employees of higher education, non-profit, and government research organizations. In 2004, the cap was reduced back to 65,000, but 20,000 additional visas were allocated for workers who had obtained a master's degree or higher from a U.S. institution. These exceptions raise the actual number of visas issued to over 120,000 each year. The cap applies only to new H1-B visa issuances for for-profit firms.

In order to obtain an H1-B visa, there are several steps to be followed and firms are central to this process. The first step requires the firm that wants to hire a foreign worker to file a Labor Condition Application (LCA) with the department of labor. In the application, the firm specifies the nature of occupation and attests that the firm will pay the worker the greater of the actual compensation paid to other employees in the same job or the prevailing compensation for that occupation. The rationale given for this attestation is to help protect domestic worker wages.

LCA forms can request for one or more foreign workers for a particular occupation and thus they signal firm vacancies in specific occupations for foreign workers. However, there are some limitations of using the LCA database. The LCA database contains records for every request submitted, but this is only an intermediate step in the process towards the final visa approval. An LCA is submitted for every H-1B request, whether new or a renewal, and each LCA can contain multiple H-1B workers. A more conservative estimate of the demand for foreign skilled workers would be to count each LCA filed as a request for one employee. Plotting the total number of LCAs filed as compared to Figure 1 that plots the total number of employees requested in LCAs filed each year does not change the main motivation regarding business cycle correlation and rising excess demand during expansionary periods.

Once the LCA has been approved by the Department of Labor, it is sent to the United States Citizenship and Immigration Services (USCIS), along with the I-129 form[1] and the required visa fees. The crucial fact is that employees can apply for an H1-B visa only if they have a job offer from an employer with an LCA approval. The employer cannot file more than one I-129 for the same prospective employee. Most of the filing and legal fees are borne by the employer. If the number of H1-B visa petitions (I-129 forms) that fall within the non-exempt category exceed the cap, the USCIS randomly selects visas for processing via a lottery system, until the 65,000 cap is reached. The filing fees paid for the unsuccessful visa applications is returned (unless it is discovered that multiple H1-B petitions are submitted for the same employee). In the last few years, the number of H1-B petitions filed by employers have reached the annual limit within days after the beginning of the filing period which is the first day of April..

A.3 Model with Complementarities between Domestic and Foreign Skilled Labor

The production technology is now given by: $y_{1,t}(z) = zZ_t l_{s,t}(z)$ where:

$$l_{s,t}(z) = \left(\lambda^{(1-\gamma)}(l^s_{h,t}(z))^\gamma + (1-\lambda)^{(1-\gamma)}(l^s_{f,t}(z))^\gamma\right)^{1/\gamma}.$$

[1]This proves the workers qualifications

$\gamma = 1 \rightarrow$ gives the baseline model. When $\gamma < 1$, foreign and domestic skilled labor are imperfect substitutes. As γ falls, foreign and domestic skilled labor increasingly become complementary. Now wages of domestic and foreign skilled households are given by:

$$w^s_{h,t} = \psi_{1,t}(z) Z_t z (l_{s,t}(z))^{(1-\gamma)} (l^h_{s,t}(z))^{(\gamma-1)} \lambda^{(1-\gamma)}$$

$$w^s_{f,t} = \psi_{1,t}(z) Z_t z (l_{s,t}(z))^{(1-\gamma)} (l^h_{f,t}(z))^{(-\gamma)} (1-\lambda)^{(1-\gamma)}$$

and the hiring condition of foreign skilled labor is given by:

$$f_R/q_t + g + f_T = (1-\delta) E_t\{\beta (C_{s,t+1}/C_{s,t})^{-1} [\rho_{t+1}(z) Z_{t+1} z (l_{s,t+1}(z))^{(1-\gamma)} (l^f_{s,t+1}(z))^{(\gamma-1)} (1-\lambda)^{(1-\gamma)} \\ - w^s_{f,t+1} + f_R/q_{t+1} + g + f_T]\}$$

Rest of the model is the same as the baseline case with perfect substitutes.

A.4 Steady-State Solution in the Baseline Model

Since the model features an occasionally binding constraint, the model is equivalent to one with two regimes. The constraint is binding under one regime and slack under the other and each regime has a separate non-stochastic steady state. I first solve for the steady state when the cap is not binding.

When the Cap does Not Bind ($q = 1$):

Here, I derive expressions for the average real prices in sector 1, $\tilde{\rho}_1$, and the average stock of foreign skilled workers, $\tilde{l}^s_f$, and all other endogenous steady-state variables can be expressed as a function of these.

From the market clearing condition in sector 1 we can get: $Z\tilde{z}(1 + \tilde{l}^s_f) = \alpha Y^c / \tilde{\rho}_1$, where the aggregate demand $Y^c = C_s + C_i + C_u + (f_R + f_T + g)\tilde{N}_e$. Substituting the households' budget constraint, we can write aggregate demand as $Y^c = w_s(1 + \tilde{l}^s_f) + \tilde{d} + T + w_u \bar{l}_u + (f_R + f_T)\tilde{N}_e$.

Consider the average price setting equation in sector 1, $w_s = \frac{\theta-1}{\theta} Z\tilde{z}\tilde{\rho}_1$, the average firm profit in sector 1, $\tilde{d} = \tilde{\rho}_1\tilde{y}_1/\theta - (f_R + g + f_T)\tilde{N}_e$, and the average transfers to households, $T = g\tilde{N}_e$, we can obtain $Y^c = \frac{\theta-1}{\theta} Z\tilde{z}\tilde{\rho}_1(1 + \tilde{l}^s_f) + \tilde{\rho}_1 Z\tilde{z}(1 + \tilde{l}^s_f)/\theta + w_u\bar{l}_u$, and therefore $Y^c = \rho_1 Z\tilde{z}(1 + \tilde{l}^s_f) + w_u\bar{l}_u$.

Then substituting for Y^c in the market clearing for sector 1, we have: $\tilde{\rho}_1 Z\tilde{z}(1 + \tilde{l}^s_f) = \alpha(\tilde{\rho}_1 Z\tilde{z}(1 + \tilde{l}^s_f) + w_u\bar{l}_u)$. Using expression for real wages in sector 2, $w_u = \rho_2 Z$, and also the price index equation, $\tilde{\rho}_1^{\alpha}\rho_2^{1-\alpha} = 1$, we can write:

$$(1-\alpha)\tilde{z}(1 + \tilde{l}^s_f) = \alpha(\tilde{\rho}_1)^{\frac{1}{\alpha-1}}\bar{l}_u \tag{A.4.1}$$

Consider the steady state aggregate hiring condition which can be written as:

$$(f_R + g + f_T) = \frac{(1-\delta)\beta\tilde{\rho}_1 Z\tilde{z}}{\theta(1-(1-\delta)\beta)} \tag{A.4.2}$$

Using A.4.2, we can get the average price of sector 1 output as $\tilde{\rho}_1 = \frac{\theta(f_R+g+f_T)(1-(1-\delta)\beta)}{(1-\delta)\beta Z\tilde{z}}$. Then, using the price setting equation for sector 1, real wages of skilled workers can be written as $w_s = \frac{(\theta-1)(f_R+g+f_T)(1-(1-\delta)\beta)}{(1-\delta)\beta}$. Finally, substituting the expression obtained for average sector 1 prices in D.1, we can get:

$$\tilde{l}^s_f = \frac{\alpha\tilde{z}^{\frac{\alpha}{(1-\alpha)}}\bar{l}_u}{(1-\alpha)}\left[\frac{(1-\delta)\beta Z}{\theta(f_R + f_T + g)(1-(1-\delta)\beta)}\right]^{\frac{1}{(1-\alpha)}} - 1$$

Once we have $\tilde{\rho}_1$ and $\tilde{l}^s_f$, we can obtain the other steady state expressions for $\tilde{N}_e, Y_1, \rho_2, w_u, C_u, C_s, C_i, Y^c$, since these variables can be expressed as a function of $\tilde{l}^s_f$, and $\tilde{\rho}_1$:

$$\begin{aligned} \rho_2 &= \tilde{\rho}_1^{\frac{\alpha}{\alpha-1}} \\ Y_1 &= Z\tilde{z}(1 + \tilde{l}^s_f) \\ \tilde{N}_e &= \delta\tilde{l}^s_f/(1-\delta) \end{aligned}$$

All other variables can be expressed as a function of these variables.

Steady-State Firm Profit and Skilled Wages as a Function of Skilled Foreign Labor Stock:

Using the expression for average firm profit in sector 1 i.e. $\tilde{d} = \tilde{\rho}_1\tilde{y}_1/\theta - (f_R + g + f_T)\tilde{N}_e$, and substituting $\tilde{\rho}_1 = \left(\frac{\alpha\bar{l}_u}{(1-\alpha)\tilde{z}(1+\tilde{l}_f^s)}\right)^{1-\alpha}$ (from D.1) and $Y_1 = Z\tilde{z}(1+\tilde{l}_f^s)$, we get:

$$\tilde{d} = \left(\frac{\alpha\bar{l}_u}{(1-\alpha)}\right)^{1-\alpha} Z\tilde{z}^{\alpha}(1+\tilde{l}_f^s)^{\alpha}/\theta - (f_R + g + f_T)\delta\tilde{l}_f^s/(1-\delta) \tag{A.4.3}$$

Also, using the price setting equation for sector 1 and equation A.4.2, we can obtain steady-state skilled wages as a function of skilled labor stock as:

$$w_s = (\theta - 1)Z\tilde{z}^{\alpha}\left(\frac{\alpha\bar{l}_u}{(1-\alpha)(1+\tilde{l}_f^s)}\right)^{1-\alpha}/\theta \tag{A.4.4}$$

Steady State When the Cap Binds

When the cap binds, $q\tilde{N}_e = \bar{N}_e$ and therefore from the law of motion for foreign skilled workers, we have $\tilde{l}_f^s = \delta\bar{N}_e/(1-\delta)$. Since the market clearing in sector 1 still needs to hold for the aggregate, we have $\tilde{\rho}_1 = \left(\frac{(1-\alpha)\tilde{z}(1+\tilde{l}_f^s)}{\alpha\bar{l}_u}\right)^{\alpha-1}$. Then, using the optimal hiring condition, we can get: $q = f_R\left[\frac{(1-\delta)\beta(\alpha\delta\bar{l}_u)^{1-\alpha}Z\tilde{z}}{\theta(1-(1-\delta)\beta)((1-\alpha)\tilde{z}(\delta+(1-\delta)\bar{N}_e))^{1-\alpha}} - f_T - g\right]^{-1}$.

A.5 Social Planner Allocation

Consider the problem of a Social Planner who maximizes welfare of domestic households and chooses the optimal entry of foreign skilled workers in the domestic labor force, taking the firm size distribution, preferences, technology, and resources available in the economy as given. Let f_T be the technologically imposed cost of hiring skilled immigrants in the economy. The planner's problem is given by:

$$\max_{\left\{(C_{u,t}, C_{s,t}, N_{e,t}(z), l_{f,t+1}^s(z), y_{1,t}(z), y_{2,t}\right\}_{t=0}^{\infty}} E_t\left[a\sum_{t=0}^{\infty}\beta^t\ln(C_{u,t}) + (1-a)\sum_{t=0}^{\infty}\beta^t\ln(C_{s,t})\right]$$

s.t.

$$C_{u,t} + C_{s,t} + f_T \int_{z_{min}}^{\infty} N_{e,t}(z) dG(z) = \left(\frac{\int_{z_{min}}^{\infty} y_{1,t}(z)^{\frac{\theta-1}{\theta}} dG(z)^{\frac{\theta}{\theta-1}}}{\alpha} \right)^{\alpha} \left(\frac{y_{2,t}}{1-\alpha} \right)^{1-\alpha} \quad \text{(A.5.1)}$$

$$\int_{z_{min}}^{\infty} y_{1,t}(z) dG(z) = \int_{z_{min}}^{\infty} (Z_t z (l_{f,t}^s(z) + l_{h,t}^s(z))) dG(z) \quad \text{(A.5.2)}$$

$$Y_{2,t} = Z_t \bar{L}_u \quad \text{(A.5.3)}$$

$$\int_{z_{min}}^{\infty} l_{f,t+1}^s(z) dG(z) = (1-\delta)(\int_{z_{min}}^{\infty} l_{f,t}^s(z) dG(z) + \int_{z_{min}}^{\infty} N_{e,t}(z) dG(z)) \quad \text{(A.5.4)}$$

$$\int_{z_{min}}^{\infty} {l_{h,t}}^s(z) dG(z) = \tilde{l}_{h,t}^s = 1 \quad \text{(A.5.5)}$$

where $a \in [0,1]$ is the planner's weight on domestic unskilled households' welfare.

The first constraint is the aggregate resource constraint — the total output can be used for aggregate consumption and incurring the technological component of the sunk cost for hiring foreign skilled workers. The Lagrange multiplier on this constraint, ς_t, represents the social marginal utility of consumption resources. In the Planner's environment, $Y_t^c = C_{u,t} + C_{s,t} + f_T N_{e,t}$.

The second constraint defines production technology for firms in sector 1. The Lagrange multiplier on this, ν_t, denotes the social marginal cost of producing one more unit of sector 1 output. Similarly, the Lagrange multiplier on constraint (A.5.3), η_t gives the social marginal cost of producing one more unit of sector 2 output.

Constraint (A.5.4) gives the law of motion of foreign skilled workers. Note that the social planner's constraint does not include the probability of an application being selected, q_t, because the Social Planner does not face a cap. The Lagrange multiplier associated to this constraint, ξ_t, denotes the real marginal value of a foreign skilled worker to society.

The first order conditions are given by:

$$\begin{aligned}
\frac{a}{C_{u,t}} &= \varsigma_t \quad \forall \text{t} \\
\frac{(1-a)}{C_{s,t}} &= \varsigma_t \quad \forall \text{t} \\
E_t[\beta(\nu_{t+1} Z_{t+1} \tilde{z} + (1-\delta)\xi_{t+1})] &= \xi_t \quad \forall \text{t} \\
-\varsigma_t f_T + (1-\delta)\xi_t &= 0 \quad \forall \text{t} \\
\varsigma_t \left(\frac{Y_{1,t}}{\alpha}\right)^{\alpha-1} \left(\frac{Y_{2,t}}{1-\alpha}\right)^{1-\alpha} \left(\frac{y_{1,t}(z)}{Y_{1,t}}\right)^{\frac{-1}{\theta}} &= \nu_t \quad \forall \text{t} \\
\varsigma_t \left(\frac{Y_{1,t}}{\alpha}\right)^{\alpha} \left(\frac{Y_{2,t}}{1-\alpha}\right)^{-\alpha} &= \eta_t \quad \forall \text{t} \\
C_{u,t} + C_{s,t} + f_T N_{e,t} &= \left(\frac{y_{1,t}}{\alpha}\right)^{\alpha} \left(\frac{y_{2,t}}{1-\alpha}\right)^{1-\alpha} \quad \forall \text{t} \\
Y_{1.t} &= Z_t \tilde{z}(1 + L^s_{f,t}) \quad \forall \text{t} \\
Y_{2.t} &= Z_t \bar{L}_u \quad \forall \text{t} \\
L^s_{f,t+1} &= (1-\delta)(L^s_{f,t} + N_{e,t}) \quad \forall \text{t}
\end{aligned}$$

where $Y_{1,t} = \int_{z_{min}}^{\infty} y_{1,t}(z)^{\frac{\theta-1}{\theta}} dG(z)$. Also, $L^s_{f,t} = \int_{z_{min}}^{\infty} l_{f,t}{}^{s}(z) dG(z)$. $L^s_{h,t}$ and $N_{e,t}$ are similarly aggregate values across all firms.

Using $C_{u,t} + C_{s,t} + f_T N_{e,t} = Y^c_t$, and $a = 1/2$ (Assuming that the social planner puts equal weights on skilled and unskilled domestic workers), the first order conditions can be expressed as:

$$
\begin{aligned}
C_{u,t} &= C_{s,t} && \text{(A.5.6)}\\
Y_{1,t} &= \alpha\frac{\varsigma_t}{\nu_t}Y_t^c && \text{(A.5.7)}\\
Y_{2,t} &= (1-\alpha)\frac{\varsigma_t}{\eta_t}Y_t^c && \text{(A.5.8)}\\
1 &= \left(\frac{\nu_t}{\varsigma_t}\right)^{\alpha}\left(\frac{\eta_t}{\varsigma_t}\right)^{1-\alpha} && \text{(A.5.9)}\\
f_{T,t} &= E_t\left[\beta(1-\delta)\frac{C_{s,t}}{C_{s,t+1}}\left(\frac{\nu_{t+1}}{\varsigma_{t+1}}Z_{t+1}\tilde{z}+f_T\right)\right] && \text{(A.5.10)}\\
Y_{1.t} &= Z_t\tilde{z}(1+L^s_{f,t}) && \text{(A.5.11)}\\
Y_{2.t} &= Z_t\bar{L}_u && \text{(A.5.12)}\\
L^s_{f,t+1} &= (1-\delta)(L^s_{f,t}+N_{e,t}) && \text{(A.5.13)}\\
C_{u,t}+C_{s,t}+f_TN_{e,t} &= Y_t^c && \text{(A.5.14)}
\end{aligned}
$$

(A.5.7) and (A.5.8) give the demand schedules for sector 1 and sector 2 output. To facilitate the comparison between the planned and decentralized economy, define the following relative prices in sector 1 and 2 for the planner's equilibrium: $\frac{\nu_t}{\varsigma_t} = \varrho_{1,t}$ and $\frac{\eta_t}{\varsigma_t} = \varrho_{2,t}$. Then (A.5.9) is the price index in the planner's economy.

Equation (A.5.10), obtained by combining the first order condition w.r.t $N_{e,t}$ with $L^s_{f,t+1}$ is the social planner's entry condition for foreign skilled workers. It shows that the social planner will allow entry of foreign skilled workers till the technological cost of hiring foreign workers is equal to the social expected benefit — the expected discounted value of output produced by an additional foreign skilled worker.

The social planner's equilibrium allocation can be solved using the 9 equations (A.5.6 - A.5.14) and 9 variables — $\varrho_{1,t}, \varrho_{2,t}, y_{1,t}, y_{2,t}, C_{s,t}, C_{u,t}, Y_t^c, L^s_{f,t}, N_{e,t}$.

A.6 Distortions and Inefficiency Wedges in the Baseline Model's Decentralized Economy

Comparing the equilibrium conditions in the decentralized economy (Table 1.1) to those for the planned economy (Table 1.4) allows us to identify the distortions in the model economy and define inefficiency wedges relative to the efficient allocation.

Entry condition under the planned economy:

$$f_T = E_t\left[\beta_{t,t+1}(1-\delta)\left(\frac{\nu_{t+1}}{\chi_{t+1}}Z_{t+1}\tilde{z} + f_T\right)\right]$$

Entry condition under the decentralized economy:

$$\frac{f_R}{q_t} + f_T + g = E_t\left[\beta_{t,t+1}(1-\delta)\left(\frac{1}{\theta}\tilde{\rho}_{1,t+1}Z_{t+1}\tilde{z} + \frac{f_R}{q_{t+1}} + f_T + g\right)\right]$$

The major distortions in the decentralized economy are[2]:

- Distortion because of the cap: When the cap binds, the probability that a firm will be able to hire a worker is $q_t < 1$. Hence the distortion because of the cap is $\Upsilon_{q,t} = 1 - q_t$.

- Distortion because of immigration policy costs: Let $\Upsilon_{x,t} = f_R + g$. This is the difference between costs that firms face and the technological hiring cost. If there was no cap and the probability of being able to hire a foreign worker is always 1, $\Upsilon_{x,t}$ would be the only distortion w.r.t. immigration policy in this framework. However, when the cap binds and $q_t < 1$ in the decentralized economy, firms face additional costs. To hire one worker, they need to submit $1/q_t$ applications and hence incur f_R/q_t as regulatory costs. Let $\Upsilon_{R,t} = f_R/q_t + g$. Then, simple manipulation yields

$$\Upsilon_{R,t} = \Upsilon_{x,t} + \frac{f_R\Upsilon_{q,t}}{1+\Upsilon_{q,t}} \tag{A.6.1}$$

  which decomposes the overall distortion due to immigration policy into distortions due to costs alone and into additional distortions that the cap imposes. Thus, if $\Upsilon_{q,t} = 0$ (no

[2]In this model with a C.E.S consumption basket for sector 1, there is no distortion in the relative allocation across firms. This is because a social planner would chose an allocation across firms such that the marginal rate of substitution is equal to the marginal rate of transformation i.e. $z_1/z_2 = (\frac{y(z_1)}{y(z_2)})^{1/\theta}$. This is preserved under the decentralized equilibrium due to market clearing in each firm z: $y_1(z) = \frac{\rho_1(z)}{\rho_1}Y^c/\rho_1$. Therefore, as long as market clearing holds under the decentralized economy, the relative allocation across firms is efficient. Market clearing across firms facilitates aggregation as $\frac{y_1(z)}{y_1(\tilde{z})} = (\frac{z}{\tilde{z}})^{\theta}$ is the condition that allows us to interpret $\tilde{z}$ as the weighted average of productivity of firms, where weights reflect relative output share of firms.

distortion because of the cap), then $\Upsilon_{R,t} = \Upsilon_{x,t}$. However, a binding cap increases the distortions due to immigration policy costs and $\Upsilon_{R,t} > \Upsilon_{x,t}$ is the relevant distortion due to skilled immigration policy costs.

- Distortion because of monopoly power: Monopoly power distorts the job creation decision by inducing a lower return from hiring foreign skilled workers, captured by: $\Upsilon_{\theta} = 1 - 1/\theta$.

The major inefficiency wedges are:

- Job Creation Margin: Comparing the entry condition for foreign skilled workers under the decentralized economy with the entry condition under the social planner's equilibrium implicitly defines the inefficiency wedge under the market economy's job creation margin for foreign skilled workers:

$$\Sigma_{jc,t} = E_t\left[B_{t,t+1}(1 - \delta)\left(\rho_{1,t+1}Z_{t+1}\tilde{z}\frac{(\Upsilon_{R,t} + f_T\Upsilon_{\theta})}{f_T(\Upsilon_{R,t} + f_T)} + \frac{\Upsilon_{R,t} - \Upsilon_{R,t+1}}{\Upsilon_{R,t} + f_T}\right)\right]$$

  where $\Upsilon_{R,t}$ is defined in equation (A.6.1) and all variables are evaluated at the decentralized allocations. If $\Upsilon_{x,t} = \Upsilon_{q,t} = \Upsilon_{\theta} = 0$ (which implies that $\Upsilon_{R,t}$ as well), the job creation wedge is equal to 0.

- Consumption Resource Constraint: Sunk regulatory costs imply a diversion of resources from consumption, leading to a consumption-output efficiency wedge. By comparing the aggregate resource constraints under the decentralized economy with the resource constraint faced by the planner, we get $\Sigma_{r,t} = \Upsilon_{R,t}\tilde{N}_{e,t} - f_T\tilde{N}_{e,t}\Upsilon_{q,t}$.

A.7 Alternate Policy: Market Driven Allocation of Permits

Steady-State Aggregate Demand Schedule and Equilibrium for Permits

Using the aggregate goods market clearing expression for sector 1, the permit demand equation (7) in the main text, and the law of motion for foreign skilled workers in sector 1, we can obtain the permit price as a function of aggregate permit demand. In steady state this is given by:

$$\zeta^p = \frac{(1-\delta)\beta Z\tilde{z}}{\theta(1-(1-\delta)\beta)}\left(\frac{\alpha\delta\bar{l}_u}{(1-\alpha)\tilde{z}(\delta+(1-\delta)N_e^p)}\right)^{1-\alpha} \tag{A.7.1}$$

The steady-state equilibrium permit price $\bar{\zeta^p}$ is obtained by substituting $N_e^p = \bar{N}_e$ in equation (A.7.1).

Inefficiency Wedges in the Alternate Framework:

In this framework, the equilibrium permit price differs from the technological hiring cost in the social planner's framework. This distortion is $\Upsilon_{\zeta,t} = \bar{\zeta^p}$ or the equilibrium price of a permit. Comparing equation (7) in the main text to the optimal entry condition under the social planner's equilibrium, we can derive the inefficiency wedge under the decentralized economy's job creation margin under the alternate immigration policy with market-driven allocation of permits as:

$$\Sigma_{jp,t} = E_t\left[B_{t,t+1}(1-\delta)\left(\rho_{1,t+1}Z_{t+1}\tilde{z}\frac{(\Upsilon_{\zeta^p,t}+f_T\Upsilon_\theta)}{f_T(\Upsilon_{\zeta^p,t}+f_T)}+\frac{\Upsilon_{\zeta^p,t}-\Upsilon_{\zeta^p,t+1}}{\Upsilon_{\zeta^p,t}+f_T}\right)\right] \tag{A.7.2}$$

If $\Upsilon_{\zeta^p,t} = \Upsilon_\theta = 0$, the job creation wedge is equal to 0.

The aggregate resource constraint in this decentralized economy is the same as the resource constraint under the planner's economy as $q = f_R = 0$. Therefore, the resource constraint wedge is 0 and the alternate policy closes the consumption resource constraint wedge.

A.8 Extension to the Baseline Model: Search and Matching Frictions

Firm z's profit maximization problem (taking wages paid to domestic and foreign workers as given)[3] is given by:

$$\max_{\left\{(\rho_{1,t}(z),v_t(z),l_{f,t}(z),l_{d,t}(z)\right\}_{t=0}^{\infty}} E_t \sum_{\tau=t}^{\infty} \beta_{\tau,t} \Big[\rho_{1,\tau}(z) y_{1,\tau}(z) - w_{d,\tau}(z) l_{d,\tau}(z) - w_{f,\tau}(z) l_{f,\tau}(z) - \kappa v_\tau(z) - q_{f,\tau} v_\tau(z) f_R - q_{f,\tau} v_\tau(z) q_\tau (f_T + g_\tau) \Big]$$

s.t.

1. $y_{1,t}(z) = Z_t z(l_{f,t}(z) + l_{d,t}(z))$

2. $l_{d,t}(z) = (1-\delta_d)(l_{d,t-1}(z) + v_{t-1}(z) q_{d,t-1})$

3. $l_{f,t}(z) = (1-\delta_f)(l_{f,t-1}(z) + v_{t-1}(z) q_{f,t-1} q_{t-1})$

4. $y_{1,t}(z) = (\frac{\rho_{1,t}(z)}{\rho_{1,t}})^{-\theta} Y_t^c / \rho_{1,t}$

Let $\Xi_{z,t}$, $\Gamma_{zd,t}$, and $\Gamma_{zf,t}$ be the Lagrange multipliers on constraints 1, 2, and 3 respectively.

F.O.Cs can be rearranged to get:

$$\begin{aligned}
\kappa &= (1-\delta_d) E_t[B_{t,t+1}\Gamma_{zd,t+1}] q_{d,t} + (1-\delta_f) E_t[B_{t,t+1}\Gamma_{zf,t+1}] q_{f,t} q_t - f_R q_{f,t} - q_{f,t} q_t (f_T + g) \\
\Gamma_{zd,t} &= \Xi_{z,t} Z_t z - w_{d,t}(z) + (1-\delta_d) E_t[B_{t,t+1}\Gamma_{zd,t+1}] \\
\Gamma_{zf,t} &= \Xi_{z,t} Z_t z - w_{f,t}(z) + (1-\delta_f) E_t[B_{t,t+1}\Gamma_{zd,t+1}]
\end{aligned}$$

The first equation implies that in equilibrium, the cost of posting a vacancy is equal to the expected discounted surplus from a domestic match and the expected discounted surplus from a foreign match, both weighed by the probability of each match, net of sunk hiring costs for foreign matches. The second and third equation give the surplus from each match

[3] I follow Cacciatore (2014) in assuming this.

— additional value generated from a skilled labor net of the real wage paid, plus the continuation value of the match.

Nash bargaining of wages: There is no match specific productivity so the surplus to the firm from every domestic match and from every foreign match is the same. However, the surplus from a foreign match may differ from the surplus from a domestic match. Equilibrium surplus sharing rule:

$$\eta_j S^F_{zj,t} = (1-\eta_j) S^W_{zj,t} \quad \forall j \in \{d, f\} \tag{A.8.1}$$

where η_j is bargaining power of worker j. $S^F_{zj,t}$ is the firm's surplus from a match with worker j, and $S^W_{j,t}$ is the worker's surplus from match with firm z. Workers' surplus is given by:

$$S^W_{zd,t} = w_{d,t}(z) - \varpi_{d,t} + (1-\delta_d) E_t B_{t,t+1} S^W_{zd,t+1} \tag{A.8.2}$$

$$S^W_{zf,t} = w_{f,t}(z) - \varpi_{f,t} + (1-\delta_f) E_t B^f_{t,t+1} S^W_{zf,t+1} \tag{A.8.3}$$

where $\beta^f_{t,t+1}$ takes into account that the stochastic discount factor of the firm and foreign skilled households may differ as foreign households are not firm owners in the baseline model. ϖ_{jt} is worker j's outside option. For now, I assume no unemployment benefits. The only outside option for domestic workers is the expected discounted value of searching for other jobs in the next period:

$$\varpi_{d,t} = E_t[\beta_{t,t+1}(1-\delta_d) i_{t+1} \int_{z_{min}}^{\infty} \frac{v_{,t+1}(z)}{V_{t+1}} S^W_{zd,t+1} dG(z)] \tag{A.8.4}$$

where i_t is the probability of finding a job for a skilled worker i.e. $i_t = \chi(\frac{V_t}{U_{d,t}+U_{f,t}})^{1-\epsilon}$. To begin with, I assume that a foreign worker would not be able to search for jobs and thus their outside option is 0. The rationale is that foreign workers cannot legally stay in the domestic economy beyond a certain point without a valid work visa. However, an alternate exercise with a positive outside option for foreign workers does not change the main implications.

Using $S^F_{zj,t} = \Gamma_{zj,t}$ (no firing costs) and the first order conditions — A.8.1, A.8.2, A.8.3, and A.8.4. we can get:

$$w_{d,t}(z) = \eta_d(\Xi_t Z_t z) + (1-\eta_d)\varpi_{d,t} \qquad \text{(A.8.5)}$$

$$w_{f,t}(z) = \eta_f(\Xi_t Z_t z) + (1-\eta_f)\varpi_{f,t} + (1-\delta_f)E_t[\Gamma_{f,t+1}(\beta_{t,t+1} - \beta^f_{t,t+1})] \qquad \text{(A.8.6)}$$

A.8.6 again takes into account the different stochastic discount factor of foreign workers and domestic firms (an implication of H.3). Since firms face the same costs and the same probabilities of being matched with workers, it can be shown as in Cacciatore (2014) that $\Xi_{z,t} = \Xi_t/z$ (the real marginal cost is symmetric across producers up to firm-specific productivity differentials). This facilitates aggregation as in the standard Melitz (2003) model.

Profit maximization with respect to prices gives $\rho_{1.t}(z) = \frac{\theta-1}{\theta}\Xi_{z,t}$, which can be aggregated to give average sector 1 prices: $\tilde{\rho}_{1.t} = \frac{\theta-1}{\theta}\tilde{\Xi}_t$. Aggregate accounting is given by $\tilde{\rho}_{1,t}Y_{1,t} + \rho_{2,t}Y_{2,t} = C_{u,t} + C_{s,t} + C_{i,t} + \kappa V_t + f_R q_{f,t} V_t + f_T q_{f,t} q_t$, where upper case letters and variables with tilde denote aggregate variables.

The summary of conditions can be written as:

$$Y_{1,t} = Z_t \tilde{z}(L_{f,t} + L_{d,t}) \tag{A.8.7}$$

$$L_{d,t} = (1-\delta_d)(L_{d,t-1} + V_{t-1}q_{d,t-1}) \tag{A.8.8}$$

$$L_{f,t} = (1-\delta_f)(L_{f,t-1} + V_{t-1}q_{f,t-1}q_{t-1}) \tag{A.8.9}$$

$$w_{d,t} = \eta_d(\tilde{\Xi}_t Z_t \tilde{z}) + (1-\eta_d)\varpi_{d,t} \tag{A.8.10}$$

$$w_{f,t} = \eta_f(\tilde{\Xi}_t Z_t \tilde{z}) + (1-\eta_f)\varpi_{f,t} + (1-\delta_f)E_t[\Gamma_{f,t+1}(\beta_{t,t+1} - \beta^f_{t,t+1})] \tag{A.8.11}$$

$$\begin{aligned}\kappa = {} & (1-\delta_d)E_t[B_{t,t+1}\Gamma_{d,t+1}]q_{d,t} + (1-\delta_f)E_t[B_{t,t+1}\Gamma_{f,t+1}]q_{f,t}q_t - f_R q_{f,t} \\ & - q_{f,t}q_t(f_T + g_t)\end{aligned} \tag{A.8.12}$$

$$\Gamma_{d,t} = \tilde{\Xi}_t Z_t \tilde{z} - w_{d,t} + (1-\delta_d)E_t[B_{t,t+1}\Gamma_{d,t+1}] \tag{A.8.13}$$

$$\Gamma_{f,t} = \tilde{\Xi}_t Z_t \tilde{z} - w_{f,t} + (1-\delta_f)E_t[B_{t,t+1}\Gamma_{f,t+1}] \tag{A.8.14}$$

$$q_{d,t} = \frac{U_{d,t}}{U_{d,t} + U_{f,t}}\chi(\frac{V_t}{U_t})^{-\epsilon} \tag{A.8.15}$$

$$q_{f,t} = \frac{U_{f,t}}{U_{d,t} + U_{f,t}}\chi(\frac{V_t}{U_t})^{-\epsilon} \tag{A.8.16}$$

$$q_t = min[\frac{\bar{N}_{e,t}}{\tilde{N}_{e,t}}, 1] \tag{A.8.17}$$

$$\tilde{\rho}_{1.t} = \frac{\theta - 1}{\theta}\tilde{\Xi}_t \tag{A.8.18}$$

$$1 = (\tilde{\rho}_{1,t})^{\alpha}(\rho_{2,t})^{1-\alpha} \tag{A.8.19}$$

$$Y_{2,t} = Z_t \bar{L}_u \tag{A.8.20}$$

$$\tilde{\rho}_{1,t}Y_{1,t}/\alpha = \rho_{2,t}Y_{2,t}/(1-\alpha) \tag{A.8.21}$$

$$U_{d,t} = \bar{L}_d - L_{d,t} \tag{A.8.22}$$

$$U_{f,t} = \bar{L}_f - L_{f,t} \tag{A.8.23}$$

$$U_t = U_{d,t} + U_{f,t} \tag{A.8.24}$$

$$\rho_{2,t} = w_{u,t}/Z_t \tag{A.8.25}$$

$$\tilde{d}_t = \tilde{\rho}_{1,t}Y_{1,t} - w_{d,t}L_{d,t} - w_{f,t}L_{f,t} - \kappa_t V_t - f_R q_{f,t}V_t - (f_T + c)q_{f,t}q_t V_t \tag{A.8.26}$$

$$\varpi_{d,t} = E_t[\beta_{t,t+1}(1-\delta_d)i_{t+1}\frac{\eta_d}{1-\eta_d}\tilde{\Gamma}_{d,t+1}] \tag{A.8.27}$$

$$i_t = \chi(\frac{V_t}{U_{d,t} + U_{f,t}})^{1-\epsilon} \tag{A.8.28}$$

There are 22 equations in 22 endogenous variables: $Y_{1,t}$, $Y_{2,t}$, $L_{f,t}$, $L_{d,t}$, V_t, q_t, $U_{d,t}$, $U_{f,t}$, $\tilde{\rho_{1,t}}$, $\rho_{2,t}$, $q_{d,t}$, $q_{f,t}$, $w_{d,t}$, $w_{f,t}$, $\Gamma_{d,t}$, $\Gamma_{f,t}$, $\tilde{\Xi}_t$, $w_{u,t}$, U_t, d_t, $\varpi_{d,t}$, i_t.

To see how this model relates to the baseline model with no search and matching frictions, note that in the simple version, $q_{d,t} = 0$, $q_{f,t} = 1$, and the matching function is such that matches are formed instantaneously. In other words, $U_{d,t} = 0$ and therefore, $\bar{L}_d = L_{d,t}$. All posted vacancies are filled by foreign workers, $\chi = 1$, and vacancy posting cost $\kappa = 0$ in baseline model.

Steady State for the Search and Matching Model

The steady state for the search and matching model boils down to a system of 8 equations in 8 endogenous variables — L_f, L_d, V, $\tilde{\rho}_1$, q_d, q_f, ϖ_d, and i. I show this for the steady state under the non-binding regime.[4] Using (A.8.10), (A.8.11), (A.8.13), and (A.8.14), we can write the steady-state surplus obtained from domestic and foreign workers as $\Gamma_d = \frac{(1-\eta_d)(\tilde{\Xi}Z\tilde{z}-\varpi_d)}{(1-(1-\delta_d)\beta)}$, and $\Gamma_f = \frac{(1-\eta_f)(\tilde{\Xi}Z\tilde{z}-\varpi_f)}{(1-(1-\delta_f)\beta)}$. Then substituting these expressions in the steady state hiring condition we get:

$$\kappa = (1-\delta_d)\beta\frac{(1-\eta_d)(\frac{\theta-1}{\theta}\tilde{\rho}_1 Z\tilde{z}-\varpi_d)}{(1-(1-\delta_d)\beta)}q_d+(1-\delta_f)\beta\frac{(1-\eta_f)(\frac{\theta-1}{\theta}\tilde{\rho}_1 Z\tilde{z}-\varpi_f)}{(1-(1-\delta_f)\beta)}q_f q-(f_R+f_T+g)q_f \tag{A.8.29}$$

Using the market-clearing equation for sector one, and aggregate accounting, we can get:

$$(1-\alpha)\tilde{z}(L_d+L_f) = \alpha(\tilde{\rho}_1)^{\frac{1}{(1-\alpha)}}\bar{l}_u \tag{A.8.30}$$

(A.8.8), (A.8.9), (A.8.15), and (A.8.16) can be written as:

$$L_d = (1-\delta_d)Vq_d/\delta_d \tag{A.8.31}$$

$$L_f = (1-\delta_f)Vq_f q/\delta_f \tag{A.8.32}$$

[4]For the binding case, there will be 10 equations in 10 variables with $q = \bar{N}_e/(q_f V)$ as an additional equation for determining q.

$$q_d \quad = \quad \frac{\bar{L}_d - L_d}{\bar{L}_d + \bar{L}_f - L_d - L_f}\chi\left(\frac{V}{\bar{L}_d + \bar{L}_f - L_d - L_f}\right)^{-\epsilon} \tag{A.8.33}$$

$$q_f \quad = \quad \frac{\bar{L}_f - L_f}{\bar{L}_d + \bar{L}_f - L_d - L_f}\chi\left(\frac{V}{\bar{L}_d + \bar{L}_f - L_d - L_f}\right)^{-\epsilon} \tag{A.8.34}$$

Also, using the surplus sharing rule (A.8.1) and the outside-option equation (A.8.4), the outside option of domestic skilled workers can be written as:

$$\varpi_d = \beta(1-\delta_d)i\frac{\eta_d}{1-\eta_d}\Gamma_d \tag{A.8.35}$$

The steady-state job finding probability of skilled workers is given by:

$$i = \chi\left(\frac{V}{\bar{L}_d + \bar{L}_f - L_d - L_f}\right)^{1-\epsilon} \tag{A.8.36}$$

(A.8.29), (A.8.30), (A.8.31), (A.8.32), (A.8.33), (A.8.34), (A.8.35), and (H.36) constitute a system of 9 equations in 9 variables.

Relationship Between Domestic Skilled Employment and the Immigration Cap

When the cap binds in steady state, the probability of hiring a foreign skilled worker is given by $q = \frac{\bar{N}_e}{q_f V}$, and therefore from the law of motion of foreign labor, we get that the steady-state foreign labor employed is $L_f = (1-\delta_f)\bar{N}_e/\delta_f$. To see relationship between L_d and $\bar{N}_e$, take the ratio of (H.31) and (H.32), and use $L_f = (1-\delta_f)\bar{N}_e/\delta_f$, and after rearranging terms, we get:

$$L_d = \bar{L}_d\left(\frac{\bar{L}_f\delta_d}{(1-\delta_d)\bar{N}_e} - \frac{\delta_d(1-\delta_f)}{\delta_f(1-\delta_d)} + 1\right)^{-1} \tag{A.8.37}$$

i.e. as the cap on foreign skilled workers increases, for a given pool of domestic and foreign labor, aggregate domestic skilled workers employed increases. Intuitively, an increase in the entry cap increases firms' incentive to post more vacancies as there is a higher probability that a foreign worker that was matched would eventually be able to join the firm.

Appendix B

B.1 Model Summary

Below, we summarize the model. We have a system of 17 equations in 17 endogenous variables $\{\rho_{m,t},\ \rho^*_{m,t},\ \mu_t,\ w_{s,t},\ w^*_{s,t},\ Q_t,\ l_{f,t},\ N_{e,t}, l_{o,t},\ d_{1,t},\ d_{c,t},\ w_{u,t},\ l_{u,t},\ l^*_{s,t},\ d^*_{1,t},\ d^*_{c,t},\ w^*_{u,t}\}$

Table B.1: Baseline Model Summary

Equation Label	Equilibrium Condition
Home Consumption Price Index	$\rho_{d,t} = 1$
Foreign Consumption Price Index	$\rho^*_{d,t} = 1$
Home Intermediate Price Index	$(\rho_{m,t})^{1-\phi} = (\rho_{1,t})^{1-\phi} + N^*_d(\rho^*_{x,t})^{1-\phi}$
Foreign Intermediate Price Index	$(\rho^*_{m,t})^{1-\phi} = N^*_d(\rho^*_{1,t})^{1-\phi} + (\rho_{x,t})^{1-\phi}$
Immigrant Labor Hiring Condition	$\frac{f_{R,t}}{\mu_t} = (1-\delta)E_t\left\{\beta_{t,t+1}\left[aw_{s,t+1} - Q_{t+1}\tau w^*_{s,t+1}Z_{t+1}/Z^*_{t+1} + \frac{f_{R,t+1}}{\mu_{t+1}}\right]\right\}$
Immigrant Labor Stock	$l_{f,t+1} = (1-\delta)(l_{f,t} + \mu_t N_{e,t})$
Hiring Probability	$\mu_t = \frac{\bar{N}_{e,t}}{N_{e,t}}$
Home Intermediate Profits	$d_{1,t} = \rho_{1,t}y_{1,t} + Q_t\rho_{x,t}y_{x,t} - w_{s,t}(1+l_{f,t}) - Q_t w^*_{s,t}l_{o,t} - f_{R,t}N_{e,t} - f_{o,t}w^*_{s,t}Q_t/Z^*_t$
Home Final Profits	$d_{c,t} = \rho_{d,t}y_{d,t} - \rho_{1,t}y_{1,t} - N^*_d\rho^*_{x,t}y^*_{x,t} - w_{u,t}l_{u,t}$
Foreign Intermediate Profits	$d^*_{1,t} = \rho^*_{1,t}y^*_{1,t} + Q_t^{-1}\rho^*_{x,t}y^*_{x,t} - w^*_{s,t}l^*_{s,t}$
Foreign Final Profits	$d^*_{c,t} = \rho^*_{d,t}Y^{c*}_t - N^*_d\rho^*_{1,t}y^*_{1,t} - \rho_{x,t}y_{x,t} - w^*_{u,t}\bar{l}^*_u$
Home Aggregate Accounting	$Y^c_t = w_{s,t}(1+l_{f,t}) + w_{u,t}\bar{l}_u + d_{c,t} + d_{1,t} + f_R N_{e,t}$
Foreign Aggregate Accounting	$Y^{c*}_t = w^*_{s,t}(l_{o,t} + f_{o,t} + N^*_d l^*_{s,t}) + w^*_{u,t}\bar{l}^*_u + d^*_{c,t} + N^*_d d^*_{1,t}$
Balance of Payments	$Q_t\rho_{x,t}y_{x,t} - N^*_d\rho^*_{x,t}y^*_{x,t} = Q_t w^*_{s,t}l_{o,t} + Q_t f_o w^*_{s,t}$
Home Goods Market Clearing	$y_{m,t} = y_{1,t} + \tau y_{x,t}$
Foreign Goods Market Clearing	$y^*_{m,t} = y^*_{1,t} + \tau y^*_{x,t}$
Foreign Skilled Labor Market Clearing	$\bar{L_s}^* = N^*_d l^*_{s,t} + l_{f,t} + f_{o,t} + l_{o,t}$

B.2 Cyclicality of Services Offshoring

Looking at correlations of detrended US Real GDP and the employment at US owned Foreign affiliates from Figure B.1 and Table B.3, we find procyclicality of offshoring in manufacturing but countercyclicality for the Professional, Scientific, and Technical Services Sector.

Table B.2: Cylicality of Employment at Foreign Affiliates

Time Period	Variable	Correlation with Real GDP
1999-2015	PST Employment	-0.53
	Manufacturing Employment	0.15

To explore this further in our model, we study the response to a 1 standard deviation increase in Home productivity. The AR(1) process for Z_t is specified as $Z_t = \rho(Z_{t-1} - \bar{Z}) + e_h$ where $\rho = 0.906$, and e_h is a random shock drawn from a standard normal distribution with mean 0 and standard deviation equal to 0.01. From Figure C.3 we see a comparison of these responses under the original versus stricter immigration policy. While an increase in productivity leads Home firms to demand more immigrant labor (consistent with data as seen in Figure B.2), since their entry is fixed due to the cap, the probability of being able to hire immigrant labor declines and this decline is greater under the lower cap. Despite being unable to hire immigrant labor, Home firms decrease offshoring due to the rise in the real marginal cost of offshore labor relative to hiring labor in Home. This decline is significantly smaller under the lower cap due to greater decline in the immigration probability which causes firms to reduce demand for immigrant labor and substitute towards offshoring.

B.3 Figures

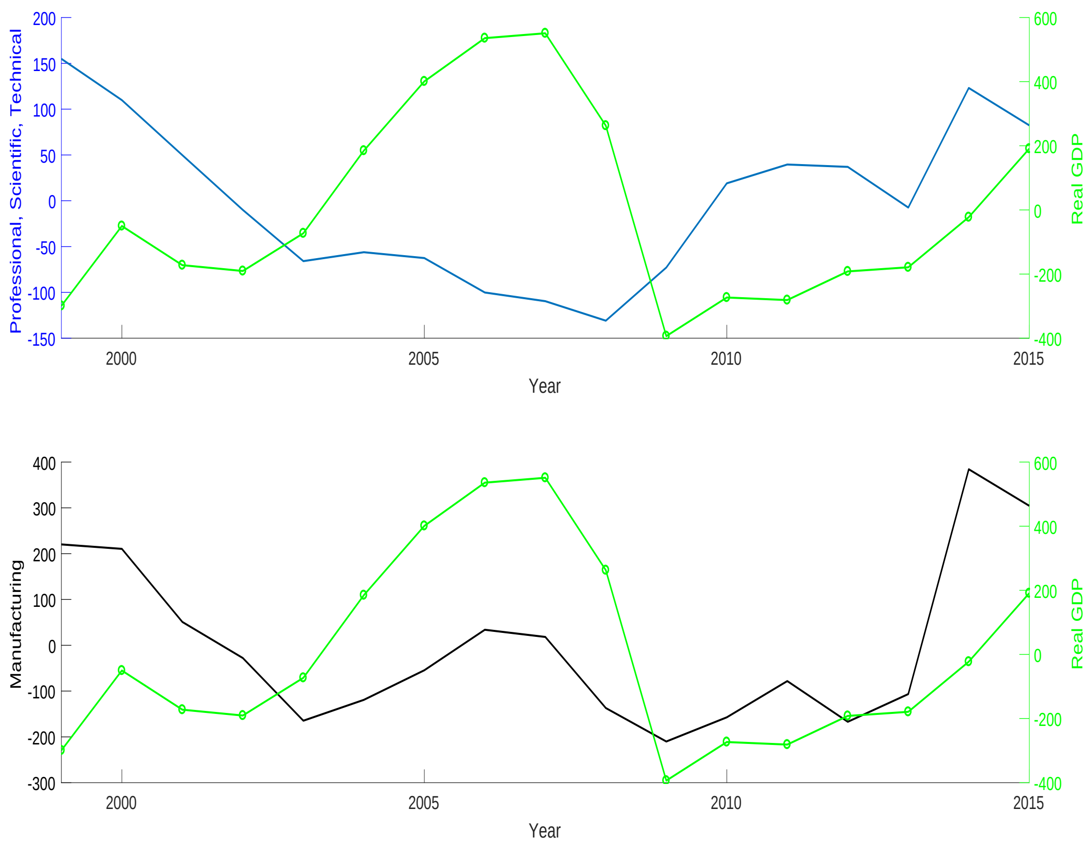

Figure B.1: Cyclicality of Employment at Foreign Affiliates

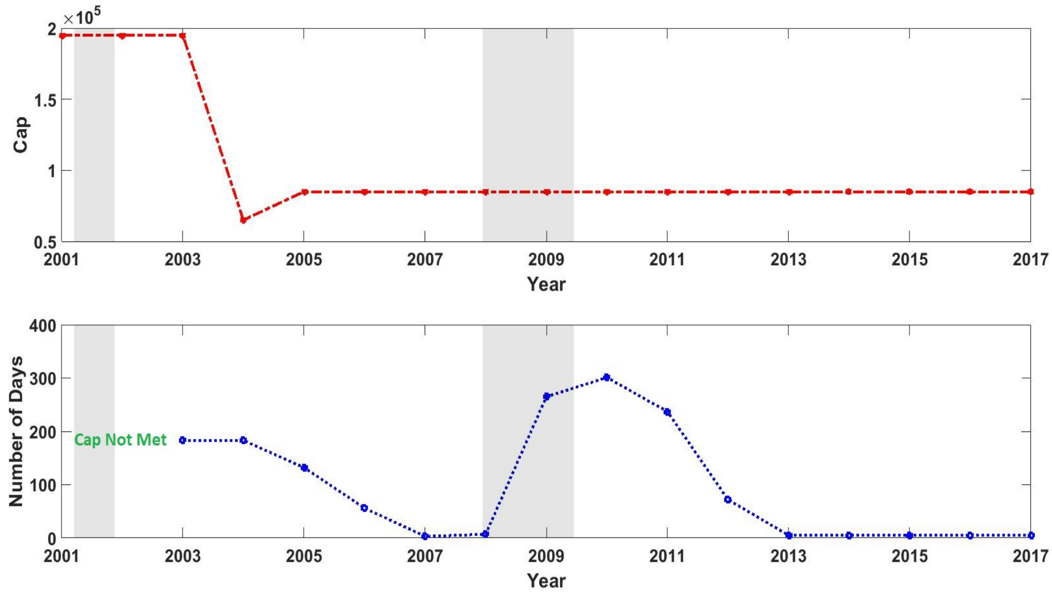

Figure B.2: Top Panel: H-1B Visa Cap. Bottom Panel: Days Taken to Meet Cap

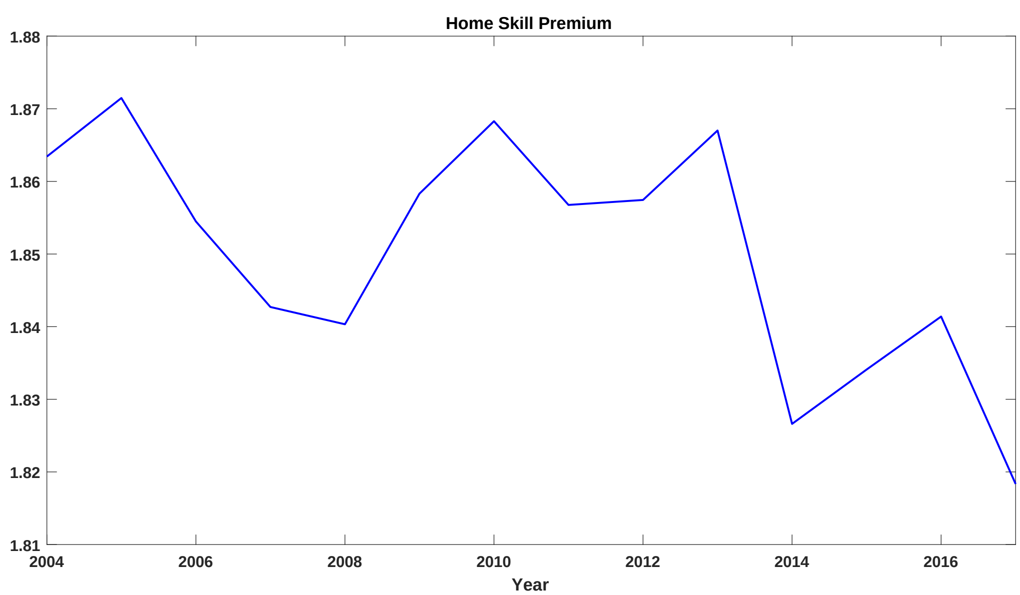

Figure B.3: U.S. Skill Premium 2004-2017

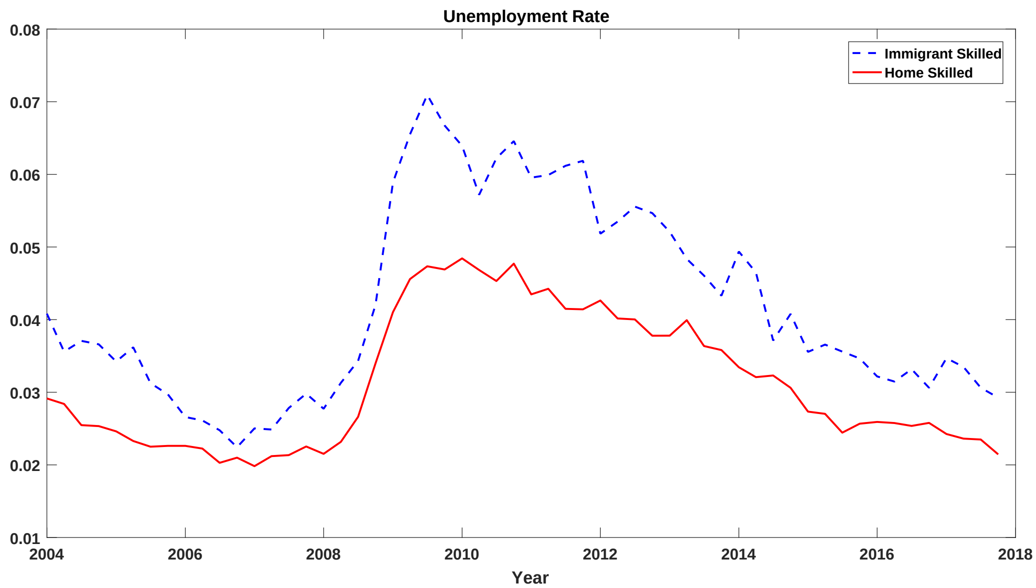

Figure B.4: U.S. Skilled Unemployment Rates by Nativity 2004-2017

For Figures C.3 and C.4 above, we defie skilled as those individuals with a Bachelor's degree or higher and thus, unskilled as those without a Bachelor's degree.

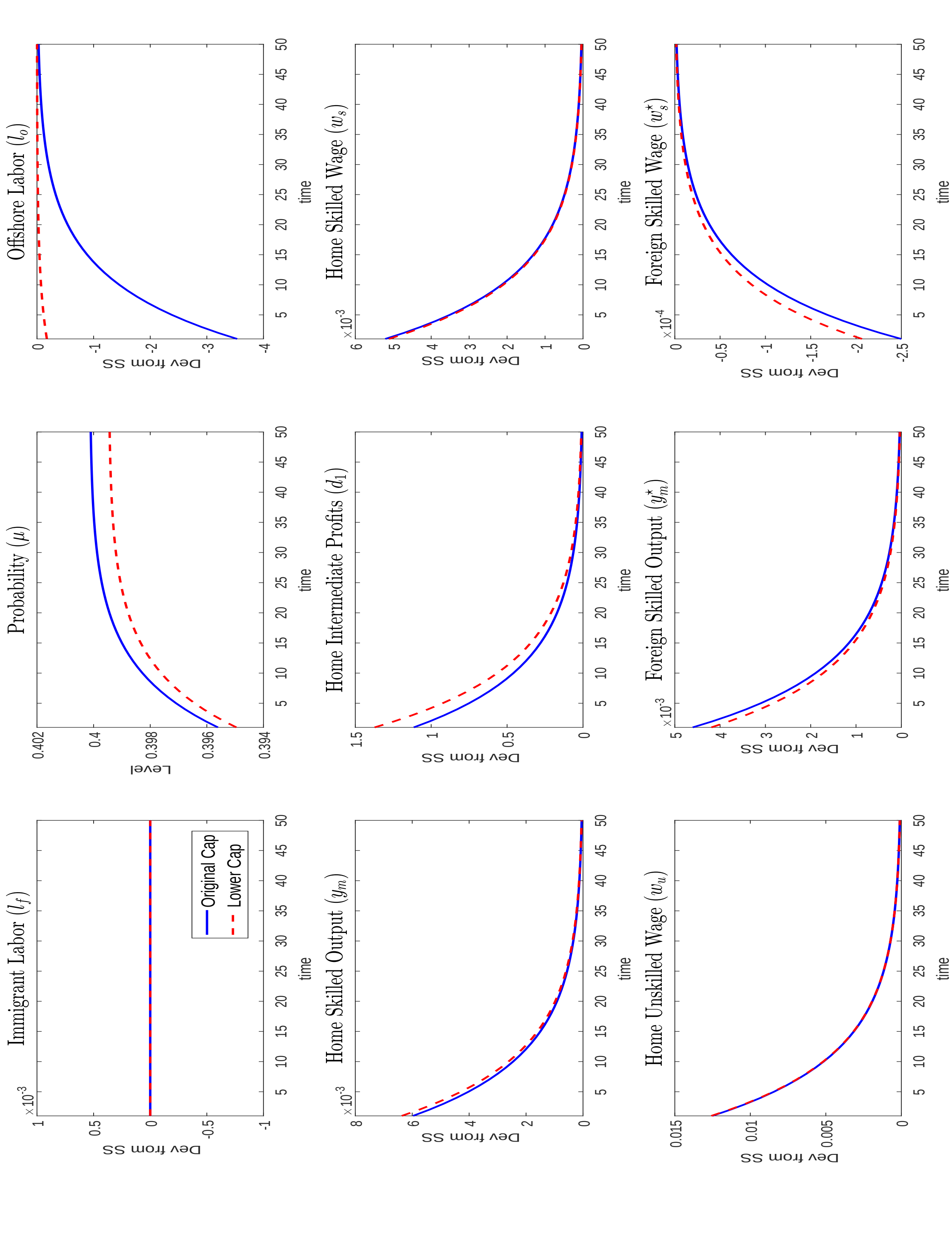

Figure B.5: Response to a 1 Standard Deviation Increase in Home Productivity in Baseline Model versus Lower Cap

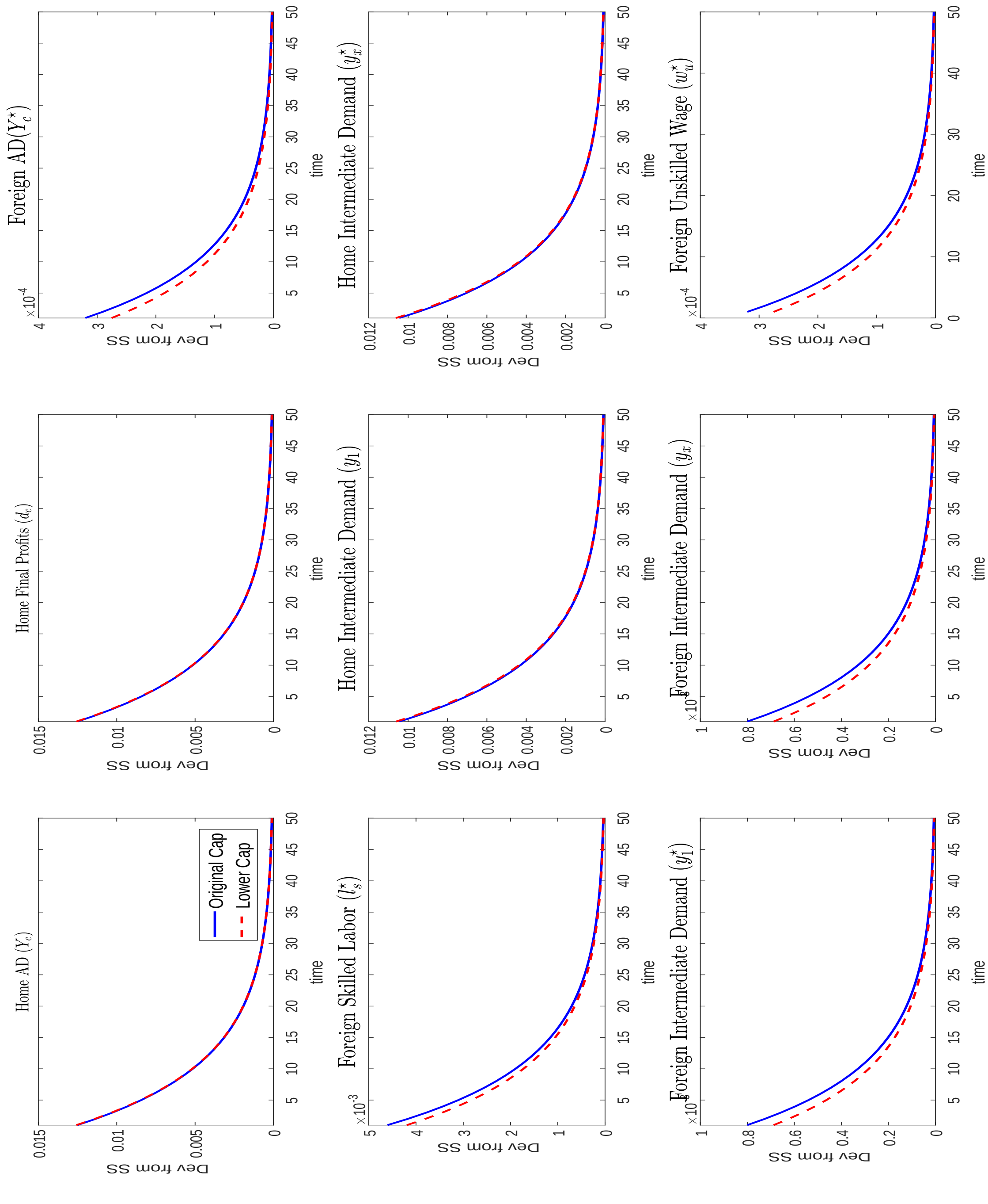

Figure B.6: Response to a 1 Standard Deviation Increase in Home Productivity in Baseline Model versus Lower Cap

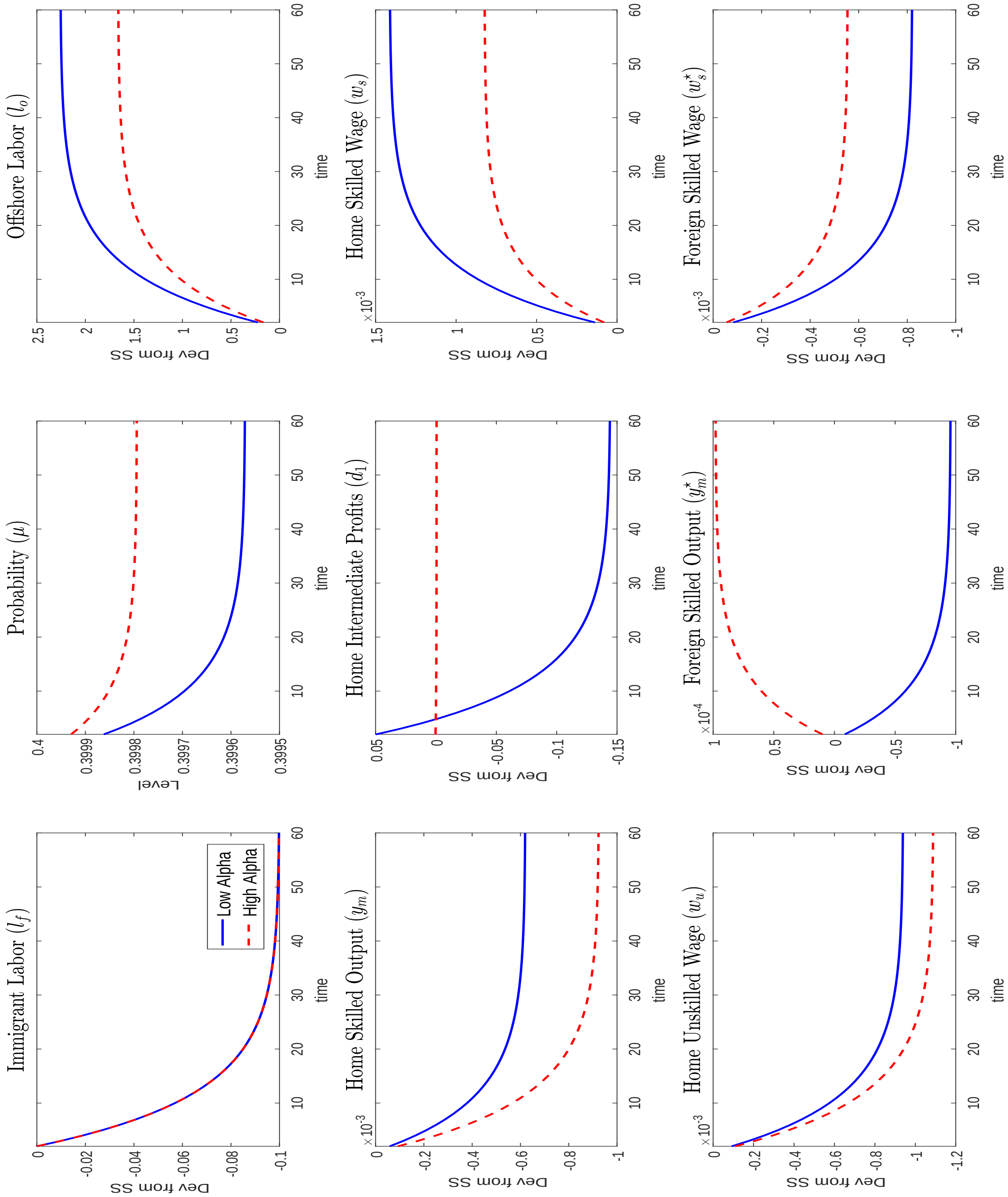

Figure B.7: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus Higher Alpha

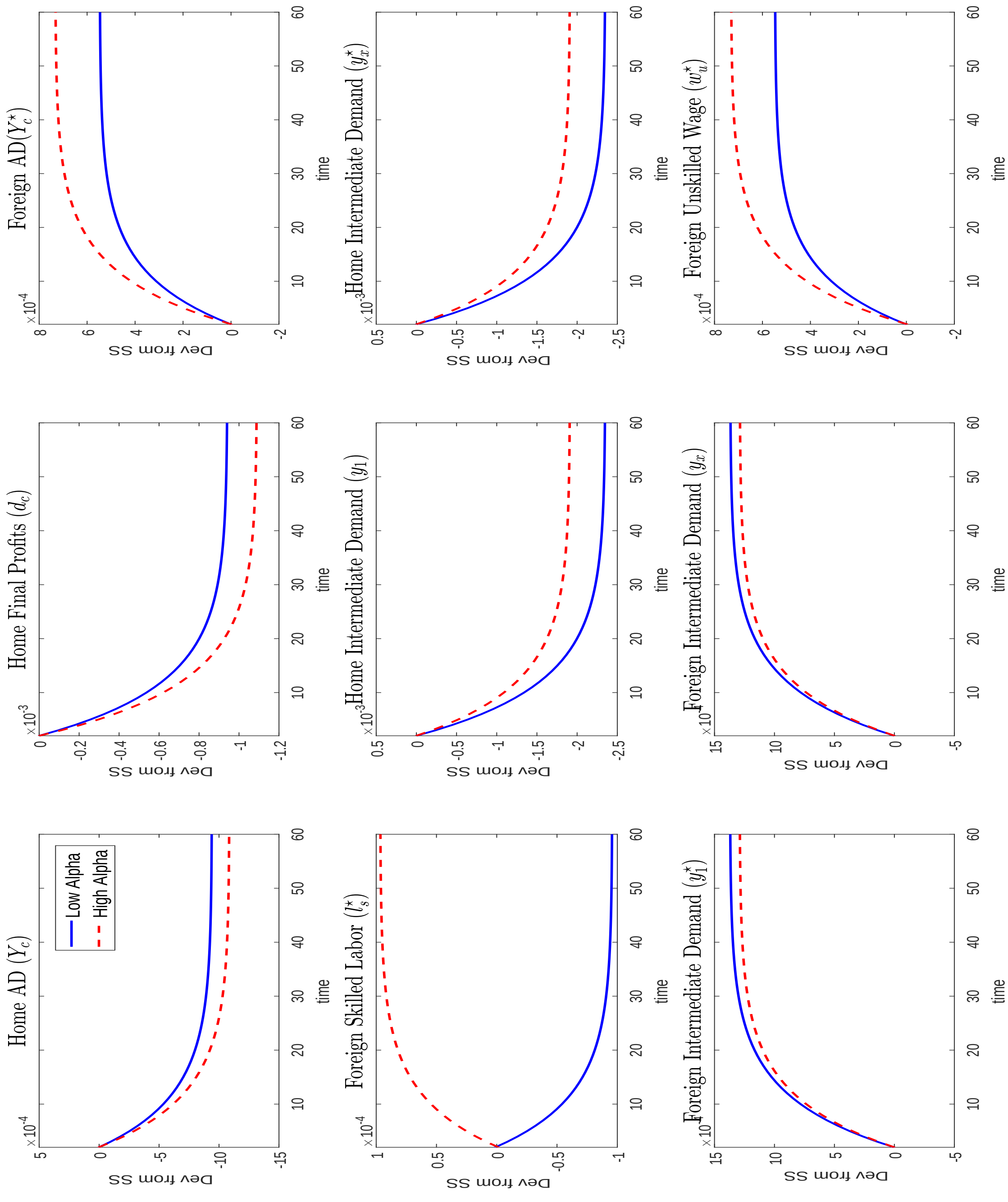

Figure B.8: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus Higher Alpha