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# Three Essays on Policy Issues in International Macroeconomics

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**Abstract**

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The purpose of this dissertation is to investigate issues of importance in the formation of macroeconomic policy.

- In the first chapter, I explore the role of multinationals and intra-firm trade in exchange-rate pass-through into US imports. Conventional international macroeconomics models exploring exchange-rate pass-through, and informing monetary policy, often ignore transfer pricing. This results in predictions about firm-level pass-through that are at odds with the micro-level, empirical evidence. Motivated by the transaction level evidence that exchange-rate pass-through tends to be higher intra-firm than at arms-length, I construct a simple two-country, two-sector model of intra-firm and arms-length trade. Intra-firm trade is carried out by vertically integrated multinationals that compete in Bertrand fashion with regular exporters in the upstream sector. Under reasonable assumptions on pricing decisions and the cost function, my model is able to match the micro evidence. I add to the conventional literature by showing that along with exporters' shares, intra-firm trade and transfer pricing by multinationals are important factors for exchange rate pass-through. Furthermore, this model provides a framework to evaluate changes in monetary policy, as well as the interaction between the profit-shifting incentives of transfer pricing and changes in fiscal policy.

- In chapter two, we propose and quantify one potential explanation for the empirical evidence on the large productivity gaps between urban and agricultural sectors in developing countries. If residing in a village provides access to a network that effectively insures against income fluctuations, then households are less willing to live in the cities where labor income risk is uninsured. As a result, labor remains cheap in agriculture, and the incentives for switching to capital-intensive methods of farming remain weak. In order to understand the quantitative importance of this mechanism, we calibrate the model to Indian data and study an abstract policy-intervention: a provision of complete insurance against earnings risk in the city. The policy intervention decreases the urban-rural labor productivity gap by 64 percent. This effect comes about because of the 10 percent drop in agricultural share of employment, which encourages an inflow of capital and raises average farm size by 18 percent.
- In chapter three, we study 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 and the presence of labor market frictions. This analysis 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, we study the interaction between immigration and offshoring in a dynamic general equilibrium model with a realistic skilled immigration policy setup.

## TABLE OF CONTENTS

	Page
List of Figures . . . . .	iii
List of Tables . . . . .	v
Chapter 1: Market Shares and Exchange-Rate Pass-Through: The Role of Transfer Pricing by U.S. Multinationals . . . . .	1
1.1 Introduction . . . . .	1
1.2 Model . . . . .	4
1.3 Exchange Rate Pass-Through into Firm-Level Prices . . . . .	9
1.4 Exchange Rate Pass-Through into Home CPI . . . . .	12
1.5 Conclusion . . . . .	14
1.6 Figures . . . . .	15
Chapter 2: Why Is Agricultural Productivity So Low in Poor Countries?: The Case of India . . . . .	20
2.1 Introduction . . . . .	20
2.2 Model . . . . .	23
2.3 Calibration . . . . .	31
2.4 Results . . . . .	33
2.5 Conclusion . . . . .	34
Chapter 3: Skilled Immigration Policy and Offshoring by U.S. Firms . . . . .	35
3.1 Introduction . . . . .	35
3.2 Related Literature . . . . .	40
3.3 Baseline Model . . . . .	41
3.4 Steady-State Intuition . . . . .	48
3.5 Calibration . . . . .	49

3.6	Transition Dynamics and Welfare Results in the Baseline Model . . . . .	50
3.7	Model with Labor Market Frictions . . . . .	54
3.8	Conclusion . . . . .	61
3.9	Figures . . . . .	62
	Bibliography . . . . .	71
	Appendix A: Appendix for Chapter 1 . . . . .	79
	A.1 Analytical Derivations . . . . .	79
	Appendix B: Appendix for Chapter 2 . . . . .	88
	B.1 Data Sources . . . . .	88
	B.2 Model Solution . . . . .	89
	Appendix C: Appendix for Chapter 3 . . . . .	94
	C.1 H1-B Program: Institutional Framework and Background . . . . .	94
	C.2 Model Summary . . . . .	97
	C.3 Cyclicity of Services Offshoring . . . . .	97
	C.4 Figures . . . . .	99

## LIST OF FIGURES

Figure Number	Page
1.1 Percent Change in Real U.S. Dollar Export Prices 2006-08 versus Share of Intra-Firm Trade for U.S. Multinationals 2008 in Manufacturing Industries . . . . .	15
1.2 Percent Change in Real U.S. Dollar Export Prices 2006-08 versus Share of Related Party Trade 2008 in Manufacturing Industries . . . . .	15
1.3 Percent of U.S. Multinational Plants versus Herfindahl Hirschman Index in 2007	16
1.4 Percent of U.S. Multinational Sales versus Herfindahl Hirschman Index in 2007	16
1.5 Exchange Rate Pass-Through Elasticity into Firm-Level Prices versus Share of Multinationals in Home Upstream Market . . . . .	17
1.6 Exchange Rate Pass-Through Elasticity into Home CPI versus Share of Multinationals in Home Upstream Market ( $\alpha = 1$ ) . . . . .	18
1.7 Exchange Rate Pass-Through Elasticity into Home CPI versus Share of Multinationals in Home Upstream Market ( $\alpha = 0.4$ ) . . . . .	19
3.1 Rising Importance of Skilled Service Sector for U.S. . . . .	62
3.2 Employment at Foreign Affiliates in Professional, Scientific, and Technical Services . . . . .	63
3.3 Earnings of Native Born as Percent of Foreign Born: Bachelor's Degree and Higher, 25 Years and Over . . . . .	64
3.4 Response to a 10 Percent Immigration Cap Reduction in Baseline Model . . . . .	65
3.5 Response to a 10 Percent Immigration Cap Reduction in Baseline Model . . . . .	66
3.6 Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus No Offshoring . . . . .	67
3.7 Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus No Offshoring . . . . .	68
3.8 Response to a 10 Percent Immigration Cap Reduction with Labor Market Frictions . . . . .	69
3.9 Response to a 10 Percent Immigration Cap Reduction with Labor Market Frictions . . . . .	70

C.1	Cyclicality of Employment at Foreign Affiliates . . . . .	99
C.2	H-1B Visa Cap . . . . .	100
C.3	U.S. Skill Premium 2004-2017 . . . . .	100
C.4	U.S. Skilled Unemployment Rates by Nativity 2004-2017 . . . . .	101
C.5	Response to a 1 Standard Deviation Increase in Home Productivity in Baseline Model versus Lower Cap . . . . .	102
C.6	Response to a 1 Standard Deviation Increase in Home Productivity in Baseline Model versus Lower Cap . . . . .	103
C.7	Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus Higher Alpha . . . . .	104
C.8	Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus Higher Alpha . . . . .	105

## LIST OF TABLES

Table Number	Page
2.1 Parameter Values . . . . .	32
2.2 Model Output . . . . .	33
3.1 A Priori Parameters . . . . .	49
3.2 Targeted Moments . . . . .	50
3.3 Calibrated Parameters . . . . .	50
3.4 Welfare Impact of 10 Percent Immigration Cap Reduction . . . . .	54
3.5 Calibrated Parameters Under Labor Market Frictions . . . . .	59
3.6 Welfare Impact of a 10 Percent Immigration Cap Reduction: Competitive versus Frictional Labor Markets . . . . .	60
C.1 Major Entry Routes for Foreign Skilled Workers (2014) . . . . .	94
C.2 Baseline Model Summary . . . . .	97
C.3 Cyclicalilty of Employment at Foreign Affiliates . . . . .	98

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## **DEDICATION**

To my parents and sister, without you I would not be who I am today, and especially to my best friend and future wife Tanya.

## Chapter 1

# MARKET SHARES AND EXCHANGE-RATE PASS-THROUGH: THE ROLE OF TRANSFER PRICING BY U.S. MULTINATIONALS

### *1.1 Introduction*

It is well known that intra-firm (i-f) trade, between affiliates of a multinational firm, accounts for a large portion of total trade for the U.S. economy. In 2016, 49 percent (31 percent) of U.S. imports (exports) were carried out i-f, and in 2015 67 percent (68 percent) of multinational imports (exports) were between a U.S. parent and its foreign affiliate.<sup>1</sup> Despite their significance, the mainstream macroeconomics literature ignores the associated pricing decisions. Since these transactions involve the transfer of goods across divisions of a firm, I refer to them as transfer prices.<sup>2</sup>

In this chapter, I am interested in understanding the transfer pricing decisions of a vertically integrated multinational firm, where each division plays a value addition role, and how these decisions affect exchange-rate pass-through (ERPT) into prices. Through understanding this channel, I develop the first step in answering the question: What is the role of transfer pricing by multinational firms in the international transmission of monetary policy?

A large body of literature in international macroeconomics has explored the role of ERPT in the transmission of monetary policy. A subset of these typically assume some form of

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<sup>1</sup>Data on multinational trade between parents and affiliates is obtained from the BEA's database on U.S. Direct Investment Abroad. The share of intra-firm trade in total U.S. trade is obtained from the Related Party Trade Database of the U.S. Census.

<sup>2</sup>In the context of this paper, transfer prices have nothing to do with profit-shifting, a popular issue in the public finance and managerial accounting literature. I revisit the discussion on profit-shifting and its relevance for fiscal policy decisions in future work by extending the framework I employ in this analysis.

nominal rigidity, which causes the currency of invoicing to become an important determinant of ERPT. For example, Obstfeld and Rogoff (1995) assume producer currency pricing (PCP), Chari et al. (2002) and Betts and Devereux (2000) assume local currency pricing (LCP). In the short-run, ERPT into import prices is 1 under PCP and 0 under LCP. Once prices adjust, ERPT is complete in both cases. Two relevant results arise from these models: first that ERPT into prices does not depend on market share and second that ERPT into all prices (under similar nominal rigidity in the short-run) should be the same. Both of these implications are strongly negated by the empirical literature.

Feenstra et al. (1996) and Dornbusch (1987) show that ERPT depends on market shares and match the evidence by assuming Bertrand and Cournot competition respectively. However, even after accounting for the role of market shares, these models ignore the role of i-f trade and transfer pricing in ERPT. Recent empirical literature studying ERPT into U.S. imports, using transaction-level data, has found significant differences in pass-through i-f relative to arms-length (a-l) transactions. Neiman (2010), for example, finds greater pass-through in transfer prices, and also that transfer prices tend to be less sticky and less synchronized across firms.<sup>3</sup> Furthermore, Lawrence and Rangan (1993) find evidence that ERPT increases in the share of i-f trade for U.S. exports. Given that U.S. multinationals typically operate in sectors with a large chunk of market share concentrated among a few firms, conventional models would incorrectly suggest more i-f trade should imply incomplete ERPT.<sup>4</sup>

Motivated by this evidence, and the gap in the literature, I construct a two sector, two country model of i-f and a-l trade that is consistent with the micro-level evidence. Transfer pricing, along a vertically-integrated supply chain, is driven by efficiency and a-l pricing is driven by the preservation of market share under Bertrand competition.

To the best of my knowledge, Lawrence and Rangan (1993) were the first to point out

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<sup>3</sup>Cristea and Nguyen (2016), Bernard et al. (2008), and Gopinath and Rigobon (2008) also find evidence of greater pass-through in transfer prices relative to a-l.

<sup>4</sup>Figures 1.3 and 1.4 show that U.S. Multinationals tend to be more active in industries with a higher Herfindahl-Hirschman Index. The data for these is obtained from Flaaen (2014).

the potential importance of transfer pricing for ERPT.<sup>5</sup> Given that transfer prices exhibit higher pass-through, it is likely true that ERPT into U.S. import prices is increasing in the share of i-f trade, and is a result of my model under standard assumptions. The novelty of this analysis, relative to Feenstra et al. (1996) and Dornbusch (1987), is that while exporters' shares are still relevant, the vertically integrated supply chain introduces the importance of the share of the downstream multinational affiliate, and hence that of i-f trade in ERPT. In addition, my model allows different ERPT at a-l versus in transfer prices, consistent with empirical findings. Other related work includes the research agenda developed by Gopinath and co-authors on the relevance of dominant currency pricing in explaining observed ERPT. Gopinath and Rigobon (2008) find that, in at least 60 percent of their samples across different specifications, ERPT in transfer prices is higher than at a-l for finely defined commodity categories. Further, they find evidence of incomplete pass-through also in transfer prices, which my model is able to replicate under firm-level market interdependence. Lai and Secieru (2004) is another related article that explores the importance of transfer pricing in ERPT, however, they take a different modeling approach by employing linear demand functions and an economies of scope assumption on the cost function.

Transfer prices serve a cost-signaling role in my model, as the decentralized multinational signals the costs of production upstream to its downstream affiliate. Under constant returns to scale for the multinational upstream affiliate, my model generates complete ERPT in transfer prices, and incomplete ERPT in a-l transactions that depends on exporters' shares and the elasticity of substitution. ERPT at a-l is complete if the exporter's share is small enough that they behave as monopolistic competitors or if they have the whole market.

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<sup>5</sup>Figures 1.1 and 1.2 further confirm their findings. Figure 1.1 plots the change in ratio of U.S. Export Price Index (EXP) to U.S. Producer Price Index (PPI) from 2006-08 against the share of intra-firm exports in total exports by U.S. owned multinationals. Figure 1.2 uses the share of intra-firm exports without controlling for multinational ownership. In both of these figures, a higher Y-axis value corresponds to lower ERPT. The intuition for these is as follows. Between 2006-08 the U.S. dollar was depreciating relative to a basket of major currencies. Suppose now that the PPI for a particular industry was 1 dollar and the EXP was 20 pesos. Once the dollar depreciated and the pesos are converted back to dollars, these should yield more than a dollar if the EXP did not fully adjust. Thus, a higher value of the ratio on the Y-axis represents lower ERPT.

Under constant returns to scale, ERPT into Home country's CPI is strictly increasing in the market share of the downstream affiliate. Under non-constant returns to scale, transfer prices also exhibit incomplete ERPT but pass-through remains greater than at a-1 so long as multinationals only compete with domestic firms when exporting.<sup>6</sup>

My model implies that a greater presence of vertically integrated multinationals or a greater involvement of them in U.S. imports should be carefully analyzed when considering the international spillover of changes in monetary policy. Given the importance of i-f trade for U.S. imports, my results suggest that U.S. consumers might stand to gain more significantly from the recent U.S. dollar appreciation due to the tightening of U.S. monetary policy. Further, conventional models ignoring i-f trade and the role of transfer pricing likely generate inaccurate welfare implications of monetary tightening.<sup>7</sup>

The following section details the model, section 1.3 discusses ERPT into firm level prices, section 1.4 describes ERPT into Home CPI, and section 1.5 concludes.

## **1.2 Model**

The world economy consists of two countries: Home and Foreign. Both countries are comprised of an intermediate good (upstream) and a consumption good (downstream) sector. There are a fraction  $a$  of consumption good producers, indexed by  $i$ , in the Home country, and  $(1 - a)$  in Foreign. These downstream producers serve only their respective domestic markets. There are fraction  $\chi$  firms in the upstream sector, indexed by  $j$ , in Foreign, and  $(1 - \chi)$  in Home. All upstream producers trade. In addition, I assume that fraction  $n$  firms downstream in Home and upstream in Foreign are related parties, such that there are  $n$  vertically-integrated multinational firms. Since I am interested in the short-run, I take the industrial structure of the economy as given, however, market shares are allowed to adjust

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<sup>6</sup>Under export competition from regular exporters, ERPT in transfer prices is higher so long as the multinationals share is small enough that it behaves like a monopolistic competitor or large enough that it assigns a very small weight to losing market share in its pricing decision.

<sup>7</sup>I intend to use this framework, in future work, to explore the welfare implications of my findings here relative to those under conventional models.

endogenously, through movements in relative prices. Below, I characterize the problem of the Home downstream producers, and Foreign upstream producers. The problem of Foreign downstream producers and Home upstream producers is similar, except neither sector has multinational affiliates.

### 1.2.1 Home, Downstream

Home households obtain log-utility from the consumption of a basket of domestically available varieties  $C$ :

$$C = \left[ \sum_{i=0}^n c_1(i)^{\frac{\phi-1}{\phi}} + \sum_{i=n}^a c(i)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} \quad (1.1)$$

Where  $c_1$  represents varieties produced by downstream affiliates of a multinational firm,  $c$  those produced by regular domestic firms, and  $\phi > 1$  is the symmetric elasticity of substitution. Thus, the demands for varieties produced by multinational affiliates and regular firms, respectively, are:

$$c_1 = \left( \frac{p_1}{P} \right)^{-\phi} C \quad (1.2)$$

$$c = \left( \frac{p}{P} \right)^{-\phi} C \quad (1.3)$$

### Multinational Downstream Affiliate

Multinational affiliates serve the consumption good market by producing output ( $y_{Id}$ ) with a Cobb-Douglas technology over an internally transferred good  $m_{IN}$  and domestically available labor employed  $l_{Id}$ . Their technology is subject to Home total factor productivity ( $Z$ ):

$$y_{Id} = Z m_{IN}^{\alpha} l_{Id}^{1-\alpha} \quad (1.4)$$

In line with the managerial accounting, and public finance literature, I assume that the headquarter instructs the downstream affiliate to set its own prices while taking the transfer price as given. While making upstream decisions, the headquarter then takes into account

the effect of the transfer price on joint profits. The associated downstream cost-minimization and profit maximization problems yield the optimal marginal cost ( $mc_{Id}$ ) and price ( $p_I$ ):

$$mc_{Id} = \left(\frac{1}{Z}\right) \left(\frac{q_{IN}}{\alpha}\right)^\alpha \left(\frac{w}{1-\alpha}\right)^{1-\alpha} \quad (1.5)$$

From equation (1.5) we see that the marginal cost for the downstream affiliate depends on the transfer price  $q_{IN}$  and  $w$  which represents the Home nominal wage that downstream affiliates also take as given.

$$p_I = \frac{\phi}{\phi-1} mc_{Id} \quad (1.6)$$

### *Regular Downstream Firms*

Regular firms downstream produce output ( $y_d$ ) with a Cobb-Douglas technology over an intermediate good composite  $m$  and domestically available labor employed  $l_d$ :

$$y_d = Zm^\alpha l_d^{1-\alpha} \quad (1.7)$$

The intermediate composite  $m$  is made up of  $(1-\chi)$  domestically produced varieties ( $m_h$ ),  $n$  varieties imported from multinational upstream affiliates in Foreign ( $m_{If}$ ), and  $(\chi-n)$  varieties imported from regular upstream firms in Foreign ( $m_f$ ). Here  $\sigma > 1$  is the symmetric elasticity of substitution.

$$m = \left[ \sum_{j=0}^n m_{If}(j)^{\frac{\sigma-1}{\sigma}} + \sum_{j=n}^{\chi} m_f(j)^{\frac{\sigma-1}{\sigma}} + \sum_{j=\chi}^1 m_h(j)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (1.8)$$

The demands for each of these are:

$$m_k = \left(\frac{q_k}{q}\right)^{-\sigma} m, \text{ for } k \in \{If, f, h\}, q_k \text{ are firm prices and } q \text{ is the price index} \quad (1.9)$$

Then, from the cost minimization and profit maximization problem I find the expressions for marginal cost ( $mc_d$ ) and price ( $p$ ) as:

$$mc_d = \left(\frac{1}{Z}\right) \left(\frac{q}{\alpha}\right)^\alpha \left(\frac{w}{1-\alpha}\right)^{1-\alpha} \quad (1.10)$$

$$p = \frac{\phi}{\phi-1} mc_d \quad (1.11)$$

### 1.2.2 Foreign Upstream Firms

#### Regular Firms

The regular Foreign upstream firm uses a production technology that is linear in domestic labor employed ( $l_u^*$ ), subject to Foreign total factor productivity ( $Z^*$ ) to produce intermediate output ( $y_u^*$ ) to meet the demand from Foreign and Home downstream firms.

$$y_u^* = Z^* l_u^* \quad (1.12)$$

When setting prices to maximize profits, the firms are large enough relative to their competitors that they internalize the effect of their prices on the price index and on the demand for the intermediate goods basket. I detail the results from this decision in the appendix. From the first order conditions, one can easily derive the optimal domestic ( $q_f^*$ ) and export ( $q_f$ ) prices as:

$$q_f^* = \frac{\sigma - (\sigma - 1)s_f^*}{\sigma - (\sigma - 1)s_f^* - 1} \frac{w^*}{Z^*}, \text{ where } s_f^* \equiv \left(\frac{q_f^*}{q^*}\right)^{1-\sigma} \quad (1.13)$$

$$q_f = \frac{\sigma - (\sigma - 1)s_f}{\sigma - (\sigma - 1)s_f - 1} \frac{\epsilon w^*}{Z^*}, \text{ where } s_f \equiv \left(\frac{q_f}{q}\right)^{1-\sigma} \quad (1.14)$$

Here  $\epsilon$  is the nominal exchange-rate, defined as units of Home currency per unit of Foreign currency. It can be readily seen from (1.13 and 1.14) that as firm level share approaches zero ( $s_f$  or  $s_f^* \rightarrow 0$ ), the mark-up approaches the CES mark-up typically seen under monopolistic competition.

### *Multinational Upstream Affiliate*

The multinational affiliate upstream employs domestically available labor ( $l_{Iu}^*$ ) to produce intermediate output ( $y_{Iu}^*$ ) to service the demand from regular firms in Home and Foreign as well as its downstream affiliate in the Home country.

$$y_{Iu}^* = Z^* l_{Iu}^{*\theta} \quad (1.15)$$

Where  $\theta$  represents the returns to scale parameter. From the cost minimization problem:

$$mc_{Iu}^* = \left( \frac{y_{Iu}^*}{Z^*} \right)^{\frac{1-\theta}{\theta}} \frac{w^*}{Z^*} \quad (1.16)$$

As can be seen in equation (1.16), the multinational affiliate's marginal cost of production ( $mc_{Iu}^*$ ) does not depend on output as long as the technology is constant returns to scale ( $\theta = 1$ ). If the affiliate experiences decreasing returns to scale ( $\theta < 1$ ), the marginal cost of production is increasing in output, and vice-versa if it experiences increasing returns to scale ( $\theta > 1$ ). This more general cost function assumption introduces an interdependence between i-f and a-l transactions, which I detail below.

Given equations (1.10), (1.11), and (1.16), the multinational headquarter jointly decides the transfer and upstream a-l prices in order to maximize the profits of the entire firm:

$$\begin{aligned} \max_{q_{IN}, q_{If}, q_{If}^*} & \underbrace{(p_{Id} - mc_{Id})c_I}_{(i)} + \underbrace{(q_{IN} - \epsilon mc_{Iu}^*)m_{IN}}_{(ii)} + \underbrace{(a - n)(q_{If} - \epsilon mc_{Iu}^*)m_{If}}_{(iii)} \dots \\ & \dots + \underbrace{(1 - a)(\epsilon q_{If}^* - \epsilon mc_{Iu}^*)m_{If}^*}_{(iv)} \end{aligned}$$

In the above expression, (i) represents profits from the sales of the downstream affiliate, (ii) profits from the internal transfer of goods from upstream to downstream affiliate, (iii) profits from the a-l sales of intermediates to Home regular firms, and (iv) profits from the a-l sales of intermediates to Foreign regular firms.

Then, taking first order conditions with respect to prices yields the following:

$$q_{IN} = \frac{\epsilon mc_{Iu}^*}{\theta} \quad (1.17)$$

From equation (1.17), we see that as long as  $\theta < 1$  ( $\theta > 1$ ), it is optimal for the multinational to mark up (mark down) the transfer price ( $q_{IN}$ ) so that the demand for output is lower (higher), which lowers the cost of production upstream.<sup>8</sup>

$$q_{If} = \frac{\sigma - (\sigma - 1)s_{If}}{\sigma - (\sigma - 1)s_{If} - 1} \frac{\epsilon mc_{Iu}^*}{\theta}, \text{ where } s_{If} \equiv \left( \frac{q_{If}}{q} \right)^{1-\sigma} \quad (1.18)$$

$$q_{If}^* = \frac{\sigma - (\sigma - 1)s_{If}^*}{\sigma - (\sigma - 1)s_{If}^* - 1} \frac{mc_{Iu}^*}{\theta}, \text{ where } s_{If}^* \equiv \left( \frac{q_{If}^*}{q^*} \right)^{1-\sigma} \quad (1.19)$$

We also see a similar result in the a-l domestic ( $q_{If}$ ) and export prices ( $q_{If}^*$ ) set upstream.

### 1.3 Exchange Rate Pass-Through into Firm-Level Prices

Using the optimal pricing decisions, I derive the following pass-through elasticities:

$$\frac{\partial \ln q_f}{\partial \ln \epsilon} = \left[ 1 - \frac{(\sigma - 1)(1 - \sigma)s_f(1 - (\chi - n)s_f)}{(\sigma - (\sigma - 1)s_f - 1)(\sigma - (\sigma - 1)s_f)} \right]^{-1} \left[ 1 + (\sigma - 1)s_f n s_{If} \frac{\partial \ln q_{If}}{\partial \ln \epsilon} \right] \quad (1.20)$$

The pass-through elasticity of regular exporters depends on their market share ( $s_f$ ), the share of multinational affiliates ( $s_{If}$ ), and the responsiveness of the multinational affiliates' prices  $\left( \frac{\partial \ln q_{If}}{\partial \ln \epsilon} \right)$

The multinationals' export prices respond to exchange rate changes according to the equations (1.21) and (1.22) below:

$$\frac{\partial \ln q_{IN}}{\partial \ln \epsilon} = 1 + \frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} \quad (1.21)$$

While the mark-up for the transfer price does not absorb any changes in the exchange-rate, since the multinationals marginal cost of production upstream varies in the level of output, pass-through will depend on the responsiveness of the marginal cost.

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<sup>8</sup>This would not be the case if downstream and upstream prices were decided jointly as the downstream a-l price mark-up would be augmented with  $\theta$  instead.

$$\frac{\partial \ln q_{I_f}}{\partial \ln \epsilon} = \left[ 1 - \frac{(\sigma - 1)(1 - \sigma)s_{I_f}(1 - ns_{I_f})}{(\sigma - (\sigma - 1)s_{I_f} - 1)(\sigma - (\sigma - 1)s_{I_f})} \right]^{-1} \cdots \left[ 1 + \frac{\partial \ln mc_{I_u}^*}{\partial \ln \epsilon} + (\sigma - 1)s_{I_f}(\chi - n)s_f \frac{\partial \ln q_f}{\partial \ln \epsilon} \right] \quad (1.22)$$

For the a-l price, the pass-through elasticity depends on the response of marginal cost as well as the change in prices of competitors. This elasticity is scaled by the responsiveness of the a-l mark up. Below, I consider the relative pass-through under varying assumptions on the cost function.

*Pass-through under constant returns to scale*

Suppose first that the multinational affiliates upstream technology experiences constant returns to scale such that  $\theta = 1$ . This implies that the marginal cost of upstream production, for the multinational, no longer depends on the level of output. Thus, the marginal cost does not respond to changes in the exchange rate ( $\frac{\partial \ln mc_{I_u}^*}{\partial \ln \epsilon} = 0$ ). Then it can be clearly seen that:

**Proposition 1: Under constant returns to scale, ERPT into transfer prices is always complete.** Proof: When  $\theta = 1$ , we know  $\frac{\partial \ln mc_{I_u}^*}{\partial \ln \epsilon} = 0$ , then from equation (1.21), it is easily seen that  $\frac{\partial \ln q_{I_f}}{\partial \ln \epsilon} = 1$ .

**Proposition 2: Under constant returns to scale, ERPT into transfer prices is greater than at a-l as long as exporters share is less than one and each exporter's firm level share is not zero.** ( $0 < s_f < \frac{1}{\chi}$ )

Proof in appendix

Keeping in mind these propositions, the intuition for the middle panel of figure 1.5 becomes clear. The red-lines in the middle panel represent the pass-through elasticity into transfer and a-l prices for the multinational firm, as a function of the upstream affiliate's share in the intermediate goods sector. It can be clearly seen that since pass-through into

transfer prices is complete, the pass-through elasticity (dashed line) is unchanging in the multinationals share. For a-l prices (solid line), the ERPT is complete only if they resemble monopolistic competitors or if multinationals have complete share of the Home upstream market. Whenever the share is between the bounds specified in proposition 2, ERPT is incomplete, and can be negative if  $1 < s_{If} < \frac{\sigma}{\sigma-1}$ . Thus, pass-through elasticity takes on a U-shape, which results in little to no pass-through for fairly large market shares.<sup>9</sup>

*Pass-through under non-constant returns to scale*

Suppose now that the multinational affiliates' upstream technology experiences non-constant returns to scale such that  $\theta \neq 1$ . This implies that the marginal cost of upstream production depends on the level of output, and thus the marginal cost responds to changes in the exchange rate. I relegate the derivation of pass-through elasticity of multinationals marginal cost to the appendix.

Now, if we assume that multinationals are the only intermediate goods exporters to Home such that  $s_f = 0$ , then the expression in equation (1.22) becomes :

$$\frac{\partial \ln q_{If}}{\partial \ln \epsilon} = \left[ 1 - \frac{(\sigma - 1)(1 - \sigma)s_{If}(1 - ns_{If})}{(\sigma - (\sigma - 1)s_{If} - 1)(\sigma - (\sigma - 1)s_{If})} \right]^{-1} \left[ 1 + \frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} \right]$$

**Proposition 3: If multinational affiliates are the only intermediates exporters to Home, ERPT into transfer prices is lesser than one (greater than one) under decreasing returns to scale (increasing returns to scale).**

Proof: From the appendix, it can be easily verified that while  $\theta < 1$  ( $> 1$ ),  $\frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} < 0$  ( $> 0$ ). Then using equation (21), the proposition is proven.

**Proposition 4: If multinational affiliates are the only intermediates exporters to Home, ERPT into transfer prices is greater than at a-l so long as the exporters'**

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<sup>9</sup>For a detailed discussion on pass-through under Bertrand competition see Feenstra et al. (1996).

share is less than one and each exporter's firm level share is greater than zero.

$$(0 < s_{If} < \frac{1}{n})$$

Proof in appendix

Returning to figure 1.5, and focusing first on the case of decreasing returns to scale (blue), we can clearly see that ERPT into transfer prices is incomplete, and is initially increasing and then decreasing in the multinationals market share. Firstly, this pass-through is incomplete due to decreasing returns to scale: when the ER depreciates such that marginal cost of production abroad (in Home currency units) rises, the multinational begins to raise its transfer price due to its cost-signaling role. But as the transfer price increases, the demand for intermediates by downstream affiliate decreases which reduces the marginal cost of production upstream, thereby dampening the effect of the rise in the exchange-rate. Second, pass-through in transfer prices rises in multinationals share precisely due to the positive effect of this price increase on the cost of production. As multinationals share increases, pass-through into a-l prices decreases which causes an increase in marginal cost of production. In order to counter this increase in costs, the multinational increases its transfer price. The ability to adjust the transfer price in order to influence the cost of a-l transactions gives multinationals an advantage over regular firms as they are able to afford ERPT that is much lower than their competitors and capture greater market share.

Under increasing returns (green), ERPT into transfer prices is greater than one. This is due to the fact that the marginal cost is decreasing in output, and an exchange-rate depreciation that leads to an increase in the upstream marginal cost, and thus the transfer price, causes a decrease in output demand which further increases the cost. Thus, the multinational must increase the transfer price by more than the rise in the exchange-rate in order to preserve profits.

#### **1.4 Exchange Rate Pass-Through into Home CPI**

In this section, I derive and comment on the exchange rate pass-through of Home country import prices and the Home CPI under various assumptions on market shares and the multi-

national upstream affiliates cost function. Using the definition of the consumption basket, it can be easily shown that the expression for Home CPI is :

$$P^{1-\phi} = np_I^{1-\phi} + (a - n)p^{1-\phi}$$

Then, the pass-through elasticity of Home CPI is (taking wages as fixed):

$$\frac{1}{\alpha} \frac{\partial \ln P}{\partial \ln \epsilon} = ns_{Id} \frac{\partial \ln q_{IN}}{\partial \ln \epsilon} + (1 - ns_{Id}) \left( ns_{If} \frac{\partial \ln q_{If}}{\partial \ln \epsilon} + (\chi - n) s_f \frac{\partial \ln q_f}{\partial \ln \epsilon} \right) \quad (1.23)$$

Here  $ns_{Id}$  represents the multinational downstream affiliates' market share in the sale of consumption goods ( $s_{Id}$  represents multinational downstream affiliates share). Thus, pass-through into Home CPI depends on pass-through into the marginal cost of downstream producers, which is split by market share across downstream multinational affiliates and regular firms. For the multinational affiliates, the pass-through depends only on the response of the transfer price. For regular firms, their intermediates purchases involve competition between regular exporters and upstream multinational affiliates, and thus pass-through depends on the market shares of these firms and the response of their respective a-l prices.

Looking at figure 1.6, one can observe the response of Home CPI under varying assumptions on the multinationals cost function, and how this response changes in the multinationals upstream and downstream shares. Under constant returns to scale (red panel), the solid line represents the case under which there is no i-f trade i.e. this is what ERPT into Home CPI would look like under Feenstra et al. (1996). When multinationals have no share upstream ERPT is zero as the market belongs to Home upstream producers who do not respond to changes in the ER. As the multinationals share increases, ERPT begins to rise, turns around to fall and finally rises again due to the fact that firm-level ERPT is initially decreasing and then increasing for multinationals a-l prices. More importantly, as the share of i-f trade rises (multinationals downstream share rises), there is a significant level increase in ERPT into Home CPI. This is due to ERPT always being higher into transfer prices than at a-l under constant returns to scale. The other panels show the different scenarios under non-constant returns to scale and the intuition for those figures is similar. An important point to note is

that I assume multinationals are the only exporters for tractability. When there is competition from other exporters, ERPT in transfer prices is not always greater and thus, ERPT in Home CPI is not always increasing in the share of trade intra-firm. In this scenario ERPT in Home CPI is increasing in the share of i-f trade when Home intermediate producers and regular exporters have a small share such that multinationals dominate or vice-versa.<sup>10</sup>

### **1.5 Conclusion**

In this paper, I build a simple two-sector, two-country model of a-l and i-f trade to show that transfer pricing and the share of intra-firm trade may play an important role in firm-level and CPI-level ERPT. The major takeaway is that under standard assumptions on the cost functions of multinationals, ERPT is increasing in the share of i-f trade. This implies that a greater presence of vertically integrated multinationals or a greater involvement of them in U.S. imports should be carefully analyzed when considering the international spillover of changes in monetary policy. Given the importance of i-f trade for U.S. imports, my results suggest that U.S. consumers might stand to gain more significantly, as interest rates are increased by policy makers, through greater pass-through of dollar appreciation into import prices.

In lieu of future research, this model provides a simple framework to evaluate consumer welfare under changes in monetary policy with and without i-f trade in order to further understand the role of multinationals. Additionally, I plan to extend this model to evaluate optimal monetary policy as well as the interaction between fiscal and monetary policy when firms face profit shifting incentives under asymmetric corporate taxation and regulations such as the OECD arms-length principle.

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<sup>10</sup>Figure 1.7 shows the pass-through elasticity into Home CPI under the more realistic  $\alpha = 0.4$ .

## 1.6 Figures



Figure 1.1: Percent Change in Real U.S. Dollar Export Prices 2006-08 versus Share of Intra-Firm Trade for U.S. Multinationals 2008 in Manufacturing Industries

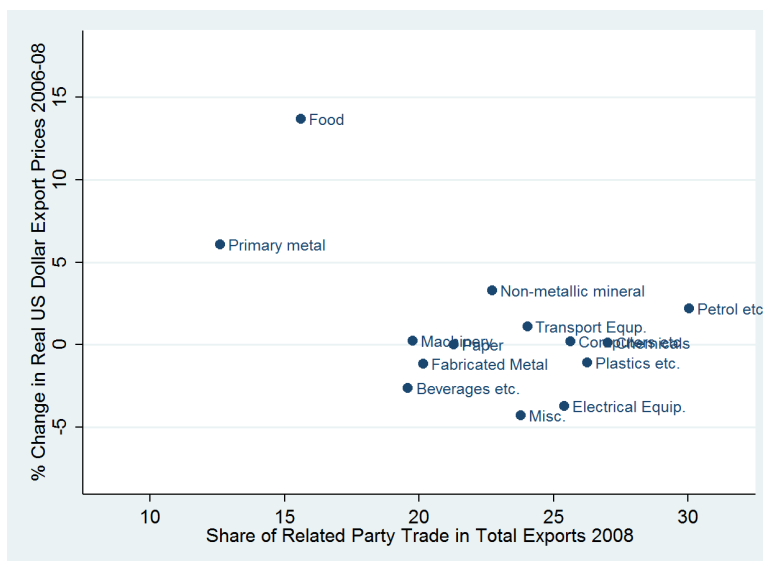


Figure 1.2: Percent Change in Real U.S. Dollar Export Prices 2006-08 versus Share of Related Party Trade 2008 in Manufacturing Industries

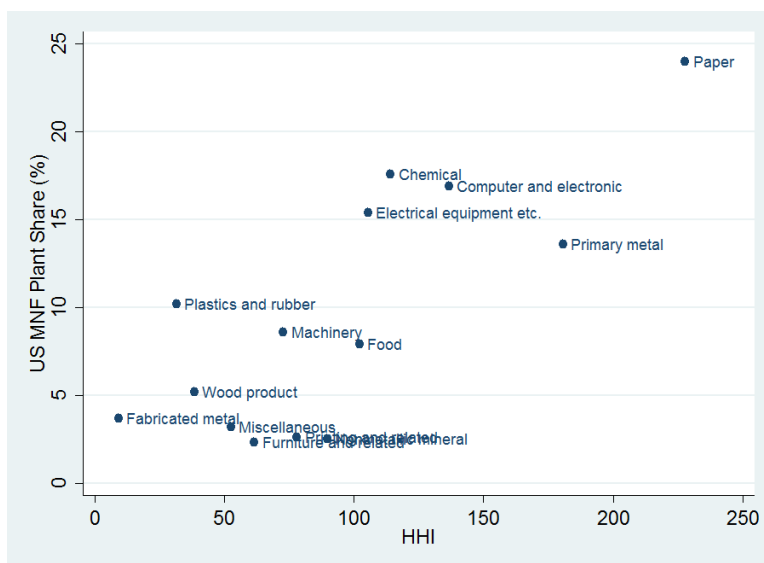


Figure 1.3: Percent of U.S. Multinational Plants versus Herfindahl Hirschman Index in 2007

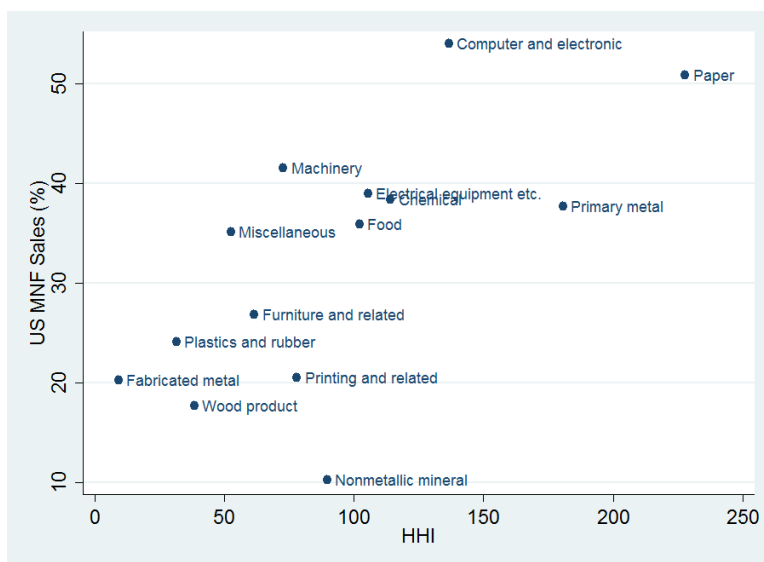


Figure 1.4: Percent of U.S. Multinational Sales versus Herfindahl Hirschman Index in 2007

Figures 1.3 and 1.4 are constructed using data reported in Flaaen (2014)

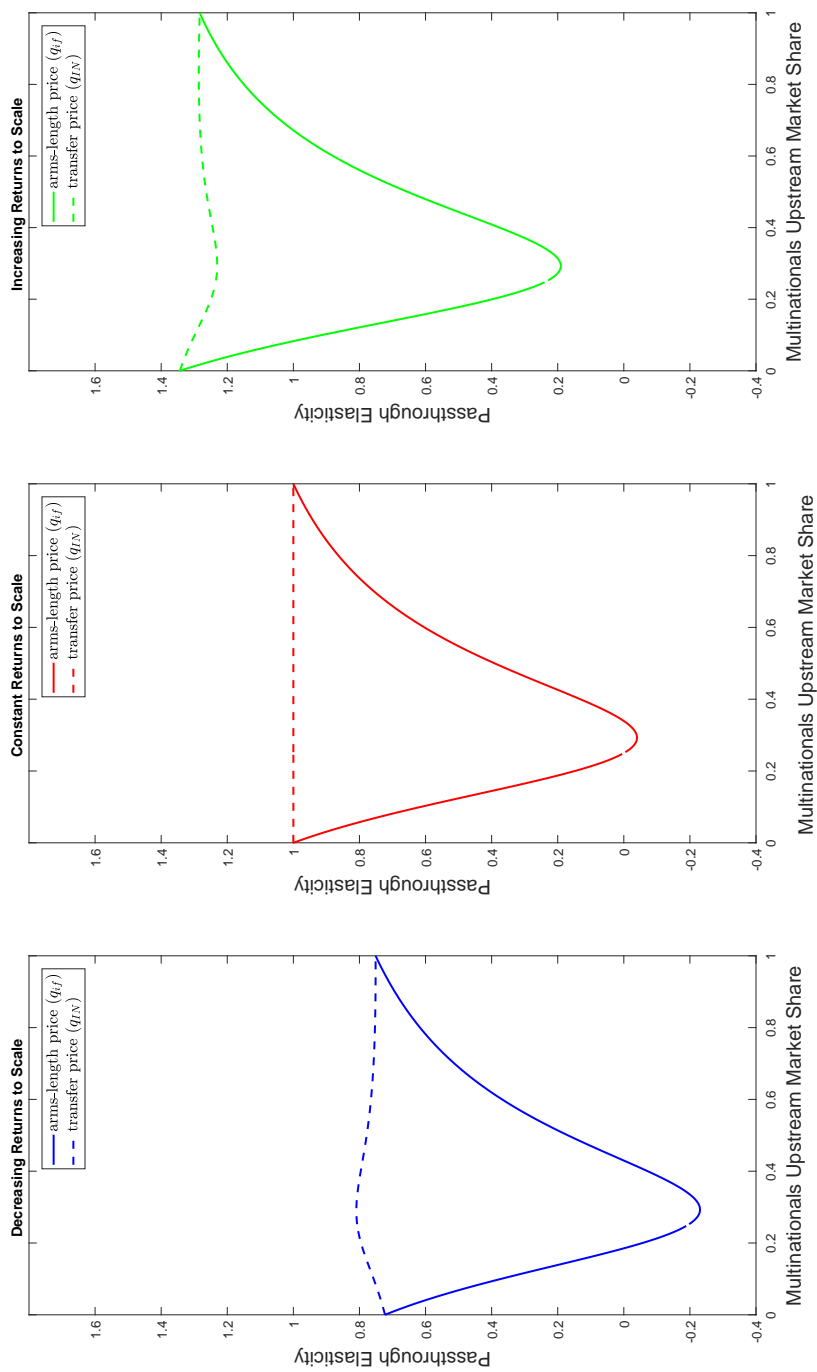


Figure 1.5: Exchange Rate Pass-Through Elasticity into Firm-Level Prices versus Share of Multinationals in Home Upstream Market

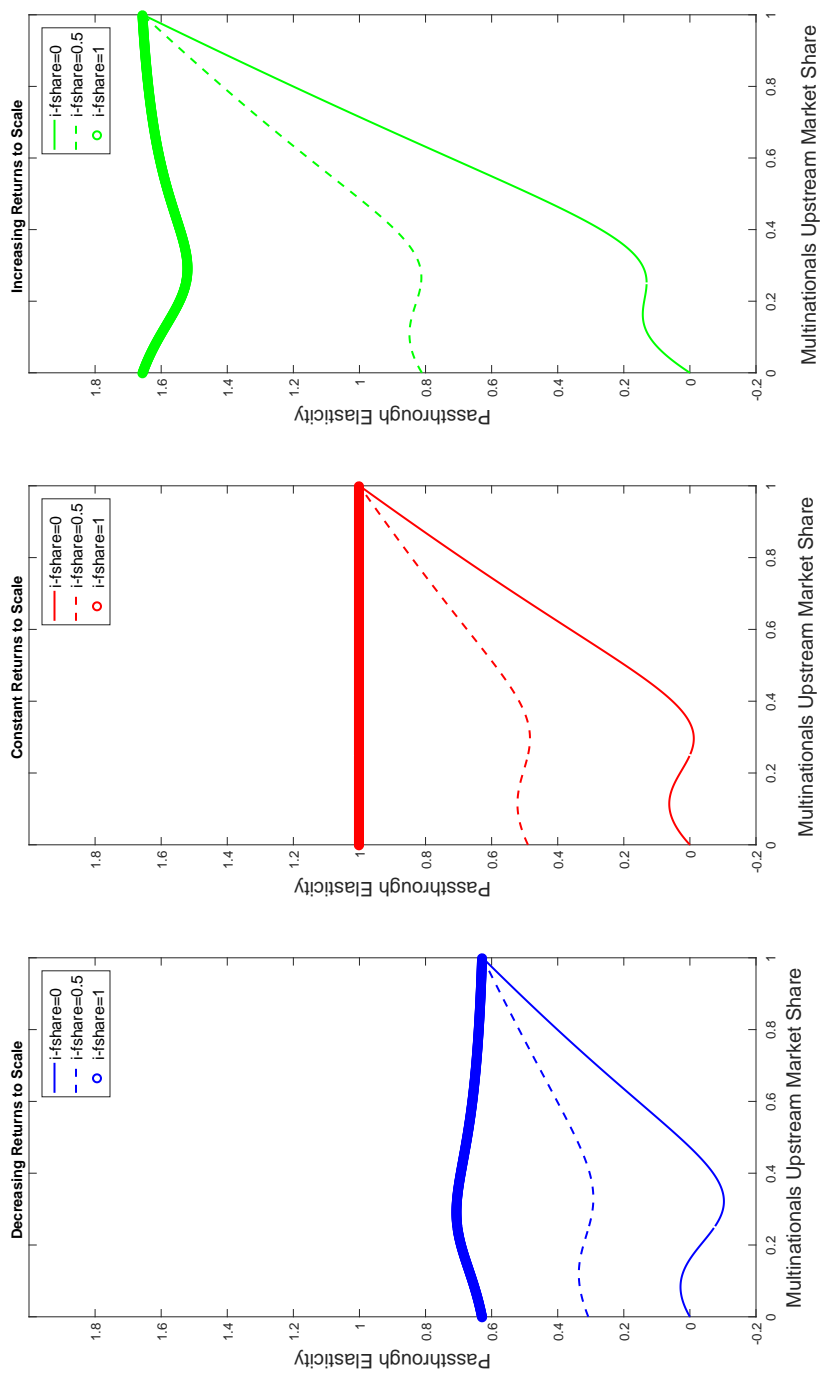


Figure 1.6: Exchange Rate Pass-Through Elasticity into Home CPI versus Share of Multinationals in Home Upstream Market ( $\alpha = 1$ )

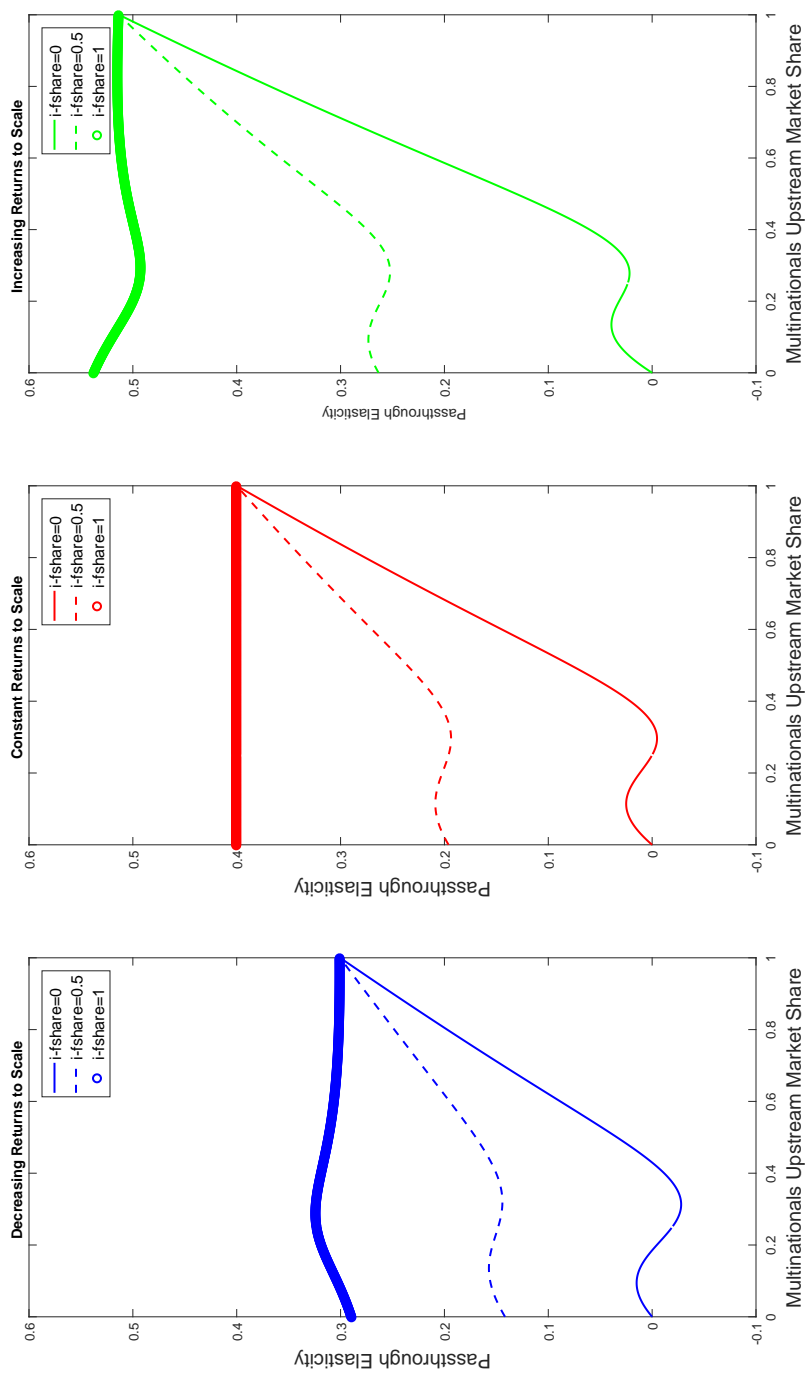


Figure 1.7: Exchange Rate Pass-Through Elasticity into Home CPI versus Share of Multinationals in Home Upstream Market ( $\alpha = 0.4$ )

## Chapter 2

# WHY IS AGRICULTURAL PRODUCTIVITY SO LOW IN POOR COUNTRIES ?: THE CASE OF INDIA

Oksana Leukhina, Raghav Paul, and Md. Mahbubur Rahman

### **2.1 Introduction**

It is well known that low agricultural labor productivity is a major impediment to development. In India, labor productivity in agriculture is only a fifth of the level of urban productivity. In other words, agriculture seems to be one sector of the economy where ways of production lag particularly far behind the frontier technology, with small non-mechanized farms persisting through time (e.g. Foster and Rosenzweig (2011)). More generally speaking, the gap in agricultural labor productivity between the rich and poor countries is so large that it accounts for most of the observed income gap. Our main goal is to understand why poor countries fail to mechanize their ways of farming.

We begin with a premise that residing in a rural area provides access to a network that effectively insures its residents against income fluctuations. This premise has a solid foundation in the large body of literature and survey data.<sup>1</sup> If households indeed value their land beyond its productive value because it provides them with access to a network that effectively insures against labor income risk, then they are less willing to migrate to the city where labor earnings risk is uninsured. As a result, labor remains cheap in agriculture, and the incentives for switching to capital-intensive methods of farming stay weak. This

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<sup>1</sup>Townsend (1994) has drawn attention to the risk sharing feature in rural areas by empirically documenting that household consumption co-moves with village average consumption in India and shows little dependence on own income. Munshi and Rosenzweig (2016) find evidence that the caste system provides access to a network of internal transfers that help insure village residents against earnings risk. Kone et al. (2017) suggest immobile benefits and employment at the state-level hinder rural-urban migration.

description captures the main essence of our mechanism <sup>2</sup>.

We capture this mechanism in a dynamic general equilibrium model that features uninsured labor income risk in the city. We allow for a very general production technology in agriculture that allows us to endogenize labor productivity through the choice of farm size and capital intensity. We assume that capital can substitute for labor, but land is a complementary input to both. As has become standard in the literature on structural transformation, our framework features non-homothetic preferences. Risk is completely insured away in rural areas. In urban areas, individuals self-insure against labor income risk through savings. Finally, newborns optimally choose whether to live in the rural or urban area.

The direct effect of the location choice is that an increase in the relative supply of urban labor will result in the fall of the rural-urban wage gap, mechanization of rural production, an increase in the average farm size and therefore labor productivity. The presence of non-insurable risk in urban labor income creates the rural-urban wage gap and consumption gap. In the scenario of no risk in urban area, there is a spatial equilibrium with no consumption gap.

In order to understand the quantitative importance of this mechanism, we calibrate the model (under the assumption of a stationary steady state) to data for India for the period around 2000. We use wage data to discipline the labor market risk in the city. We rely heavily on the agriculture census of India to discipline the technology parameters. Our model successfully replicates the urban-rural wage gap (a factor of 3) and the urban-rural productivity gap (a factor of 5). To assess the importance of differential insurance access across locations, we study an abstract policy intervention. Precisely, we employ the calibrated model to quantify the effect of introducing complete insurance in the city on migration and labor productivity in agriculture. As a result, the rural-urban consumption gap disappears and the share of workers in agricultural area declines from 0.60 to 0.50,

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<sup>2</sup>While low rural-urban migration due to risk aversion is an important component of this analysis, the main contribution of this work is that we quantify the impact of policy, that increases migration, on agricultural productivity. Thus, we can just as easily substitute the insurance policy with another policy alternative that reduces the barriers to internal migration.

implying increased labor movement to urban areas. While this effect on labor reallocation is far from dramatic, the impact on agricultural productivity is very large. In the agricultural sector, capital input per farm rises by a factor of 12 as farm size expands and capital inflows to substitute for the lost labor. In fact, we find that the average farm size increases by 18 percent. The labor productivity gap between the two sectors decreases by 64 percent. Our mechanism, working through migration, is consistent with Munshi and Rosenzweig (2016) who show that informal insurance in rural areas decreases low-skilled labor migration in India.<sup>3</sup> Kone et al. (2017) find across districts migration is fairly high but very low across state borders in India. This low migration persists despite accounting for barriers to mobility such as physical distance, language. They suggest that immobility of state-level entitlement programs (such as access to subsidized food) and public sector employment opportunities are possible barriers to mobility. Their findings are also consistent with our story of earnings risk being an important hindrance to rural-urban migration.

One clear implication of our benchmark model with uninsured labor risk in the city is the presence of the rural-urban consumption and wage gaps. Because workers have differential access to social insurance across the two locations, they must be compensated with greater levels of consumption in the city. Hnatkovska and Lahiri (2014) find that between 1983 to 2008, the rural-urban wage and consumption gaps in India have been falling but are still large. They also find that these gaps cannot be explained by differences in observed worker characteristics or by worse amenities in cities.<sup>4</sup> Young (2013) also finds that differences in skills cannot explain this gap. Gollin et al. (2017) emphasize that spatial models require that amenities (or something else) must be worse in the urban areas to justify the presence

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<sup>3</sup>Munshi and Rosenzweig (2016) find that internal migration in India is much lower than countries of similar size and level of development. Exploring the insurance networks in villages, they note that informal insurance is established through a wide reaching caste system and marriage across villages (within caste) allows risk sharing. Looking at data on loans, they show that loans from fellow caste members are the second largest source of funds. They find that males in households that benefit more from the insurance network are less likely to migrate.

<sup>4</sup>Wage gaps are obtained from a regression of (log) wages on a rural dummy, age, and age squared. Consumption gaps are obtained from a regression of (log) consumption expenditures on a rural dummy.

of the observed rural-urban consumption inequality as an equilibrium outcome. Contrary to this implication, they show (using African data) that cities tend to offer not only higher consumption but also better quality amenities along all dimensions. Our framework based on differential access to insurance across the two locations provides one alternative explanation for the presence of the consumption gap that is consistent with spatial models. Another alternative explanation is of course the difference in unobserved worker characteristics across the two locations.

Our work is also related to Adamopoulos and Restuccia (2014) and Chen et al. (2017). These papers focus on mis-allocation of inputs across farms of varying productivity. In contrast, we focus on trying to understand why the average farm size is small.

The rest of the paper is structured as follows. Section 2.2 presents the model while Section 2.3 discusses the calibration of model parameters. Section 2.4 presents quantitative results from the benchmark calibration as well as the counter-factual experiment. Section 2.5 concludes.

## **2.2 Model**

Consider a model economy where time is discrete and indexed by  $t = 0, 1, 2, \dots, N$ .  $N$  new households are born every period and live for exactly 2 periods (young and old). There are two spatially separated locations: rural and urban. We associate these locations with agricultural production and the rest of the economy. Newborns decide once and for all on their location. The location determines the sector of employment and access to insurance. We denote by  $\chi_t$  the fraction of generation  $t$  choosing to live in the rural area.

The timing of decision-making within each period is given as follows:

1. The new generation chooses their location of residence.
2. Labor endowment shocks are realized.
3. In urban areas, identical CRS firms hire labor and rent capital to produce non-agricultural

goods. In rural areas, households choose between running their own farms or working for wages, and farm managers hire labor and rent capital.

4. Agricultural farms hire workers, rent land and capital to produce agricultural goods.
5. Households receive proceeds for their factors of production and make consumption/savings decisions.

While we assume that people work where they live, we allow for capital to freely flow across locations. This means that rental rates of capital will equalize across locations, and this will be reflected in our notation from the start.

### 2.2.1 Urban Area

#### *Urban Firms*

The urban sector produces the non-agricultural good. It is comprised of a large number of identical firms endowed with a constant returns to scale technology. This allows us to restrict attention to a single aggregate firm that exhibits competitive behavior. The aggregate output of the non-agricultural good is given by  $Y_{n,t} = A_n K_{n,t}^\alpha N_{n,t}^{1-\alpha}$ , where  $K_{n,t}$  and  $N_{n,t}$  denote aggregate employment of capital and effective units of labor.  $A_n$  denotes total factor productivity. We set the non-agricultural good to be the numeraire so that all time  $t$  prices are quoted in the units of this good. Taking factor rental rates  $w_{n,t}$  and the rental price of capital  $r_t$  as given, the aggregate firm hires inputs to maximize profit:

$$\max_{K_{n,t}, N_{n,t}} \{Y_{n,t} - w_{n,t}N_{n,t} - r_t K_{n,t}\}. \quad (2.1)$$

#### *Urban Households*

Households that choose to live in urban areas face idiosyncratic labor market risk. We follow the standard approach to model this risk as a stochastic endowment of effective labor units. The effective labor endowment when young and old are given by  $\kappa \exp(\zeta^y)$  and  $\kappa \exp(\zeta^o)$

where  $\zeta^y$  is drawn from the set  $[-\zeta, \zeta]$  with probabilities  $\pi^y$  and  $1 - \pi^y$ , while  $\zeta^o$  is drawn from the same set with probabilities depending on the previous realization. We assume the transition probability matrix of the form

$$\begin{bmatrix} \pi & 1 - \pi \\ 1 - \pi & \pi \end{bmatrix},$$

We also assume the initial probability distribution  $[\pi^y, 1 - \pi^y]$  is stationary with respect to the above transition probability matrix, i.e.  $\pi^y = 0.5$ . This approach of modeling labor endowment shocks allows us to approximate the AR(1) log earnings process estimated from the data. Because there is a continuum of young and old households, the probabilities also correspond to the overall measures of households experiencing a given shock. The measure of the young households with  $\exp(-\zeta)$  endowment is always 0.5, and the measure of the old households with  $\exp(-\zeta)$  is also 0.5 (due to the stationarity assumption). This immediately implies that the average labor endowment per young and per old household in each period is given by  $\kappa (0.5) [\exp(-\zeta) + \exp(\zeta)]$  and we normalize  $\kappa = \frac{1}{(0.5)[\exp(-\zeta) + \exp(\zeta)]}$  so as to make the average labor endowment equal to 1.

Expected utility, prior to the initial shock realization, of the cohort born in  $t$  choosing the urban location, is given by

$$EU_n = E_{\zeta^y} \left\{ \phi \frac{(a_{n,t}^y(\zeta^y) - \bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi) \frac{c_{n,t}^y(\zeta^y)^{1-\sigma}}{1-\sigma} + \right. \quad (2.2)$$

$$\left. \beta E_{\zeta^o|\zeta^y} \left( \phi \frac{(a_{n,t+1}^o(\zeta^y, \zeta^o) - \bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi) \frac{c_{n,t+1}^o(\zeta^y, \zeta^o)^{1-\sigma}}{1-\sigma} \right) \right\}, \quad (2.3)$$

where  $a_{n,t}^y(\zeta^y)$  and  $c_{n,t}^y(\zeta^y)$  denote the initial state-contingent consumption of the agricultural and non-agricultural goods when young,  $a_{n,t+1}^o(\zeta^y, \zeta^o)$  and  $c_{n,t+1}^o(\zeta^y, \zeta^o)$  denote the state history-contingent consumption of agricultural and non-agricultural good when old,  $\phi$  denotes the preference weight on agricultural goods, and  $\beta$  is the discount factor. We follow the large literature on structural transformation in assuming non-homothetic preferences stemming from the subsistence consumption level  $\bar{a} > 0$ .

We now describe the state-contingent budget constraints. The household is born with no capital. There is no leisure in utility, so the household inelastically supplies the available

endowment of effective labor units to the urban firm. In period  $t$ , the young agent earns wage income  $w_{n,t}\zeta^y$  and allocates it between consumption and savings,  $k_{t+1}^n(\zeta^y)$ . In period  $t + 1$ , the old agent earns labor and capital income, all of which he consumes at this point. The following constraints must hold for all  $t$  and all possible realization histories  $(\zeta^y, \zeta^o)$  :

$$p_{a,t}a_{n,t}^y(\zeta^y) + c_{n,t}^y(\zeta^y) + k_{t+1}^n(\zeta^y) = w_{n,t}\kappa \exp(\zeta^y), \quad (2.4)$$

$$p_{a,t+1}a_{n,t+1}^o(\zeta^y, \zeta^o) + c_{n,t+1}^o(\zeta^y, \zeta^o) = w_{n,t+1}\kappa \exp(\zeta^o) + r_{t+1}k_{t+1}^n(\zeta^y), \quad (2.5)$$

where  $p_{a,t}$  denotes the price of agricultural goods in time  $t$ . Note we assume capital fully depreciates upon use which is reasonable given that the model period length is half the length of one's working years.

Also note there are no social insurance arrangements in the city. Households can self-insure against labor market risk, which gives rise to precautionary savings. This assumption is consistent with the lack of social insurance institutions typically observed in developing countries.

### 2.2.2 Agricultural Area

One defining characteristic of rural residence we aim to capture is that it provides access to a network of friends and family that effectively insures against idiosyncratic labor income risk. The straightforward way to model this is to introduce idiosyncratic labor endowment risk as in the urban households' problem described above, but allow for households to enter the risk-sharing contracts that are perfectly enforceable. If we assume that households are born identical, this would yield identical allocations for all households regardless of uncertainty realization. To simplify the exposition, we go directly to modeling a representative household that faces no uncertainty. Each household has 1 unit of time endowment when young and  $\gamma$  when old. We assume that all households either work for wages or manage farms.

Land is in fixed supply denoted by  $L$ . It is initially in the hands of the initial old residents of the agricultural areas. The old households sell land to the young at the end of the period.

### *Agricultural Farms*

Suppose an endogenous fraction  $\varepsilon_t$  of households use their entire time endowment to manage farms while the remaining households work for wages. Given the rental price of capital, land and labor  $(r_t, q_t, w_{a,t})$ , each manager hires capital, labor and land  $(k_{a,t}^f, n_{a,t}^f, l_{a,t}^f)$  to maximize profit, denoted by  $d_t$ :

$$\max_{k_{a,t}, n_{a,t}, l_{a,t}} d_t = p_{a,t} y_{a,t} - w_{a,t} n_{a,t}^f - r_t k_{a,t}^f - q_t l_{a,t}^f, \quad (2.6)$$

where  $y_{a,t}$  is the amount of non-agricultural good produced. We modify the Lucas (1978) span of control approach to endogenize the farm size and assume

$$y_{a,t} = A_a \left[ (1 - \theta) \left( l_{a,t}^f \right)^\rho + \theta \left( \nu \left( k_{a,t}^f \right)^\mu + (1 - \nu) \left( n_{a,t}^f \right)^\mu \right)^{\frac{\rho}{\mu}} \right]^{\frac{\eta}{\rho}},$$

where  $\eta \in (0, 1)$  represents the span of managerial control parameter,  $\mu$  governs the elasticity of substitution between capital and labor, and  $\rho$  the elasticity of substitution between land and the capital-labor composite,  $\theta \in (0, 1)$  captures the relative importance of land and  $\nu \in (0, 1)$  determines the relative importance of capital and labor. To be consistent with well-documented empirical facts regarding the elasticity of substitution between factors of production in agriculture in developing countries, we assume  $\mu > 0$  and  $\rho < 0$ , i.e. capital and labor are gross substitutes whereas land is a complementary factor.

We require that managers are indifferent between working for wages and running farms, which yields the no-arbitrage condition:

$$d_t = w_{a,t}. \quad (2.7)$$

### *Agricultural Households*

Households that choose to live in agricultural areas have the same preferences as households residing in the urban area, except they face no uncertainty. Again, this is a shortcut to modeling fully enforceable risk-sharing contracts. The lifetime utility of a cohort born in  $t$

that chose the agricultural location is given by

$$U_a = \phi \frac{(a_{a,t}^y - \bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi) \frac{(c_{a,t}^y)^{1-\sigma}}{1-\sigma} + \beta \left\{ \phi \frac{(a_{a,t+1}^o - \bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi) \frac{(c_{a,t+1}^o)^{1-\sigma}}{1-\sigma} \right\}, \quad (2.8)$$

where  $a_{a,t}^y$  denotes consumption of the agricultural good at young age in period  $t$ ,  $c_{a,t}^y$  denotes consumption of the non-agricultural good at young age in period  $t$ ,  $a_{a,t+1}^o$  denotes consumption of the agricultural good at old age in period  $t+1$ ,  $c_{a,t+1}^o$  is consumption of the non-agricultural good at old age in period  $t+1$ .

The household is born with no capital and no land. Therefore, the only sources of income for the young agents are labor income and profits from managing farms, earning  $w_{a,t}$  from either. The young purchase agricultural and non-agricultural goods for consumption and save in the form of capital and land. They purchase  $k_{a,t+1}$  units of capital from the non-agricultural good producer at price 1 and  $l_{t+1}$  units of land from the old households at price  $p_{l,t}$ . The time  $t$  budget constraint for the young agents is summarized as follows:

$$p_{a,t} a_{a,t}^y + c_{a,t}^y + p_{l,t} l_{t+1} + k_{a,t+1} = w_{a,t}. \quad (2.9)$$

In period  $t+1$ , the old agents either work for wages or manage firms, in either case earning  $w_{a,t+1}$ . They also get rental income from capital  $r_{a,t+1} k_{a,t+1}$ , rental income from land  $q_{t+1} l_{t+1}$  and income from land sale  $p_{l,t+1} l_{t+1}$ . The old agents consume all of their income. The time  $t+1$  budget constraint of the old agents is given by

$$p_{a,t+1} a_{a,t+1}^o + c_{a,t+1}^o = w_{a,t+1} + r_{a,t+1} k_{a,t+1} + q_{t+1} l_{t+1} + p_{l,t+1} l_{t+1}. \quad (2.10)$$

### *Equilibrium*

Measure  $\chi_t$  of each cohort decides to locate in agricultural areas. This measure is determined by equalization of lifetime utility across areas:

$$EU_n = U_a. \quad (2.11)$$

Before we can define our market clearing conditions, we need to establish additional notation. Recall that  $N$  denotes the size of each cohort. The measure of young households living

in urban locations is then given by  $N_{n,t}^y = \chi_t N$ . Because all young households survive to adulthood and because the location choice is permanent, this is also the measure of the urban old agents in time  $t + 1$ :

$$N_{n,t}^y = N_{n,t+1}^o = \chi_t N.$$

Likewise, the measure of the rural young and old households in time  $t$  and  $t + 1$  is given by

$$N_{a,t}^y = N_{a,t+1}^o = (1 - \chi_t) N.$$

The measure of farm managers in time  $t$  is given by  $\varepsilon_t(N_{a,t}^y + \gamma N_{a,t}^o)$ .

Given the nature of our study, it suffices to focus on a stationary equilibrium, i.e. a decentralized competitive equilibrium characterized by stationary allocations, prices and location choice.

**Definition** A stationary equilibrium is defined as state-contingent allocations for the urban young households  $\{a_n^y(\zeta^y), c_n^y(\zeta^y), k_n(\zeta^y)\}_{\zeta^y}$  and the urban old households  $\{a_n^o(\zeta^y, \zeta^o), c_n^o(\zeta^y, \zeta^o)\}_{(\zeta^y, \zeta^o)}$ , allocations for the rural area households  $\{a_a^y, c_a^y, k_a, l, a_a^o, a_a^o\}$ , allocations for the urban firm  $\{Y_n, K_n, N_n\}$  and rural farms  $\{y_a, k_a^f, n_a^f, l^f, d_t\}$ , prices  $\{w_n, w_a, r, q, p_l, p_a\}$ , the measure of each cohort choosing to live in the rural area ( $\chi$ ) and the measure of the rural young managing farms ( $\varepsilon$ ) such that:

1. Given the equilibrium prices, the allocations for the urban households maximize utility (2.2) subject to the budget constraints (2.4) and (2.5);
2. Given the equilibrium prices, the allocations for the rural households maximize utility (2.8) subject to the budget constraints (2.9) and (2.10);
3. Given the equilibrium prices, the allocation for the urban firm maximizes profit given in (2.1);
4. Given the equilibrium prices, the allocation for the rural firm maximizes profit given in (2.6);

5. Lifetime utility equalizes across the two locations: equation (2.11) holds;
6. Farm managers are indifferent between managing a farm and working for wages, i.e. (2.7) holds;
7. All markets clear:

- Labor market in agriculture:

$$\varepsilon(N_a^y + \gamma N_a^o)n_a^f = (N_a^y + \gamma N_a^o)(1 - \varepsilon), \quad (2.12)$$

- Labor market in the urban area:

$$N_n = N_n^y + N_n^o, \quad (2.13)$$

- Capital market:

$$K_n + \varepsilon(N_a^y + \gamma N_a^o)k_a^f = N_n^o k_n + N_a^o k_a, \quad (2.14)$$

- Land market in agriculture:

$$\varepsilon(N_a^y + \gamma N_a^o)l^f = N_a^o l = L, \quad (2.15)$$

- Agricultural goods market:

$$\varepsilon(N_a^y + \gamma N_a^o)y_a = N_n^y a_n^y + N_n^o a_n^o + N_a^y a_a^y + N_a^o a_a^o, \quad (2.16)$$

- Non-agricultural goods market:

$$Y_n = N_n^y c_n^y + N_n^o c_n^o + N_n^y k_n + N_a^y c_a^y + N_a^o c_a^o + N_a^y k_a, \quad (2.17)$$

where  $N_n^y = N_n^o = \chi N$  denote the population size of young and old residing in the urban area, and  $N_a^y = N_a^o = (1 - \chi) N$  denote the population size of young and old residing in the agricultural area, and where  $k_n = 0.5 [k_n(\zeta^y = -\zeta) + k_n(\zeta^y = \zeta)]$  is investment per urban young household (and capital holdings per urban old

household),  $a_n^y = 0.5 [a_n^y(-\zeta) + a_n^y(\zeta)]$  is the average consumption of the agricultural good for the urban young household,  $c_n^y = 0.5 [c_n^y(-\zeta) + c_n^y(\zeta)]$  is the average consumption of the non-agricultural good for the urban young household,  $a_n^o = 0.5[\pi a_n^o(-\zeta, -\zeta) + (1 - \pi) a_n^o(-\zeta, \zeta) + \pi a_n^o(\zeta, \zeta) + (1 - \pi) a_n^o(\zeta, -\zeta)]$  is the average consumption of the agricultural good for the urban old household, and  $c_n^o = 0.5[\pi c_n^o(-\zeta, -\zeta) + (1 - \pi) c_n^o(-\zeta, \zeta) + \pi c_n^o(\zeta, \zeta) + (1 - \pi) c_n^o(\zeta, -\zeta)]$  is the average consumption of the non-agricultural good for the urban old household.

A few clarifications are in order. Note the demand for labor appearing on the left hand side of (2.12) comes from the number of individual farms  $= \varepsilon(N_a^y + \gamma N_a^o)$ , each of which demands  $n_a^f$  units of labor. Only a measure  $1 - \varepsilon$  of the old and young households work for wages – the rest manage farms. The demand for capital on the left hand side of equation (2.14) comes from the aggregate firm in the urban area ( $K_n$ ) and measure  $\varepsilon(N_a^y + \gamma N_a^o)$  of individual farms each demanding  $k_a^f$ . The supply of capital is from urban and agricultural households. Taking expectations over shock realizations gives the average savings by the young. These are last period savings of the current old. Just like the capital market, there is a single market for each of the consumption goods. Expectations are used to get the appropriate averages. It should be noted that capital investment comprises a part of the demand for the non-agricultural good.

### 2.3 Calibration

We calibrate the model parameters to match the key moments of wages and the aggregate economy of Indian data around the year 2000. Following Anand and Prasad (2010), we set the utility weight  $\phi = 0.4$  and  $\bar{a} = 0.05$  to match the expenditure share on agricultural good of 0.5. We set  $\sigma = 2$  to match both the inter-temporal elasticity of substitution and the elasticity of substitution between the two goods.  $\beta = 0.42$  corresponds to a 4 percent annual interest rate and period length of approximately 22 years. In the urban technology, we set  $\alpha = 0.4$  to match the labor share of income as reported in the India KLEMS dataset. For

the rural technology,  $\rho = -2$  is set following Salhofer (2000).  $\mu = 0.6$  is set to match the elasticity of substitution between labor and capital of 2.5 in agriculture. Of the remaining parameters, we normalize  $A_a = 1$  and  $N = 20$  and calibrate  $A_n$ ,  $\eta$ , and  $L$  to simultaneously match the labor share in agriculture, value added share of agriculture, the urban-rural wage gap, and the number of farms per person.

Table 2.1: Parameter Values

Parameter		Value
Preferences	$\phi$	0.40
	$\bar{a}$	0.05
	$\beta$	0.42
	$\sigma$	2.00
Technology	$\nu$	0.60
	$1 - \theta$	0.60
	$\mu$	0.60
	$\eta$	0.88
	$\rho$	-2.00
	$A_a$	1.00
	$\alpha$	0.40
	$A_n$	2.00
Endowment	$\zeta$	1.10
	L	100
	N	20
	$\gamma$	0.70
	$\pi$	0.80

Table 2.2: Model Output

Variable	Benchmark	Counter-factual	
	Value	Value	
Population share in rural*	0.6019	0.5050	
Productivity in agriculture	0.1102	0.3084	
Farm size (acres per farm)	80.6447	94.9652	
Capital per farm	0.0019	0.0229	
Labor per farm	7.2514	6.9905	
Productivity in non-agriculture	0.4889	0.4929	
Productivity gap	4.4334	1.5981	
Aggregate labor productivity	0.5992	0.8014	
Relative wage $w_n/w_a^*$	2.6864	1.0000	
Targeted Moments	Model	Data	Source
Population share in rural	0.60	0.59	IPUMS 99
Value Added of Agriculture	0.25	0.23	India KLEMS
Urban-rural wage gap	2.70	2.95	IPUMS 99
No. of farms per person	0.18	0.50	Census of Agriculture

Note: \*Targeted in benchmark

## 2.4 Results

The model replicates the urban-rural productivity and wage gaps of approximately 5 and 3 respectively. Our main objective was to observe and quantify the endogenous response of implementing complete insurance against idiosyncratic risk in the non-agricultural area. In order to do this, we set  $\zeta, \pi = 1$ . Table 2.2 provides a picture of the implications of providing social insurance in the urban area. First, we observe that full-insurance across

the two locations leads to the disappearance of the wage premium. This is driven by a larger fraction of households choosing to live in the urban area, which rises from 0.4 to approximately 0.5. As a result of labor outflow, rising wages in the agricultural sector encourage farm managers to mechanize which raises capital per farm by a factor of 12. In addition, lesser labor and managers in agriculture results in a rise in farm size of 18 percent. Finally, agricultural productivity rises by a factor of 2.7 and the productivity gap declines by 64 percent.

## **2.5 Conclusion**

We build a simple two location, two sector dynamic general equilibrium model with overlapping generations to quantify the effect of introducing complete insurance against labor earnings risk in the city. Our framework, under the benchmark calibration, successfully matches the urban-rural wage and productivity gaps. The policy intervention decreases the share of workers in agriculture from 0.60 to 0.50, brings about mechanization in agriculture, along with an increase in farm size of about 18 percent. This results in substantial gains in agricultural productivity and a fall in the productivity and wage gaps of 64 and 63 percent respectively.

Since the calibration of risk in the city plays a crucial role in our quantitative estimates, we are currently exploring a rigorous empirical analysis on the estimation of urban earnings for India using household surveys from 2000-2015. Using these, we are conducting several robustness checks to further cement the validity of our estimates for the productivity impact of policy that improves rural to urban migration.

## Chapter 3

# SKILLED IMMIGRATION POLICY AND OFFSHORING BY U.S. FIRMS

Mishita Mehra and Raghav Paul

### **3.1 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.<sup>1</sup> 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

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<sup>1</sup>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.<sup>2</sup>

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.<sup>3</sup> This sector has also witnessed a significant increase in output used as intermediate inputs, in total exports, and imports (Figure 3.1).<sup>4</sup> The employment in U.S. majority-owned foreign affiliates within this sector has witnessed a substantial increase, especially since 2003 - 04 (Figure 3.2). 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.<sup>5</sup> 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.<sup>6</sup>

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<sup>2</sup>Two thirds of the entry of Foreign skilled workers is via the H1-B visa program (U.S. Department of State). See Appendix C.1 for an overview of the H1-B policy and quota.

<sup>3</sup>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.

<sup>4</sup>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).

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

<sup>6</sup>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.<sup>7</sup> The immigration cap restricts the amount of Foreign skilled labor domestic firms can hire and increases the cost of hiring immigrant workers.<sup>8</sup> 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

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<sup>7</sup>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.

<sup>8</sup>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 cause 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.

The next section places our work in the context of prior, related literature. Section 3.3 details the baseline model, Section 3.4 provides steady-state intuition, and 3.5 the benchmark calibration. In Section 3.6 we comment on baseline results, introduce labor market frictions in section 3.7, and conclude in Section 3.8 .

### **3.2 *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.

### **3.3 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.

### 3.3.1 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:

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

where  $C_{j,t} = \int_{v \in \Upsilon} (c_{d,t}(v))^{\frac{\theta-1}{\theta}} dv)^{\frac{\theta}{\theta-1}}$  is the consumption basket of each household. Here  $\theta > 1$  is the households' symmetric elasticity of substitution across varieties ( $v$ ) of consumption goods. Thus, the associated consumption-based price index in units of Home consumption is  $1 = \int_{v \in \Upsilon} (\rho_{d,t}(v)^{1-\theta} dv)^{\frac{1}{1-\theta}}$ . The demand for variety  $v$  is given by  $\rho_{d,t}(v)^{-\theta} C_{j,t}$ . 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.<sup>9</sup> 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.

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<sup>9</sup>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 3.3). Moreover, when filing a Labor Condition Application, firms attest that they will pay the worker the prevailing compensation for that occupation.

$l_{o,t}$  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 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  $C_{u,t}^* = w_{u,t}^* \bar{l}_u^*$ .

### 3.3.2 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  $y_{m,t}(\omega) = Z_t(l_{d,t}(\omega) + a l_{f,t}(\omega)) + Z_t^* l_{o,t}(\omega)/\tau$ . 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  $\mu_t$  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<sup>10</sup>. 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  $\delta$  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.<sup>11</sup> 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  $\mu_t$  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 immigrant skilled labor at firm producing variety  $\omega$  in period  $t + 1$  is given by:

$$l_{f,t+1}(\omega) = (1 - \delta)(l_{f,t}(\omega) + \mu_t N_{e,t}(\omega)) \quad (3.1)$$

Exogenously separated immigrant workers return back to Foreign and get added to the For-

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<sup>10</sup>This can be interpreted as labor or managers hired to maintain operations in the offshore affiliate

<sup>11</sup>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.

eign skilled labor supply. Expressed in units of the consumption basket, the inter-temporal profit function of firm producing variety  $\omega$  is given by:

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

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:

$$\frac{f_R}{\mu_t} = (1 - \delta) E_t \left\{ \beta_{t,t+1} \left[ a w_{s,t+1} - Q_{t+1} \tau w_{s,t+1}^* Z_{t+1} / Z_{t+1}^* + \frac{f_R}{\mu_{t+1}} \right] \right\} \quad (3.2)$$

The expected cost of hiring immigrant workers is  $f_R/\mu_t$ . Since firms have to pay  $f_R$  for each immigrant worker that they apply for, and  $\mu_t$  is the probability of the application being selected, firms effectively pay  $f_R/\mu_t$  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 (3.2).

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  $\phi$ . Profit maximization implies that the price set by firm  $\omega$  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  $d_{m,t}(\omega) = \rho_{1,t}(\omega)y_{1,t}(\omega) + Q_t\rho_{x,t}(\omega)y_{x,t}(\omega) - w_{s,t}l_{s,t}(\omega) - w_{s,t}l_{f,t}(\omega) - Q_t w_{s,t}^* l_{o,t}(\omega) - f_{Rqt} N_{e,t}(\omega) - f_o(w_{s,t}^*/Z_t^*)Q_t$ .

### *Foreign Intermediate Firms*

We normalize the constant mass of Foreign intermediate producers to  $N_d^*$ . Each Foreign intermediate firm  $\omega$  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  $d_{m,t}^*(\omega) = \rho_{1,t}^*(\omega)y_{1,t}^*(\omega) + Q_t^{-1}\rho_{x,t}^*(\omega)y_{x,t}^*(\omega) - w_{s,t}^* l_{s,t}^*(\omega)$ .

### *3.3.3 Consumption Good Producers*

The Home consumption basket is comprised of imperfectly substitutable varieties  $v \in \Upsilon$  produced by a constant mass 1 of monopolistically competitive Home final good producers. The production technology of each firm is given by  $y_{d,t}(v) = Z_t(m_t(v))^\alpha(l_{u,t}(v))^{1-\alpha}$ , 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  $m_t = (\alpha(\frac{\theta-1}{\theta})Y_t^c)/\rho_{m,t}$  and

unskilled labor  $l_{u,t} = ((1-\alpha)(\frac{\theta-1}{\theta})Y_t^c)/w_{u,t}$ , where  $Y_t^c$  is the Home aggregate demand (defined in 3.3.4). 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  $v$  sets their price  $\rho_{d,t}(v) = \frac{\theta}{\theta-1}(\frac{\rho_{m,t}}{\alpha})^\alpha(\frac{w_{u,t}}{1-\alpha})^{1-\alpha}$  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  $y_{d,t}(v) = \rho_{d,t}(v)^{-\theta}Y_t^c$ .

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.

### 3.3.4 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  $Y_t^c = w_{s,t}(1 + l_{f,t}) + w_{u,t}\bar{l}_u + d_t + f_R N_{e,t}$ .<sup>12</sup> 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.<sup>13</sup> Aggregate accounting in Foreign requires  $Y_t^{c*} =$

<sup>12</sup>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.

<sup>13</sup>Immigrant workers employed in Home are part of this supply and any changes in Home immigration

$w_{s,t}^*(l_{o,t} + f_{o,t} + N_d^* l_{s,t}^*) + w_{u,t}^* \bar{l}_u^* + d_{c,t}^* + N_d^* d_{1,t}^*$ . Finally, any trade imbalance must be offset by payments incurred for offshore production :  $Q_t \rho_{x,t} y_{x,t} - N_d^* \rho_{x,t}^* y_{x,t}^* = Q_t w_{s,t}^* l_{o,t} + Q_t f_o w_{s,t}^*$ .

### 3.4 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:

$$l_o = \frac{\tau N_d^*}{Z^*(1 + N_d^*)} \left[ \left( \tau \left( \frac{\rho_x}{\rho_m^*} \right)^{-\phi} - \left( \frac{\rho_1^*}{\rho_m^*} \right)^{-\phi} \frac{1}{\tau} \right) m^* - \frac{(1 - \delta) \bar{N}_e}{\delta} \left( aZ + \frac{Z^*}{N_d^* \tau} \right) + (\bar{L}_s^* - f_o) \frac{Z^*}{N_d^* \tau} - Z l_d \right] \quad (3.3)$$

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  $\left( \frac{\rho_x}{\rho_m^*} \right)^{-\phi} = \left( \frac{1}{1 + N_d^* \tau^{2(\phi-1)}} \right)^{\frac{\phi}{1-\phi}}$

(3.3) 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  $(\rho_x/\rho_m^*)$ ), also positively influences the level of offshore labor hired.

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policy affect the skilled labor supply in Foreign.

### 3.5 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).

Table 3.1: 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

We jointly calibrate  $\{\alpha, N_d^*, f_R, \tau, f_o\}$  to minimize the squared residuals between model moments and targets in Table 3.2. 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 3.3.

Table 3.2: 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 3.3: 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	$f_o = 0.4836$

### 3.6 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.

### 3.6.1 *Dynamic Response to Permanent Cap Reduction*

We study the responses (deviation from the steady state) to a deterministic, 10 percent cap reduction. Figures 3.4 and 3.5 give the dynamic responses in the baseline model. From Figure 3.4, 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 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 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 3.6 and 3.7 compare the responses of the cap reduction in the baseline model (with offshoring) with an alternate case in which we do not have offshoring.<sup>14</sup> Figure 3.6 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,

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<sup>14</sup>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.

it is important to take into account the role of offshoring when evaluating the impact of immigration policy changes on welfare of domestic households.

### 3.6.2 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 ( $\Delta$ ) 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,  $\Delta$  solves:

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

First we consider the impact of the cap reduction in the baseline model. In Section 3.7.2 we compare the welfare results with an extended model with search and matching frictions. From Table 3.4, 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 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 3.4 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 3.6 and 3.7. From Figure 3.7, 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.

Table 3.4: 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.

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.

### 3.7 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.<sup>15</sup> 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

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<sup>15</sup>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.

policy-imposed cap and additional costs of hiring immigrant workers. For each immigrant 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  $\omega$  posts  $v_t(\omega)$  vacancies for skilled workers at Home in period  $t$ . The cost of posting a vacancy is  $\kappa$ . Given a standard constant returns to scale matching technology with unemployment elasticity  $\epsilon$  and matching efficiency  $\chi$ , 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  $\delta_d$ , and that of foreign workers is  $\delta_f$ . 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.

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

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:

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

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

$\Gamma_{d,t}$  (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.  $\Psi_t$  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  $\kappa_o^*$ ) 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  $\delta^*$  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  $\eta_i S_{i,t}^F(\omega) = (1 - \eta_i) S_{i,t}^W(\omega) \quad \forall i \in \{d, f, o\}$  where  $\eta_i$  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 ( $\eta^*$ ) 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.<sup>16</sup>

Let the total measure of domestic skilled workers in the labor force be  $\bar{L}_d$  and that of immigrant households be  $\bar{L}_f$ .<sup>17</sup> 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:  $w_{s,t}^* = \eta^*(\Psi_t^* Z_t^*) + (1 - \eta^*)\varpi_{s,t}^*$ .

### 3.7.1 Calibration

The addition of labor market frictions requires us to set parameters that govern the labor market. We choose the matching elasticity  $\epsilon$  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  $\epsilon$  so that the Hosios condition holds. Vacancy posting costs at Home,  $\kappa$ , are normalized to 1. We choose  $\delta_d$  and  $\delta_f$  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

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<sup>16</sup>Except that vacancy posting costs are deducted from the intermediate firms' profits in both countries.

<sup>17</sup>At any point in time, we keep the total pool of immigrants in the Home labor force as fixed to begin with.

from monthly Current Population Survey data over 2004-2015. Table 3.5 summarizes the calibrated parameter values.

Table 3.5: 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	$\chi = 0.6913$

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.

### 3.7.2 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. Given the tight skilled labor market in Home, the impact rise in domestic skilled wages (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  $\mu$  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. The rise in Home unemployment coupled with the decline in Home intermediates’ cost of production (which affects the workers outside option) causes Home skilled wages to fall. 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.

Table 3.6: Welfare Impact of a 10 Percent Immigration Cap Reduction: Competitive versus Frictional Labor Markets

<b>Competitive Labor Markets</b>			
Profit Earners	Skilled	Unskilled	Entrepreneurs
Home Skilled	0.0104	-0.0663	
Entrepreneurs	0.0996	-0.0663	-0.0838

<b>Frictional Labor Markets</b>			
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.

Again we consider the case when Home skilled households are separated into entrepreneurs and labor. From the results in Table 3.6, 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 less than under competitive

labor markets as their wage bill falls by more due to falling Home skilled wages and wages paid to offshore workers.

### **3.8 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.

### 3.9 Figures

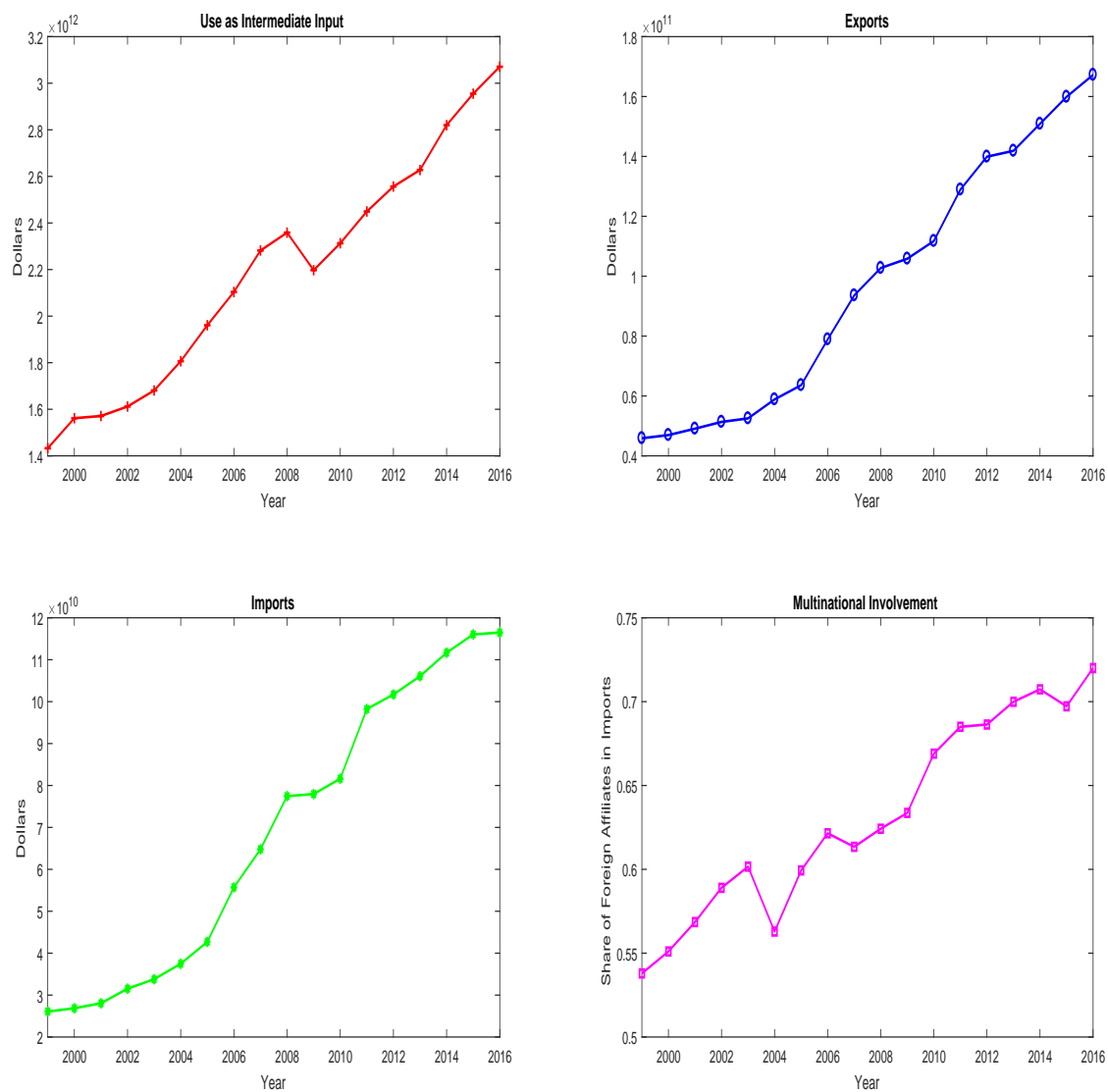


Figure 3.1: Rising Importance of Skilled Service Sector for U.S.

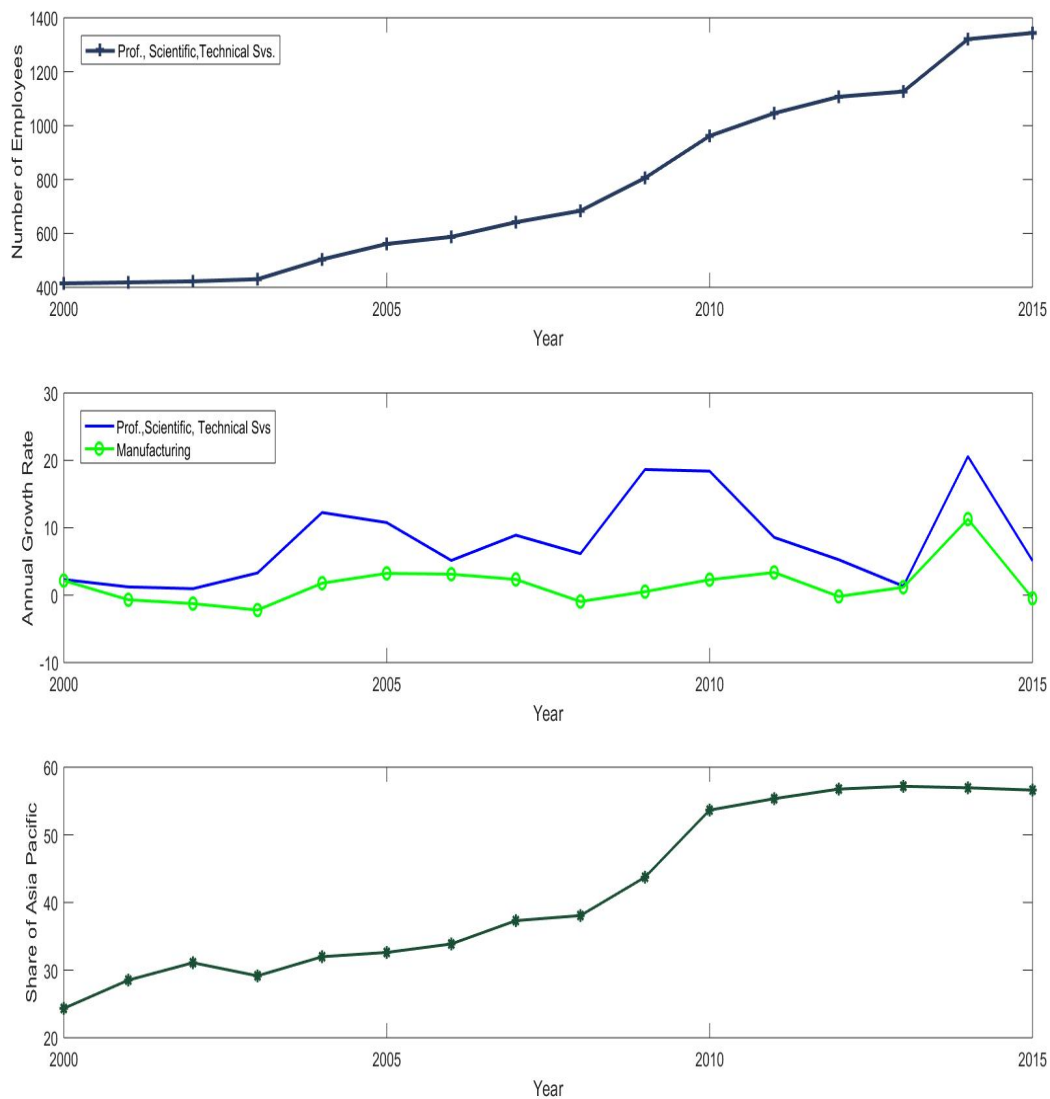


Figure 3.2: Employment at Foreign Affiliates in Professional, Scientific, and Technical Services

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.

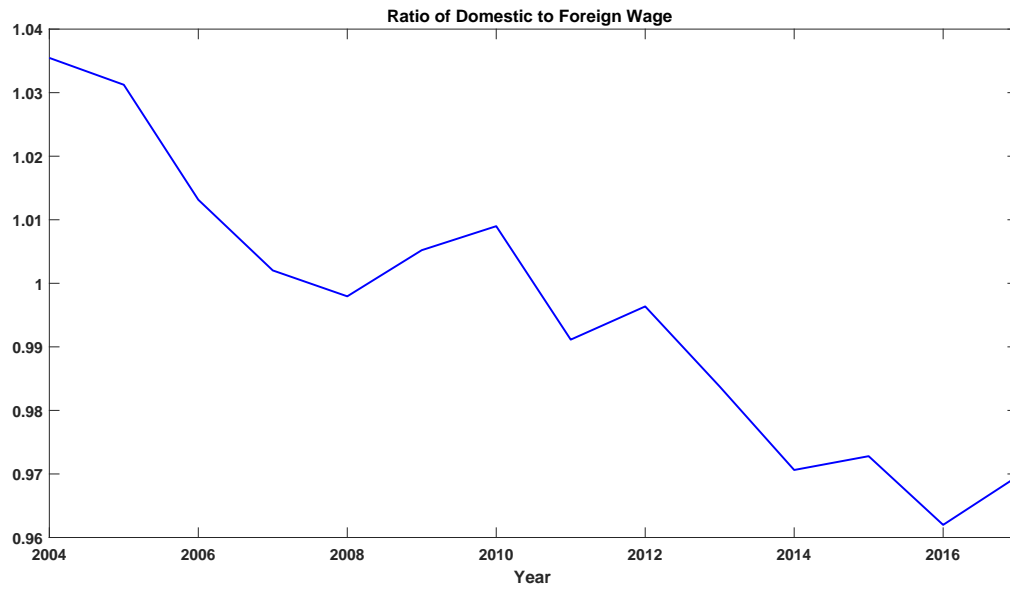


Figure 3.3: Earnings of Native Born as Percent of Foreign Born: Bachelor's Degree and Higher, 25 Years and Over

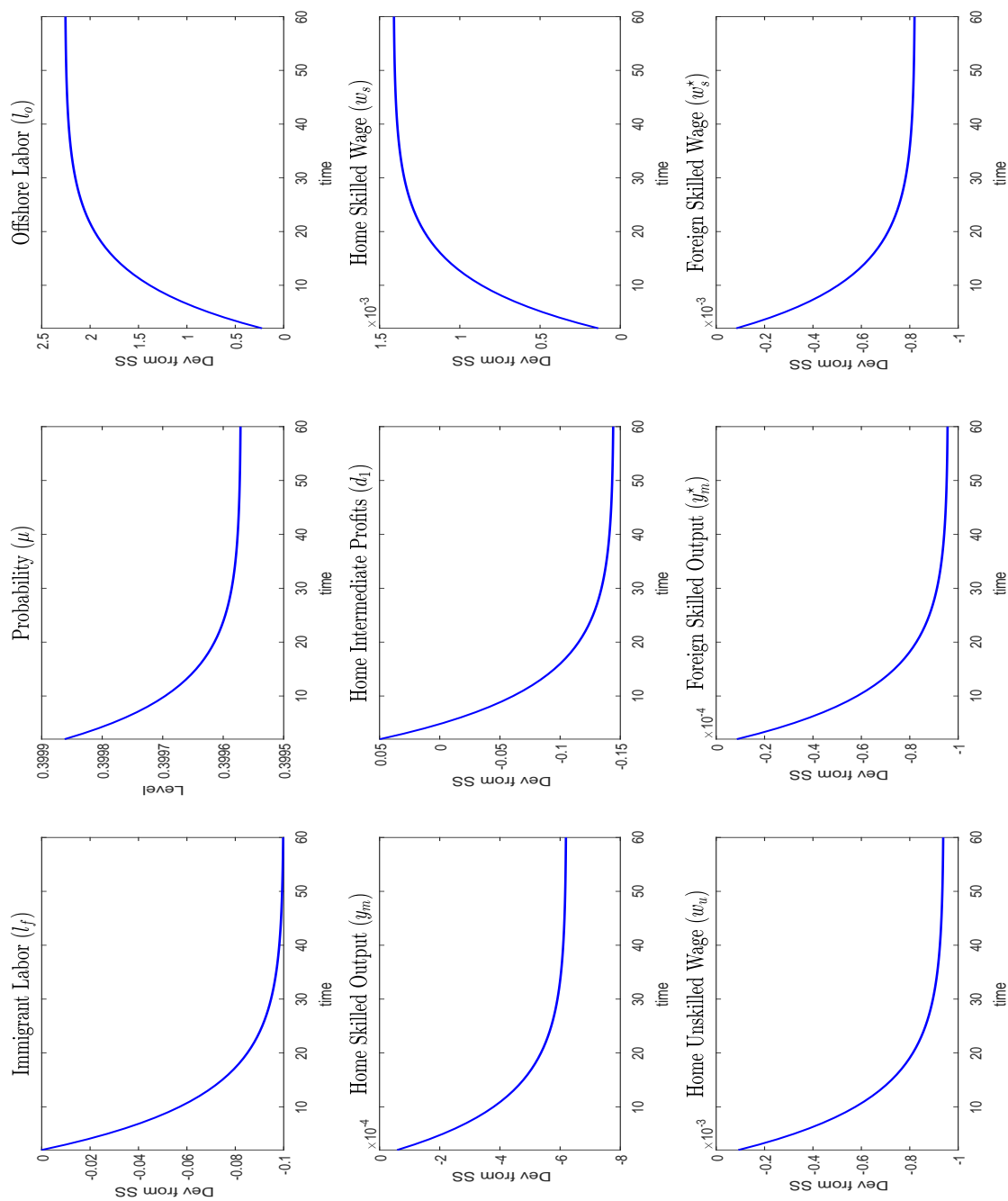


Figure 3.4: Response to a 10 Percent Immigration Cap Reduction in Baseline Model

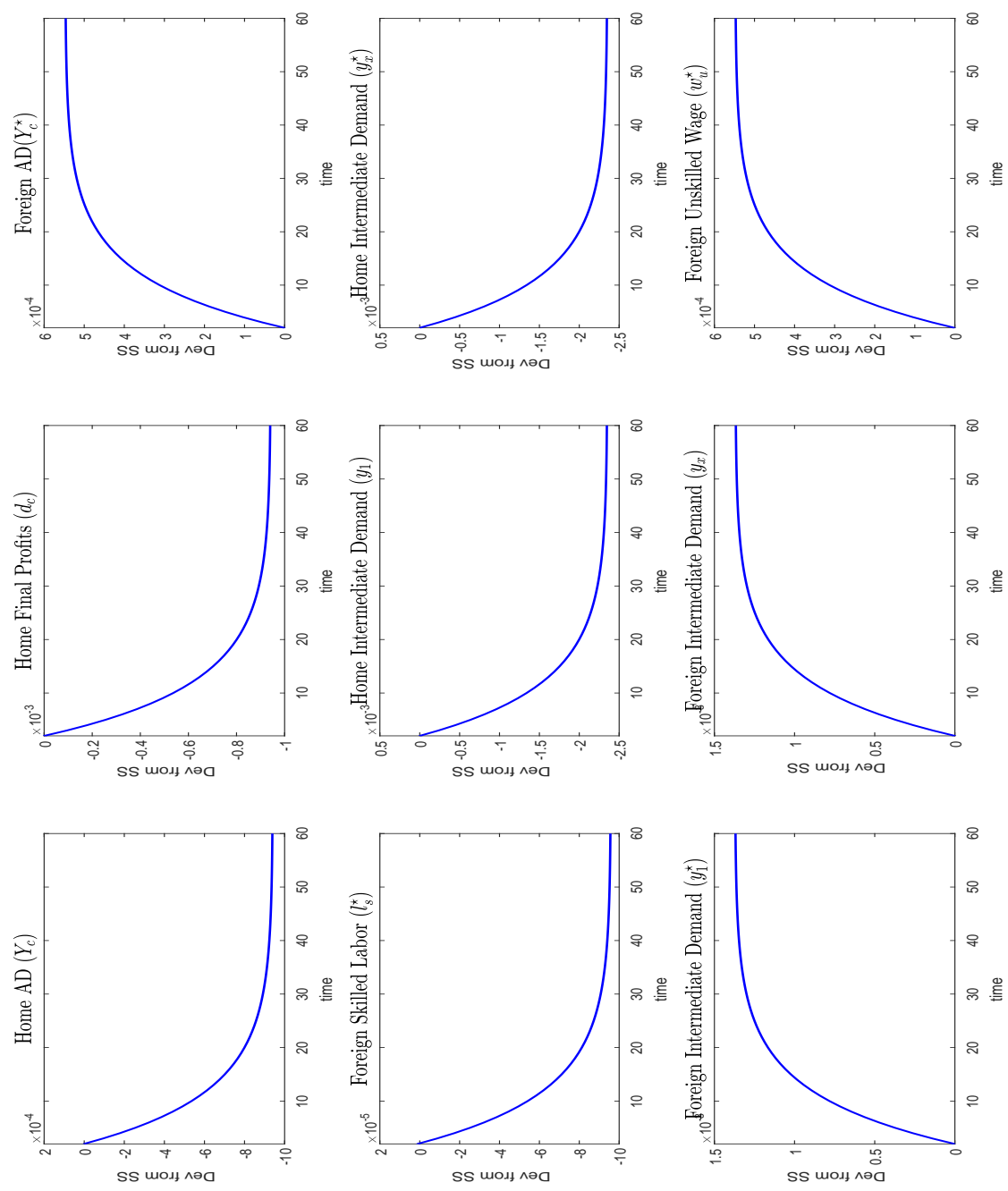


Figure 3.5: Response to a 10 Percent Immigration Cap Reduction in Baseline Model

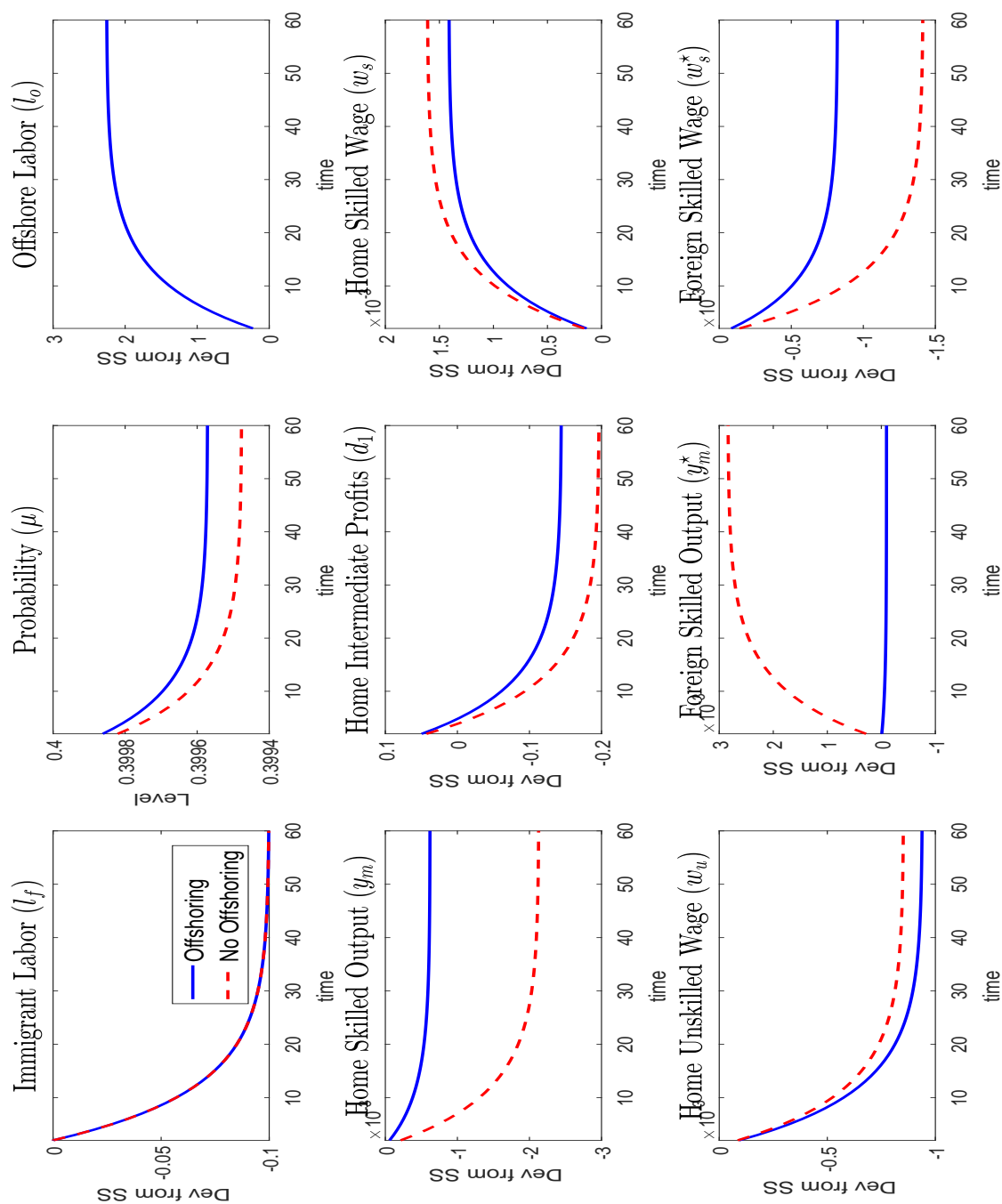


Figure 3.6: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus No Offshoring

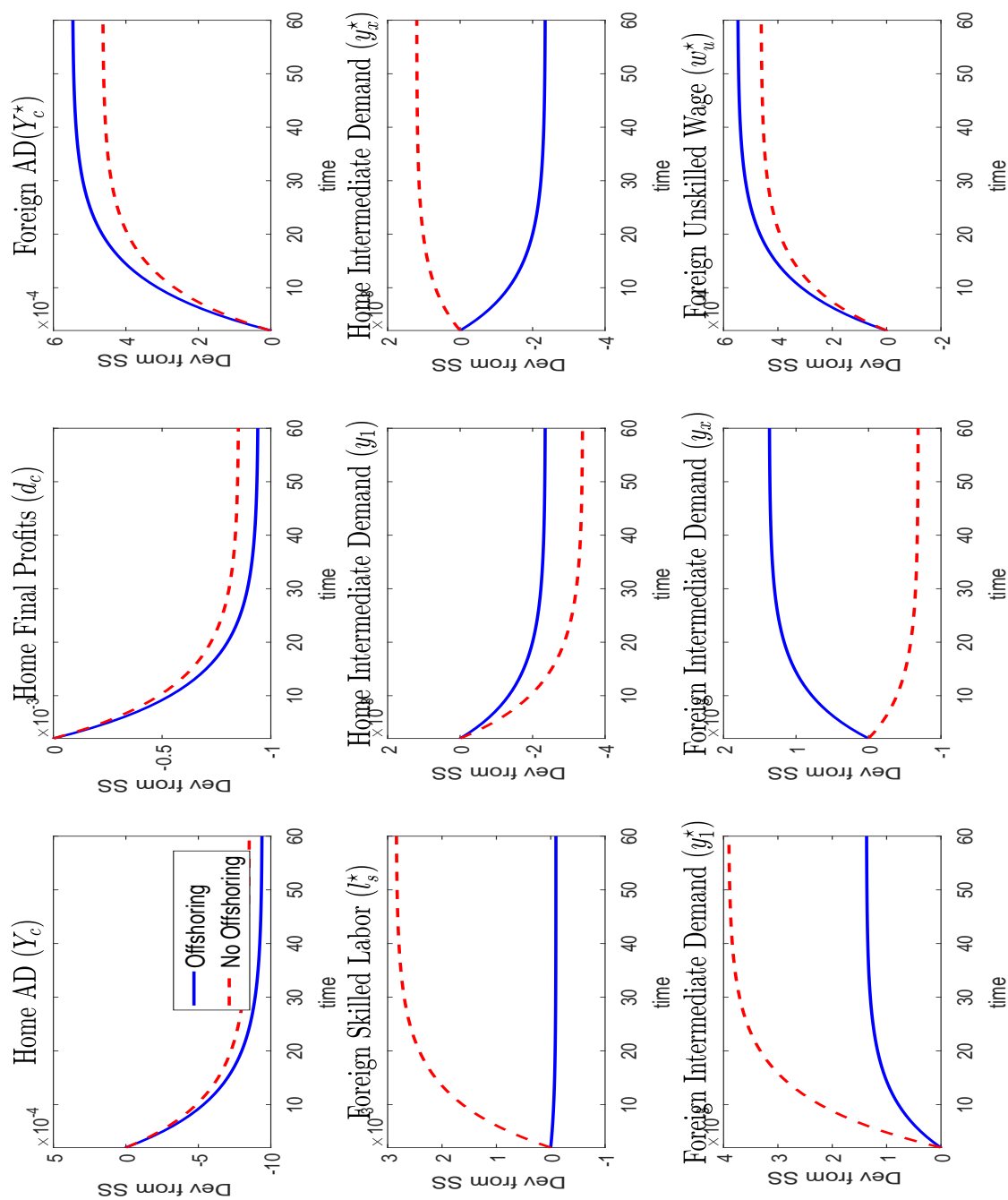


Figure 3.7: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus No Offshoring

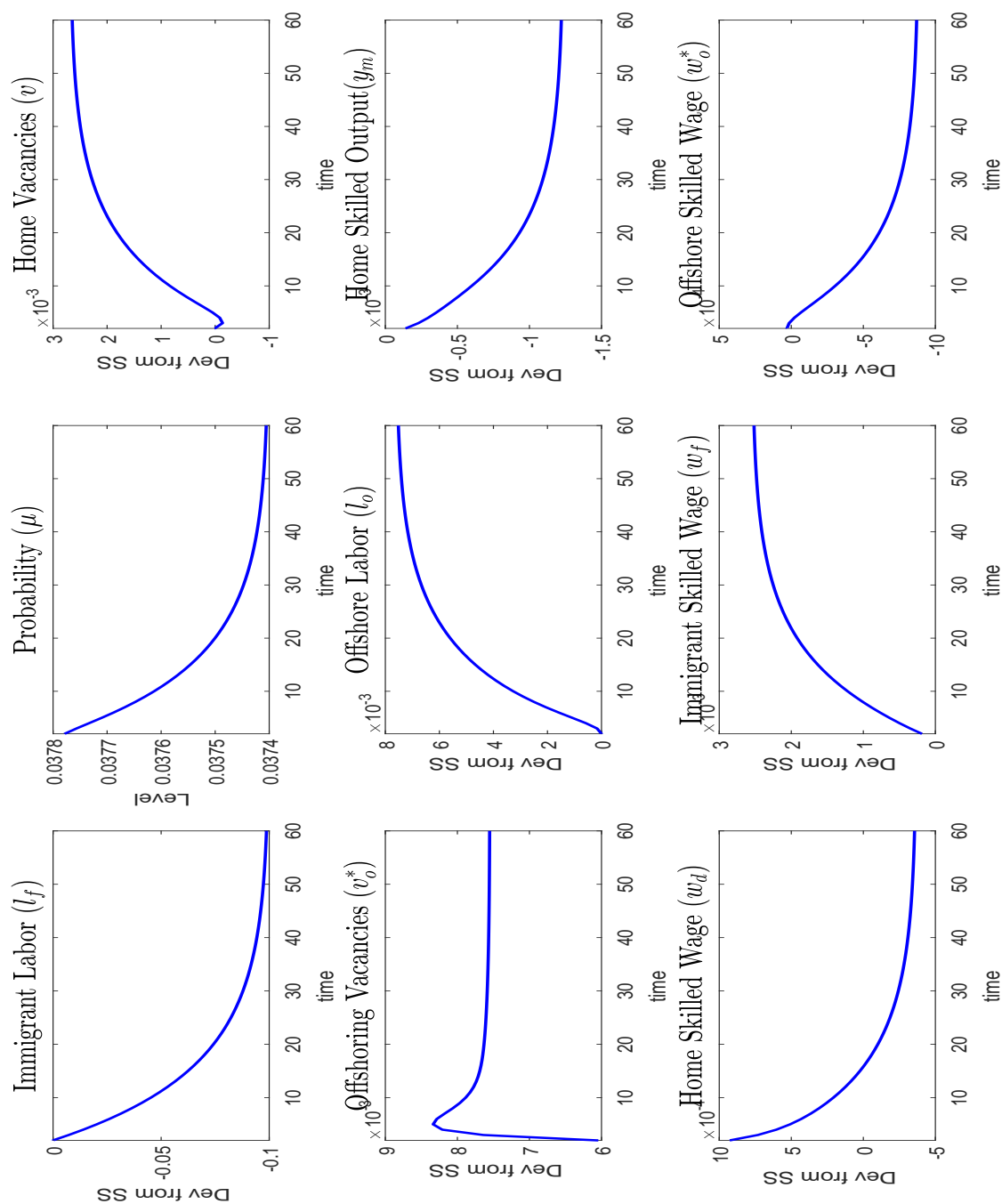


Figure 3.8: Response to a 10 Percent Immigration Cap Reduction with Labor Market Frictions

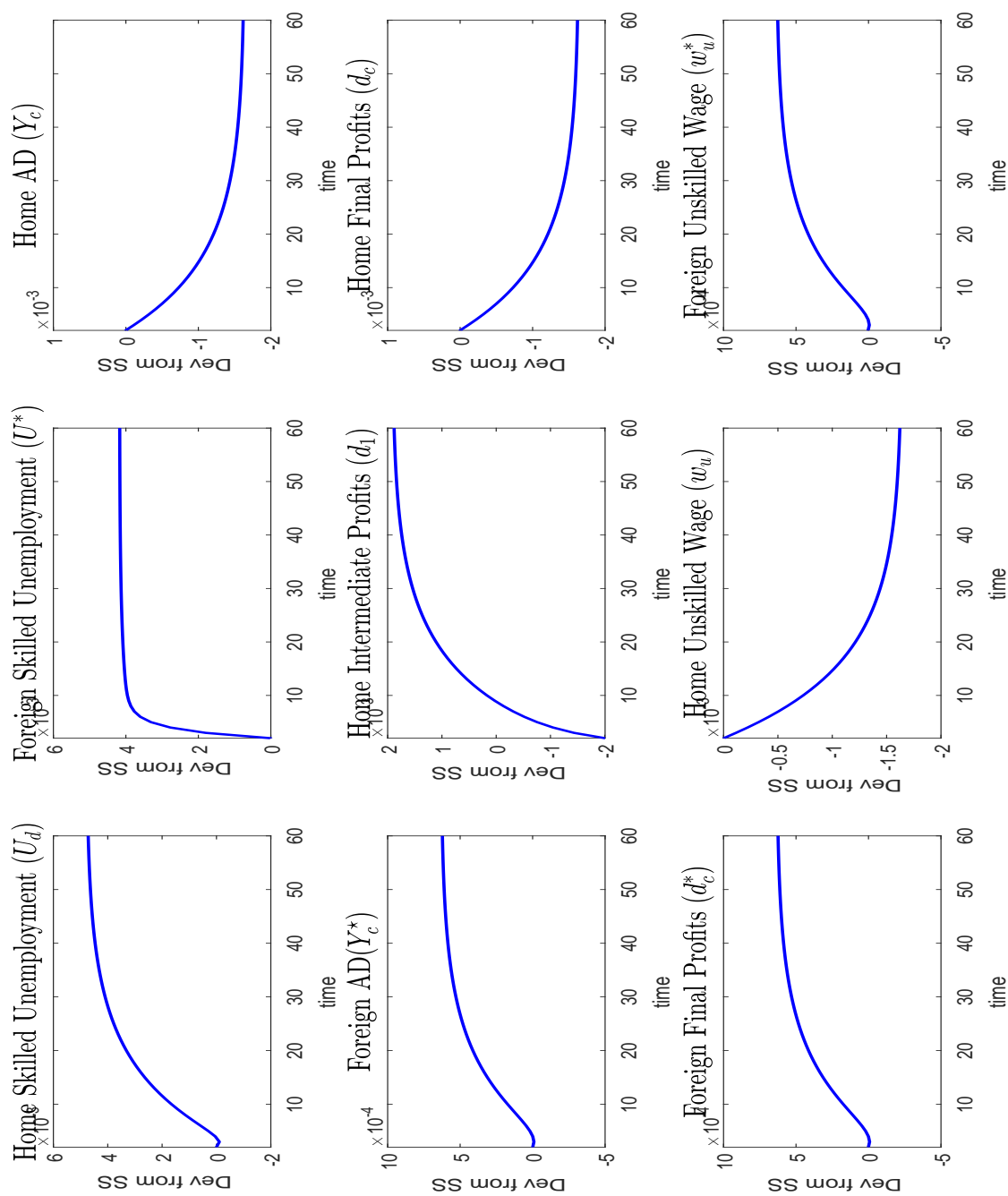


Figure 3.9: Response to a 10 Percent Immigration Cap Reduction with Labor Market Frictions

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## Appendix A

### APPENDIX FOR CHAPTER 1

#### A.1 Analytical Derivations

##### A.1.1 Foreign Upstream: Regular Firm's Problem

I focus here on the problem of the regular Foreign upstream firm, the same solution method applies to the problem of the regular Home upstream firm which is not described here.

The regular firm upstream produces output  $y_u^*$  to meet demand from Home and Foreign downstream firms such that  $y_u^* = (1 - a)m_f^* + (a - n)m_f$ . From the cost minimization of the downstream firms, we know that:

$$m_f = \left(\frac{q_f}{q}\right)^{-\sigma} m, \quad m_f^* = \left(\frac{q_f^*}{q^*}\right)^{-\sigma} m^* \quad (\text{A.1})$$

Taking the above demands into account, and noting that  $mc_u^* = \frac{w^*}{Z^*}$ , the maximization problem is:

$$\max_{q_f, q_f^*} (a - n)(\epsilon^{-1}q_f - mc_u^*)m_f + (1 - a)(q_f^* - mc_u^*)m_f^*$$

Since I assume Bertrand competition here, the firm will internalize the effect of its price on the price index as well as the demand for the intermediate basket. Focus first on the export pricing decision, as the decisions are separable due to constant marginal costs. Suppose  $E_d$  is the Home downstream firms total expenditure on inputs required for production. By definition:

$$E_d \equiv mc_d y_d = qm + wl_d \quad (\text{A.2})$$

Using results from cost minimization equation (A.2) can be re-written as:

$$\alpha E_d = qm \quad (\text{A.3})$$

Using (A.3) to substitute for  $m$  in (A.1), we get:

$$m_f = \alpha E_d q_f^{-\sigma} q^{\sigma-1} \quad (\text{A.4})$$

Now taking the first order condition on profits from exports with respect to export price we have:

$$\epsilon^{-1} m_f + \frac{dm_f}{dq_f} (\epsilon^{-1} q_f - mc_u^*) = 0 \quad (\text{A.5})$$

Then, we can take the first order condition of (A.4) with respect to  $q_f$ , which gives:

$$\frac{dm_f}{dq_f} = \alpha E_d \left[ -\sigma q_f^{\sigma-1} q^{\sigma-1} + (\sigma-1) q_f^{-\sigma} q^{\sigma-2} \frac{dq}{dq_f} \right]$$

From the expression for the price index, it is easily derived that  $\frac{dq}{dq_f} = \left(\frac{q_f}{q}\right)^{-\sigma}$ . Then using the definition  $s_f \equiv \left(\frac{q_f}{q}\right)^{1-\sigma}$ , and substituting above, we get:

$$\frac{dm_f}{dq_f} = \alpha E_d q_f^{-\sigma-1} q^{\sigma-1} \{-\sigma + (\sigma-1)s_f\}$$

Plugging above into (A.5) and solving for  $q_f$  yields:

$$q_f = \frac{\sigma - (\sigma-1)s_f}{\sigma - (\sigma-1)s_f - 1} \epsilon mc_u^* \quad (\text{A.6})$$

And similarly:

$$q_f^* = \frac{\sigma - (\sigma-1)s_f^*}{\sigma - (\sigma-1)s_f^* - 1} mc_u^* \quad (\text{A.7})$$

### A.1.2 Foreign Upstream: Mutinational Affiliate's Problem

In this section, I split the multinational affiliate's problem into two cases: under constant returns and non-constant returns to scale technology. In the first case, the marginal cost

of production is invariable in output, and thus all pricing decisions upstream are fully separable. Thus, this case is of a fully decentralized multinational, where only transfer prices are determined by the headquarters. Under non-constant returns to scale, since the pricing decision at a-l affects the cost associated with internal transfer of goods, I assume that a-l and transfer pricing decisions are made jointly by the headquarters. However, we still have partial decentralization as downstream decisions are made separately, while taking transfer prices as given.

### *Constant Returns to Scale*

Under constant returns to scale, the marginal cost of the upstream affiliate is  $mc_{Iu}^* = \frac{w^*}{Z^*}$ . Then the transfer pricing decision is carried out to maximize joint profits that depend on the transfer price:

$$\max_{q_{IN}} (p_{Id} - mc_{Id})c_I + (q_{IN} - \epsilon mc_{Iu}^*)m_{IN}$$

Recalling equations (1.2), (1.5) and (1.6), we can derive the following expressions:

$$(p_I - mc_{Id})c_I = \left( \frac{\phi}{\phi - 1} - 1 \right) mc_{Id}y_{Id} \quad (\text{A.8})$$

$$m_{IN} = \frac{\alpha mc_{Id}y_{Id}}{q_{IN}} \quad (\text{A.9})$$

substituting these into the objective above, and taking the first order condition yields:

$$\left( \frac{\phi}{\phi - 1} - 1 + \alpha \right) \frac{d(mc_{Id}y_{Id})}{dq_{IN}} - \epsilon mc_{Iu}^* \frac{d(m_{IN})}{dq_{IN}} = 0 \quad (\text{A.10})$$

Note:

$$mc_{Id}y_{Id} = \left( \frac{\phi}{\phi - 1} \right)^{1-\phi} mc_{Id}^{1-\phi} P^\phi C$$

Taking derivative wrt transfer price:

$$\frac{d(mc_{Id}y_{Id})}{dq_{IN}} = \alpha(1 - \phi) \frac{mc_{Id}y_{Id}}{q_{IN}}$$

Also

$$\frac{d(m_{IN})}{dq_{IN}} = \alpha \frac{mc_{Id}y_{Id}}{q_{IN}^2} (\alpha(1 - \phi) - 1)$$

Substituting these into (A.10) and solving yields:

$$q_{IN} = \epsilon mc_{Iu}^* \quad (\text{A.11})$$

The a-l decision for the multinational under constant returns is identical to that of regular firms, thus, I do not derive this result here.

### *Non-Constant Returns to Scale*

Recall now that marginal cost of upstream production is  $mc_{Iu}^* = \frac{w^*}{Z^*} \left(\frac{y_{Iu}}{Z^*}\right)^{\frac{1-\theta}{\theta}}$ . Thus, all upstream decisions are made jointly such that the new problem is:

$$\max_{q_{IN}, q_{If}, q_{If}^*} (p_{Id} - mc_{Id})c_1 + (q_{IN} - \epsilon mc_{Iu}^*)m_{IN} + (a - n)(q_{If} - \epsilon mc_{Iu}^*)m_{If} + (1 - a)(\epsilon q_{If}^* - \epsilon mc_{Iu}^*)m_{If}^*$$

Since we know that the marginal cost depends on level of output, and recall from the associated market clearing that  $y_{Iu}^* = m_{IN} + (a - n)m_{If} + (1 - a)m_{If}^*$

Then using prior results and re-writing the objective above we have:

$$\max_{q_{IN}, q_{If}, q_{If}^*} \left( \frac{\phi}{\phi - 1} - 1 + \alpha \right) mc_{Id}y_{Id} + (a - n)q_{If}m_{If} + (1 - a)\epsilon q_{If}^*m_{If}^* - \epsilon mc_{Iu}^*y_{Iu}^*$$

Taking the first order condition with respect to the transfer price yields:

$$\left( \frac{\phi}{\phi - 1} - 1 + \alpha \right) \frac{d(mc_{Id}y_{Id})}{dq_{IN}} - \epsilon \frac{d(mc_{Iu}^*y_{Iu}^*)}{dq_{IN}} = 0 \quad (\text{A.12})$$

Using the expression for marginal cost and taking the derivative wrt transfer price gives:

$$\frac{d(mc_{1u}^* y_{1u}^*)}{dq_{1N}} = \frac{\alpha mc_{1u}^*}{\theta} (\alpha(1 - \phi) - 1) \frac{mc_{1d} y_{1d}}{q_{1N}^2}$$

Using the above with the prior expression for  $\frac{d(mc_{1d} y_{1d})}{dq_{1N}}$  in equation (A.12) and solving for transfer price yields:

$$q_{1N} = \frac{\epsilon}{\theta} mc_{1u}^* \quad (\text{A.13})$$

Now taking the derivative of the objective wrt  $q_{1f}$  yields:

$$(a - n) \frac{d(q_{1f} y_{1f})}{dq_{1f}} - \epsilon \frac{d(mc_{1u}^* y_{1u}^*)}{dq_{1f}} = 0 \quad (\text{A.14})$$

It is easily derived that:

$$\frac{d(q_{1f} y_{1f})}{dq_{1f}} = (a - n) \{m_{1f} + m_{1f}(-\sigma + (\sigma - 1)s_{1f})\}$$

$$\frac{d(mc_{1u}^* y_{1u}^*)}{dq_{1f}} = (a - n) \frac{mc_{1u}^*}{\theta} (-\sigma + (\sigma - 1)s_{1f}) \frac{m_{1f}}{q_{1f}}$$

Using the above expressions in (A.14) and solving for  $q_{1f}$  yields:

$$q_{1f} = \frac{\sigma - (\sigma - 1)s_{1f}}{\sigma - (\sigma - 1)s_{1f} - 1} \frac{\epsilon mc_{1u}^*}{\theta} \quad (\text{A.15})$$

### A.1.3 Derivation of Pass-Through Elasticities

#### *Constant Returns to Scale*

Under constant returns to scale, we know that  $\frac{\partial \ln mc_{1u}^*}{\partial \ln \epsilon} = 0$ . Then from equation (A.11), we can find:

$$\frac{\partial \ln q_{1N}}{\partial \ln \epsilon} = 1 \quad (\text{A.16})$$

The above shows that in the absence of firm level market interdependence, ERPT into transfer prices is always complete.

Now looking at ERPT into a-l prices, I begin by examining the pass-through elasticity of the multinationals export price. Using equation (A.15), and taking derivative wrt  $\epsilon$  yields:

$$\frac{\partial q_{If}}{\partial \epsilon} = \frac{q_{If}}{\epsilon} + \frac{(\sigma - 1)q_{If}}{\{\sigma - (\sigma - 1)s_{If} - 1\}\{\sigma - (\sigma - 1)s_{If}\}} \frac{\partial s_{If}}{\partial \epsilon}$$

Recalling definition of  $s_{If}$  and taking partial wrt  $\epsilon$ :

$$\frac{\partial s_{If}}{\partial \epsilon} = (1 - \sigma) \left( \frac{q_{If}}{q} \right)^{1-\sigma} \left\{ \frac{1}{q_{If}} \frac{\partial q_{If}}{\partial \epsilon} - \frac{1}{q} \frac{\partial q}{\partial \epsilon} \right\}$$

From the intermediate price index  $q$  we know:

$$q^{1-\sigma} = nq_{If}^{1-\sigma} + (\chi - n)q_f^{1-\sigma} + (1 - \chi)q_h^{1-\sigma}$$

Given that all upstream exporters in Foreign face the same marginal cost and the same demand function, their pricing decisions are identical. Using this information and taking the derivative of the price index above yields:

$$\frac{\partial q}{\partial \epsilon} = \chi \left( \frac{q_f}{q} \right)^{-\sigma}$$

Using the above in the partial derivative expression of  $s_{If}$ :

$$\frac{\partial s_{If}}{\partial \epsilon} = \frac{\partial s_f}{\partial \epsilon} = \frac{(1 - \sigma)s_f(1 - \chi s_f)}{q_f} \frac{\partial q_f}{\partial \epsilon}$$

Using this expression in the partial wrt  $q_{If}$ , multiplying by  $\frac{\epsilon}{q_{If}}$ , and solving for  $\frac{\partial \ln q_{If}}{\partial \ln \epsilon}$  yields:

$$\frac{\partial \ln q_{If}}{\partial \ln \epsilon} = \left[ 1 - \frac{(1 - \sigma)(\sigma - 1)s_{If}(1 - \chi s_{If})}{(\sigma - (\sigma - 1)s_{If} - 1)(\sigma - (\sigma - 1)s_{If})} \right]^{-1} \quad (\text{A.17})$$

And similarly:

$$\frac{\partial \ln q_f}{\partial \ln \epsilon} = \left[ 1 - \frac{(1 - \sigma)(\sigma - 1)s_f(1 - \chi s_f)}{(\sigma - (\sigma - 1)s_f - 1)(\sigma - (\sigma - 1)s_f)} \right]^{-1} \quad (\text{A.18})$$

From (A.17) and (A.18), it can be seen that when exporters' market share  $\chi s_f$  is one, i.e. exporters are the only ones that serve the intermediates market for Home, ERPT is complete

in a-l prices as well. This is also the case when firm level share approaches zero since the mark-up approaches the CES monopolistic competition mark-up.

### *Non Constant Returns to Scale*

In this case, the marginal cost of upstream production for multinational affiliate is:

$$mc_{Iu}^* = \frac{w^*}{Z^*} \left( \frac{y_{Iu}^*}{Z^*} \right)^{\frac{1-\theta}{\theta}}$$

Then it can be easily derived that:

$$\frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} = \frac{1-\theta}{\theta} \frac{\partial \ln y_{Iu}^*}{\partial \ln \epsilon} \quad (\text{A.19})$$

Recalling market clearing  $y_{Iu}^* = m_{IN} + (a-n)m_{If} + (1-a)m_{If}^*$ . This implies:

$$\frac{\partial \ln y_{Iu}^*}{\partial \ln \epsilon} = (a-n) \frac{m_{If}}{y_{Iu}^*} \frac{\partial \ln m_{If}}{\partial \ln \epsilon} + \frac{m_{IN}}{y_{Iu}^*} \frac{\partial \ln m_{IN}}{\partial \ln \epsilon} \quad (\text{A.20})$$

From the mark-up for multinationals transfer price we have:

$$\frac{\partial \ln q_{IN}}{\partial \ln \epsilon} = 1 + \frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} \quad (\text{A.21})$$

In deriving the a-l pass-through elasticity, I note that under non-constant returns, the decisions of the multinational affiliate and the regular exporters are different and thus they cannot be grouped as before.

$$\frac{\partial \ln q_{If}}{\partial \ln \epsilon} = \Omega_{If} + \Omega_{If} \frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} - \Psi_{If} \frac{\partial \ln q_f}{\partial \ln \epsilon} \quad (\text{A.22})$$

in (A.21)  $\Omega_{If}$  and  $\Psi_{If}$  are defined as:

$$\Omega_{If} \equiv \left[ 1 - \frac{(\sigma-1)(1-\sigma)s_{If}(1-ns_{If})}{(\sigma-(\sigma-1)s_{If}-1)(\sigma-(\sigma-1)s_{If})} \right]^{-1}$$

$$\Psi_{If} \equiv \Omega_{If} \frac{(\sigma-1)(1-\sigma)s_{If}(\chi-n)s_f}{(\sigma-(\sigma-1)s_{If}-1)(\sigma-(\sigma-1)s_{If})}$$

In order to express (A.21) and (A.20) as functions of market shares, and parameters we need to find the following  $\frac{\partial \ln y_{1u}^*}{\partial \ln \epsilon}$  and  $\frac{\partial \ln q_f}{\partial \ln \epsilon}$ .

Following the same method as before for a-1 prices, it can be easily derived that:

$$\frac{\partial \ln q_f}{\partial \ln \epsilon} = \Omega_f - \Psi_f \frac{\partial \ln q_{1f}}{\partial \ln \epsilon} \quad (\text{A.23})$$

Where:

$$\Omega_f \equiv \left[ 1 - \frac{(\sigma - 1)(1 - \sigma)s_f(1 - (\chi - n)s_f)}{(\sigma - (\sigma - 1)s_f - 1)(\sigma - (\sigma - 1)s_f)} \right]^{-1}$$

$$\Psi_f \equiv \Omega_f \frac{(\sigma - 1)(1 - \sigma)s_f n s_{1f}}{(\sigma - (\sigma - 1)s_f - 1)(\sigma - (\sigma - 1)s_f)}$$

Substituting (A.22) into (A.21) and solving:

$$\frac{\partial \ln q_{1f}}{\partial \ln \epsilon} = \frac{\Omega_{1f} - \Psi_f \Omega_f}{1 - \Psi_f \Psi_{1f}} + \frac{\Omega_f}{1 - \Psi_f \Psi_{1f}} \frac{\partial \ln m c_{1u}^*}{\partial \ln \epsilon} \quad (\text{A.24})$$

And using (A.23) in (A.22):

$$\frac{\partial \ln q_f}{\partial \ln \epsilon} = \frac{\Omega_f - \Psi_f \Omega_{1f}}{1 - \Psi_f \Psi_{1f}} + \frac{\Psi_f \Omega_{1f}}{1 - \Psi_f \Psi_{1f}} \frac{\partial \ln m c_{1u}^*}{\partial \ln \epsilon} \quad (\text{A.25})$$

Using equations (A.19)-(A.25), and taking partials with respect to the log exchange-rate along the way, it can be shown that:

$$\frac{\partial \ln m c_{1u}^*}{\partial \ln \epsilon} = \frac{\Gamma_{IN} \frac{y_{1N}}{y_{1u}^*} + \left\{ \frac{\Gamma_{1f}(\Omega_{1f} - \Psi_f \Omega_f) + \Gamma_f(\Omega_f - \Psi_f \Omega_{1f})}{1 - \Psi_f \Psi_{1f}} \right\} (a - n) \frac{y_{1f}}{y_{1u}^*}}{\frac{\theta}{1 - \theta} - \Gamma_{IN} \frac{y_{1N}}{y_{1u}^*} - \left\{ \frac{\Gamma_{1f}(\Omega_{1f} - \Psi_f \Omega_f) + \Gamma_f(\Omega_f - \Psi_f \Omega_{1f})}{1 - \Psi_f \Psi_{1f}} \right\} (a - n) \frac{y_{1f}}{y_{1u}^*}} \quad (\text{A.26})$$

Where:

$$\Gamma_{IN} \equiv \alpha(1 - \phi) - 1$$

$$\Gamma_{1f} \equiv \{\alpha(1 - \phi) + (\sigma - 1)\} n s_{1f} - \sigma$$

$$\Gamma_f \equiv (\chi - n) s_f \{\alpha(1 - \phi) + (\sigma - 1)\}$$

#### A.1.4 Proofs

##### *Proof of Proposition 2*

Looking at the pass-through elasticity into multinationals' export a-l price:

$$\frac{\partial \ln q_{If}}{\partial \ln \epsilon} = \left[ 1 - \frac{(1 - \sigma)(\sigma - 1)s_{If}(1 - \chi s_{If})}{(\sigma - (\sigma - 1)s_{If} - 1)(\sigma - (\sigma - 1)s_{If})} \right]^{-1} \quad (\text{A.27})$$

Note here that when  $s_{If} = 0$  or  $s_{If} = \frac{1}{\chi}$ , the expression in (A.27) equals 1. While  $0 < s_{If} < 1$  or  $\frac{\sigma}{\sigma-1} < s_{If} < \frac{1}{\chi}$  ERPT is incomplete and positive as the numerator of the expression is larger than the denominator. For  $1 < s_{If} < \frac{\sigma}{\sigma-1}$ , ERPT is negative as the denominator is positive but numerator is negative, but here too the denominator is larger, in absolute value, than the numerator.

##### *Proof of Proposition 4*

The proof of proposition 4 follows from the proof above. When  $s_f=0$ , we have:

$$\frac{\partial \ln q_{If}}{\partial \ln \epsilon} = \left[ 1 - \frac{(\sigma - 1)(1 - \sigma)s_{If}(1 - ns_{If})}{(\sigma - (\sigma - 1)s_{If} - 1)(\sigma - (\sigma - 1)s_{If})} \right]^{-1} \left[ 1 + \frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} \right]$$

$$\frac{\partial \ln q_{IN}}{\partial \ln \epsilon} = 1 + \frac{\partial \ln mc_{Iu}^*}{\partial \ln \epsilon} \quad (\text{A.28})$$

From the above equations, it can be clearly seen that ERPT into transfer prices is strictly larger than at a-l so long as  $\left[ 1 - \frac{(\sigma-1)(1-\sigma)s_{If}(1-ns_{If})}{(\sigma-(\sigma-1)s_{If}-1)(\sigma-(\sigma-1)s_{If})} \right]^{-1} < 1$  and this is true so long as  $0 < s_{If} < \frac{1}{n}$ .

## Appendix B

### APPENDIX FOR CHAPTER 2

#### ***B.1 Data Sources***

The Agriculture Census, conducted by the Ministry of Agriculture of the Government of India, provides data on the structural characteristics of the agricultural sector in India. We use the 2000-01 census to obtain the number of farms per person for India as 0.25. The National Sample Survey (NSS), set up by the Government of India, conducts rounds of sample surveys to collect socioeconomic data. We use round 55 (July 1999-June 2000) on Employment and Unemployment (Schedule 10). According to the round, around 60 percent of the workforce is employed in agriculture sector. From IPUMS, we find that approximately 59 percent of the workforce works in agriculture sector in rural areas. In our calculations, we consider only people who are employed. We use the value of 59 percent to match the model moment for labor share in the rural area. We obtain the rural-urban wage gap of 2.56 in 1999, by regressing wages (log) on a rural dummy. This regression is run on data after aggregating the sample into agricultural and non-agricultural sector and appropriately excluding observations so that location and sector of employment are tied together as in our model. The World KLEMS initiative provides data on output, inputs and productivity, available at the industry- level across countries including India. From the India KLEMS database Version 2015, we find data on value added share in agriculture which is 0.23 in 2000 from Table *VA at Current Price*.

In order to calibrate the earnings process in the urban region, we employ Tauchen's method to discretize a continuous earnings process. We use the Indian Human Development Survey (IHDS) round one (IHDS-I) from 2004-05 and round two (IHDS-II) from 2011-12 to estimate the persistence of wage for employed male worker living in urban area. The

estimates are obtained from a regression of (log) wages in 2011 on (log) wages in 2005, i.e.  $\log w_{2011-12} = \rho_w \log w_{2004-05} + \epsilon_w$ . From the estimation, we get  $\rho_w$  as approximately 0.6 and variance for  $\epsilon_w$  as 0.3969.

Using the above estimate, we calculate  $\zeta$  and  $\pi$  as:

$$2\zeta = \exp\left(\sqrt{\frac{\epsilon_w^2}{1 - \rho_w^2}}\right)$$

$$\pi = \frac{1 + \rho_w}{2}$$

## B.2 Model Solution

The unknowns are

$\{a_n^y(-\zeta), c_n^y(-\zeta), k_n(-\zeta), a_n^y(\zeta), c_n^y(\zeta), k_n(\zeta)\}$  (6 variables)

$\{a_n^o(-\zeta, -\zeta), a_n^o(-\zeta, \zeta), a_n^o(\zeta, -\zeta), a_n^o(\zeta, \zeta), c_n^o(-\zeta, -\zeta), c_n^o(-\zeta, \zeta), c_n^o(\zeta, -\zeta), c_n^o(\zeta, \zeta)\}$  (8 variables)

$\{a_a^y, c_a^y, k_a, l\}$  (4 variables)

$\{a_a^o, a_a^o\}$  (2 variables)

$\{Y_n, K_n, N_n\}$  (3 variables)

$\{y_a, k_a^f, n_a^f, l^f, d\}$  (5 variables)

$\{w_n, w_a, r, q, p_l, p_a\}$  (6 variables)

$\chi, \varepsilon$  (2 variables)

So we have 36 unknowns.

### B.2.1 Urban Firm

Given  $r, w_n$ , we solve for  $\{Y_n, K_n, N_n\}$ . The aggregate urban firm profit maximization yields the following 3 conditions:

$$\begin{aligned} Y_n &= A_n K_n^\alpha N_n^{1-\alpha}, \\ w_n &= (1-\alpha) A_n K_n^\alpha N_n^{-\alpha}, \\ r &= \alpha A_n K_n^{\alpha-1} N_n^{1-\alpha}. \end{aligned}$$

### B.2.2 Individual Farms

Given  $r, w_a, p_a$ , we solve for  $\{y_a, k_a^f, n_a^f, l^f, d\}$ . Individual farm profit maximization yields the following 5 conditions:

$$\begin{aligned} y_a &= A_a \left[ (1-\theta) (l^f)^\rho + \theta (\nu (k_a^f)^\mu + (1-\nu) (n_a^f)^\mu)^{\frac{\rho}{\mu}} \right]^{\frac{\rho}{\rho}}, \\ w_a &= \theta p_a \eta A_a [\cdot]^{\frac{\rho}{\rho}-1} (\nu (k_a^f)^\mu + (1-\nu) (n_a^f)^\mu)^{\frac{\rho}{\mu}-1} (1-\nu) (n_a^f)^{\mu-1}, \\ r &= \theta p_a \eta A_a [\cdot]^{\frac{\rho}{\rho}-1} (\nu (k_a^f)^\mu + (1-\nu) (n_a^f)^\mu)^{\frac{\rho}{\mu}-1} \nu (k_a^f)^{\mu-1}, \\ q &= p_a \eta A_a [\cdot]^{\frac{\rho}{\rho}-1} (1-\theta) (l^f)^{\rho-1}, \\ d &= (1-\eta) p_a y_a. \end{aligned}$$

### B.2.3 Urban Area Households

Given  $p_a, r, w_n$ , the urban household variables,  $\{a_n^y(-\zeta), c_n^y(-\zeta), k_n(-\zeta), a_n^y(\zeta), c_n^y(\zeta), k_n(\zeta)\}$  and  $\{a_n^o(-\zeta, -\zeta), a_n^o(-\zeta, \zeta), a_n^o(\zeta, -\zeta), a_n^o(\zeta, \zeta), c_n^o(-\zeta, -\zeta), c_n^o(-\zeta, \zeta), c_n^o(\zeta, -\zeta), c_n^o(\zeta, \zeta)\}$  (14 variables), must satisfy the following conditions:

6 budget constraints:

$$\begin{aligned} p_a a_n^y(\zeta^y) + c_n^y(\zeta^y) + k_t^n(\zeta^y) &= w_n \kappa \exp(\zeta^y), \text{ for } \zeta^y = -\zeta, \zeta \\ p_a a_n^o(\zeta^y, \zeta^o) + c_n^o(\zeta^y, \zeta^o) &= \gamma w_n \kappa \exp(\zeta^o) + r_n k^n(\zeta^y), \text{ for } (\zeta^y, \zeta^o) = (-\zeta, -\zeta), (-\zeta, \zeta), (\zeta, \zeta), (\zeta, -\zeta) \end{aligned} \quad (\text{B.1})$$

6 conditions involving the marginal rate of substitution between  $c$  and  $a$  at each tree

node:

$$\begin{aligned} \frac{\phi}{1-\phi} \left( \frac{c_n^y(\zeta^y)}{a_n^y(\zeta^y) - \bar{a}} \right)^\sigma &= p_a, \text{ for } \zeta^y = -\zeta, \zeta \\ \frac{\phi}{1-\phi} \left( \frac{c_n^o(\zeta^y, \zeta^o)}{a_n^o(\zeta^y, \zeta^o) - \bar{a}} \right)^\sigma &= p_a, \text{ for } (\zeta^y, \zeta^o) = (-\zeta, -\zeta), (-\zeta, \zeta), (\zeta, \zeta), (\zeta, -\zeta) \end{aligned}$$

2 conditions involving the intertemporal expected rate of substitution between  $c^y$  and  $c^o$  :

$$\begin{aligned} \frac{c_n^y(-\zeta)^{-\sigma}}{\pi c_n^o(-\zeta, -\zeta)^{-\sigma} + (1-\pi) c_n^o(-\zeta, \zeta)^{-\sigma}} &= \beta r \text{ for } \zeta^y = -\zeta \\ \frac{c_n^y(\zeta)^{-\sigma}}{\pi c_n^o(\zeta, \zeta)^{-\sigma} + (1-\pi) c_n^o(\zeta, -\zeta)^{-\sigma}} &= \beta r \text{ for } \zeta^y = \zeta \end{aligned}$$

#### B.2.4 Rural Area Households

Given  $p_a, r, w_a, q, p_l$ , the rural area household variables,  $\{a_a^y, c_a^y, k_a, l\}$  and  $\{a_a^o, a_a^o\}$  (6 variables), must satisfy the following conditions:

2 budget constraints:

$$p_a a_a^y + c_a^y + p_l l + k_a = w_a, \quad (\text{B.3})$$

$$p_a a_a^o + c_a^o = w_a + r k_a + (q + p_l) l. \quad (\text{B.4})$$

2 conditions involving the marginal rate of substitution between  $c$  and  $a$  at each age:

$$\begin{aligned} \frac{\phi}{1-\phi} \left( \frac{c_n^y}{a_n^y - \bar{a}} \right)^\sigma &= p_a \\ \frac{\phi}{1-\phi} \left( \frac{c_n^o}{a_n^o - \bar{a}} \right)^\sigma &= p_a \end{aligned}$$

1 condition involving the inter-temporal rate of substitution between  $c^y$  and  $c^o$  :

$$\left( \frac{c_n^y}{c_n^o} \right)^{-\sigma} = \beta r$$

Note the household will save in terms of capital only if  $r > \frac{q+p_l}{p_l}$ , and in terms of land only otherwise. We will focus on the interior solution, which means that the rates of return equalize across the two assets, i.e.

$$r = \frac{q + p_l}{p_l}$$

we can solve the above equations to determine  $a_a^y, c_a^y, a_a^o, a_a^o$  and savings  $s_a = p_l l + k_a$ .

### B.2.5 Labor Market Clearing

To summarize what we have so far, for given prices,  $\{w_n, w_a, r, q, p_l, p_a\}$ , we have solved for all household and firm variables (except  $l$  and  $k_a$ ) and we have obtained 2 additional conditions

$$\begin{aligned} r &= \frac{q + p_l}{p_l}, \\ s_a &= p_l l + k_a, \end{aligned}$$

where  $s_a$  is known.

It remains to find  $\{w_n, w_a, r, q, p_l, p_a\}, l, k_a, \chi, \varepsilon$  (10 variables).

The remaining conditions are 6 market clearing where we substituted for the population size of the young and old in urban areas,  $N_n^y = N_n^o = \chi N$ , and for the population size of young and old in agricultural areas  $N_a^y = N_a^o = (1 - \chi) N$ :

Labor market in agriculture:

$$\varepsilon (1 - \chi) (1 + \gamma) N n_a^f = (1 - \chi) N (1 - \varepsilon) (1 + \gamma).$$

Labor market in the urban area:

$$N_n = \chi N (1 + \gamma).$$

Capital market:

$$K_n + \varepsilon (1 - \chi) N (1 + \gamma) k_a^f = \chi N k_n + (1 - \chi) N k_a.$$

Land market in agriculture:

$$\varepsilon (1 - \chi) N (1 + \gamma) l^f = (1 - \chi) N l = L.$$

Agricultural goods market:

$$\varepsilon (1 - \chi) (1 + \gamma) N y_a = \chi N (a_n^y + a_n^o) + (1 - \chi) N (a_a^y + a_a^o).$$

Non-agricultural goods market:

$$Y_n = \chi N (c_n^y + c_n^o + k_n) + (1 - \chi) N (c_a^y + c_a^o + k_a).$$

$k_n = 0.5 [k_n (\zeta^y = -\zeta) + k_n (\zeta^y = \zeta)]$  is investment per urban young household (and capital holdings per urban old household),

$a_n^y = 0.5 [a_n^y (-\zeta) + a_n^y (\zeta)]$  is the average consumption of the agricultural good for the urban young household,

$c_n^y = 0.5 [c_n^y (-\zeta) + c_n^y (\zeta)]$  is the average consumption of the non-agricultural good for the urban young household,

$a_n^o = 0.5 [\pi a_n^o (-\zeta, -\zeta) + (1 - \pi) a_n^o (-\zeta, \zeta) + \pi a_n^o (\zeta, \zeta) + (1 - \pi) a_n^o (\zeta, -\zeta)]$  is the average consumption of the agricultural good for the urban old household,

$c_n^o = 0.5 [\pi c_n^o (-\zeta, -\zeta) + (1 - \pi) c_n^o (-\zeta, \zeta) + \pi c_n^o (\zeta, \zeta) + (1 - \pi) c_n^o (\zeta, -\zeta)]$  is the average consumption of the non-agricultural good for the urban old household.

Measure  $\chi_t$  of each cohort decides to locate in agricultural areas. This measure is determined by equalization of lifetime utility across areas:

$$EU_n = U_a.$$

We also know

$$d_t = w_t.$$

## Appendix C

**APPENDIX FOR CHAPTER 3*****C.1 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 C.1 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 C.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 this, 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. 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. 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<sup>1</sup> 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

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<sup>1</sup>This proves the workers qualifications

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.

## C.2 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 C.2: 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	$\mu_t = \frac{N_{e,t}}{N_{e,t}}$
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	$d_{c,t}^* = \rho_{d,t}^*Y_t^{c*} - N_d^*\rho_{1,t}^*y_{1,t}^* - \rho_{x,t}y_{x,t} - w_{u,t}^*\bar{l}_u^*$
Home Aggregate Accounting	$Y_t^c = w_{s,t}(1 + l_{f,t}) + w_{u,t}\bar{l}_u + d_{c,t} + d_{1,t} + f_{R,t}N_{e,t}$
Foreign Aggregate Accounting	$Y_t^{c*} = w_{s,t}^*(l_{o,t} + f_{o,t} + N_d^*l_{s,t}^*) + w_{u,t}^*\bar{l}_u^* + d_{c,t}^* + N_d^*d_{1,t}^*$
Balance of Payments	$Q_t\rho_{x,t}y_{x,t} - N_d^*\rho_{x,t}^*y_{x,t} = Q_t w_{s,t}^* l_{o,t} + Q_t f_{o,t} w_{s,t}^*$
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	$\bar{l}_s^* = N_d^*l_{s,t}^* + l_{f,t} + f_{o,t} + l_{o,t}$

## C.3 Cyclicity of Services Offshoring

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

Table C.3: Cyclicalilty 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 C.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.

## C.4 Figures

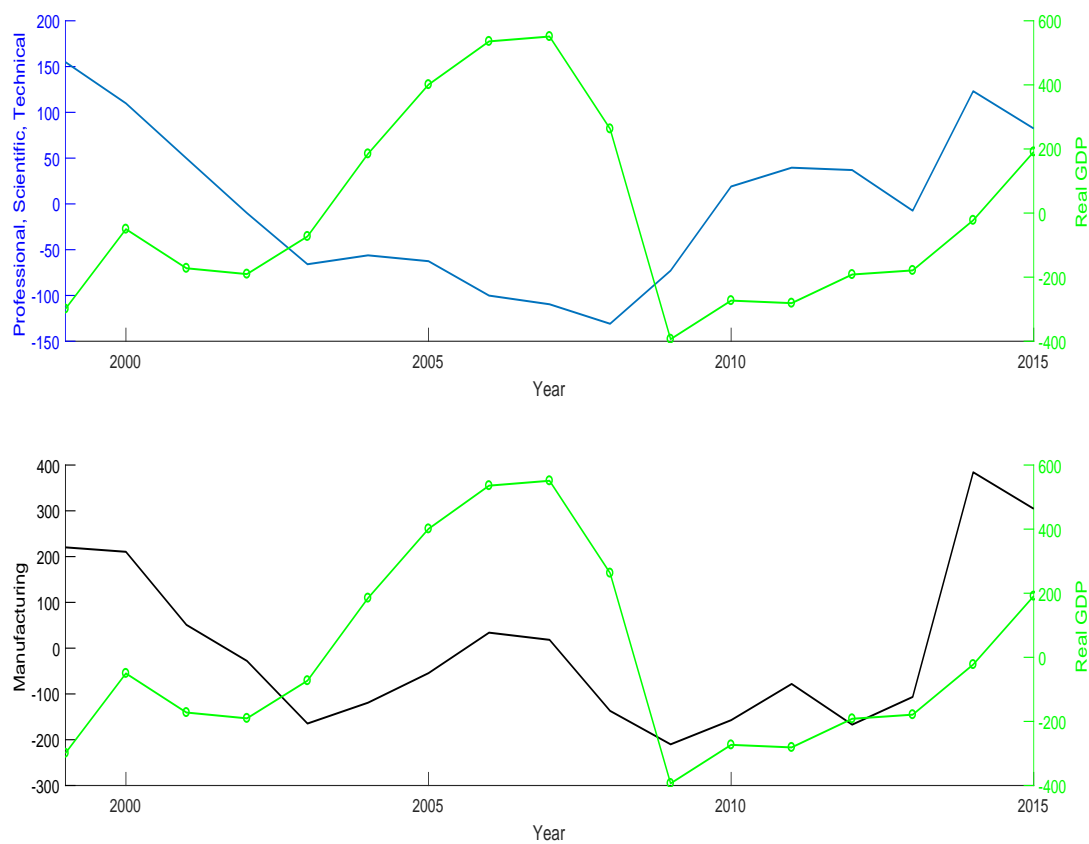


Figure C.1: Cyclicity of Employment at Foreign Affiliates

The top panel plots detrended growth rates of employment at U.S. owned foreign affiliates in the Professional, Scientific, and Technical services sector against that of real U.S. GDP. The bottom panel repeats this plot with detrended employment growth at Manufacturing affiliates.

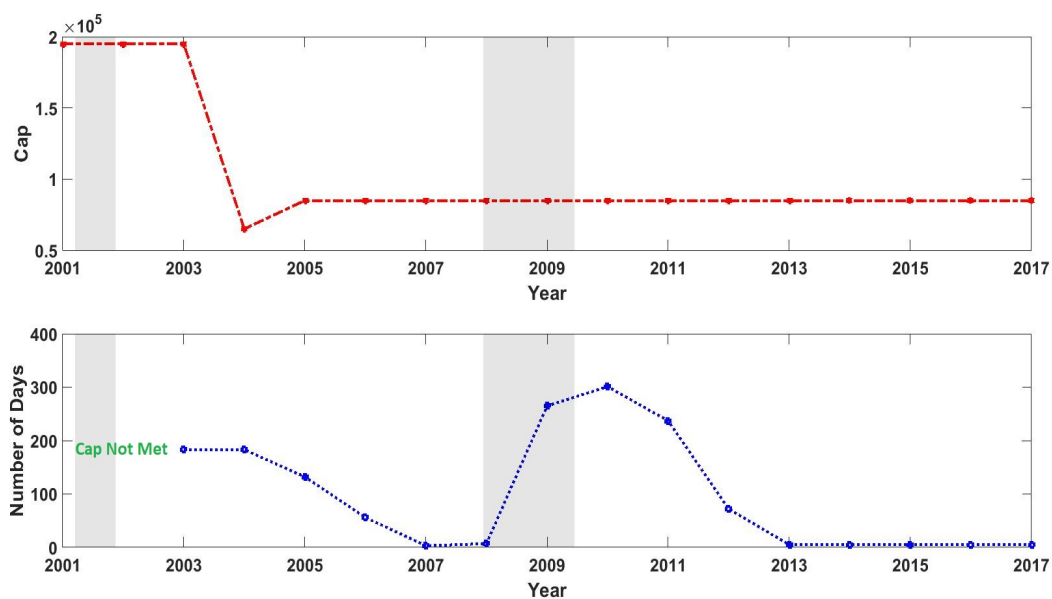


Figure C.2: H-1B Visa Cap

The top panel plots the number of H-1B visas granted. The bottom panel plots the number of days taken to meet the H-1B visa cap.

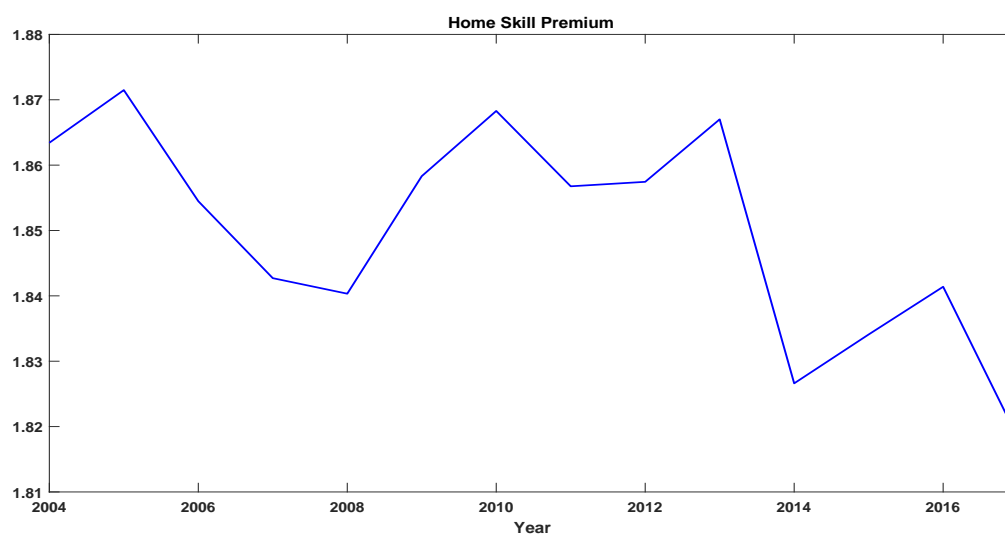


Figure C.3: U.S. Skill Premium 2004-2017

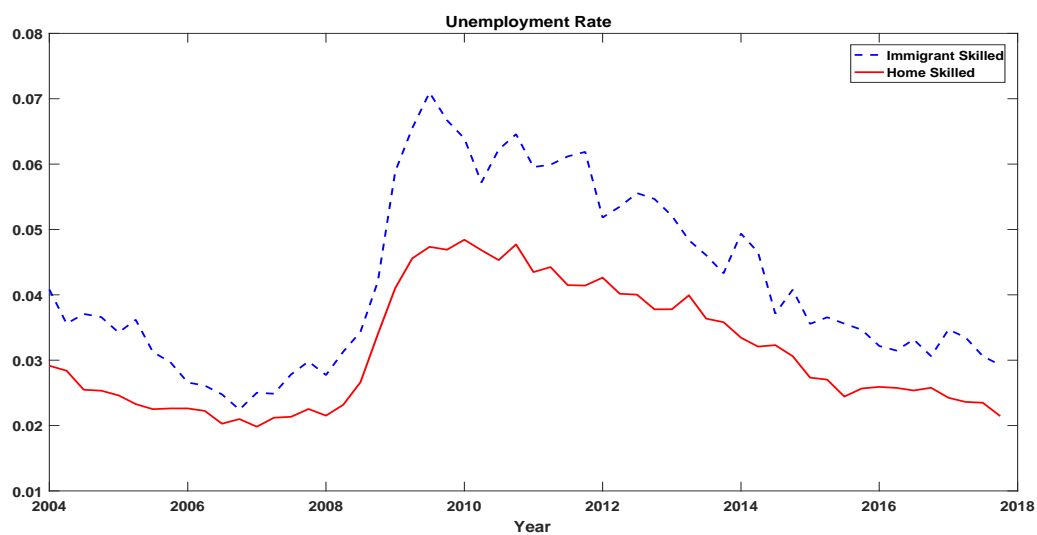


Figure C.4: U.S. Skilled Unemployment Rates by Nativity 2004-2017

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

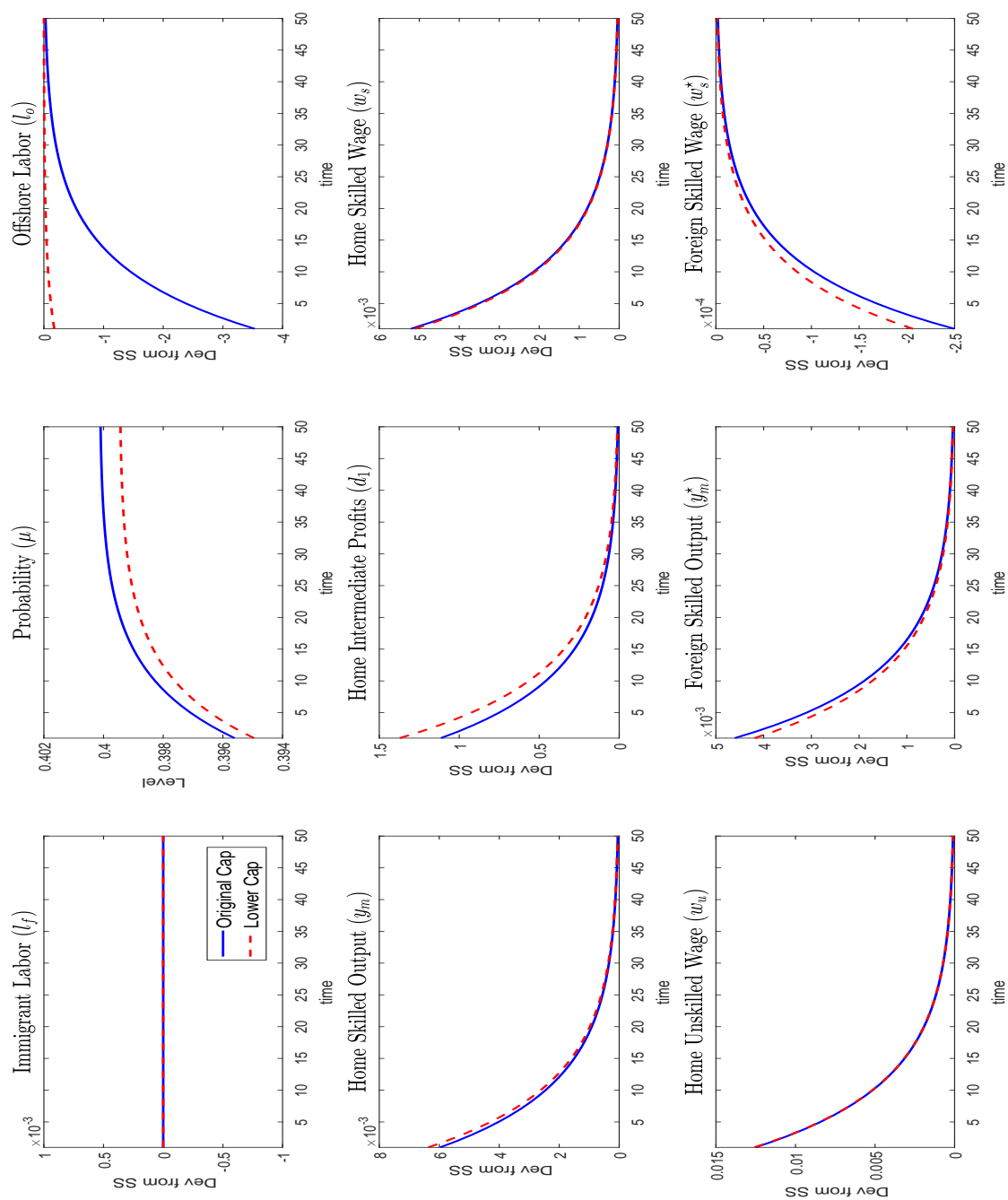


Figure C.5: Response to a 1 Standard Deviation Increase in Home Productivity in Baseline Model versus Lower Cap

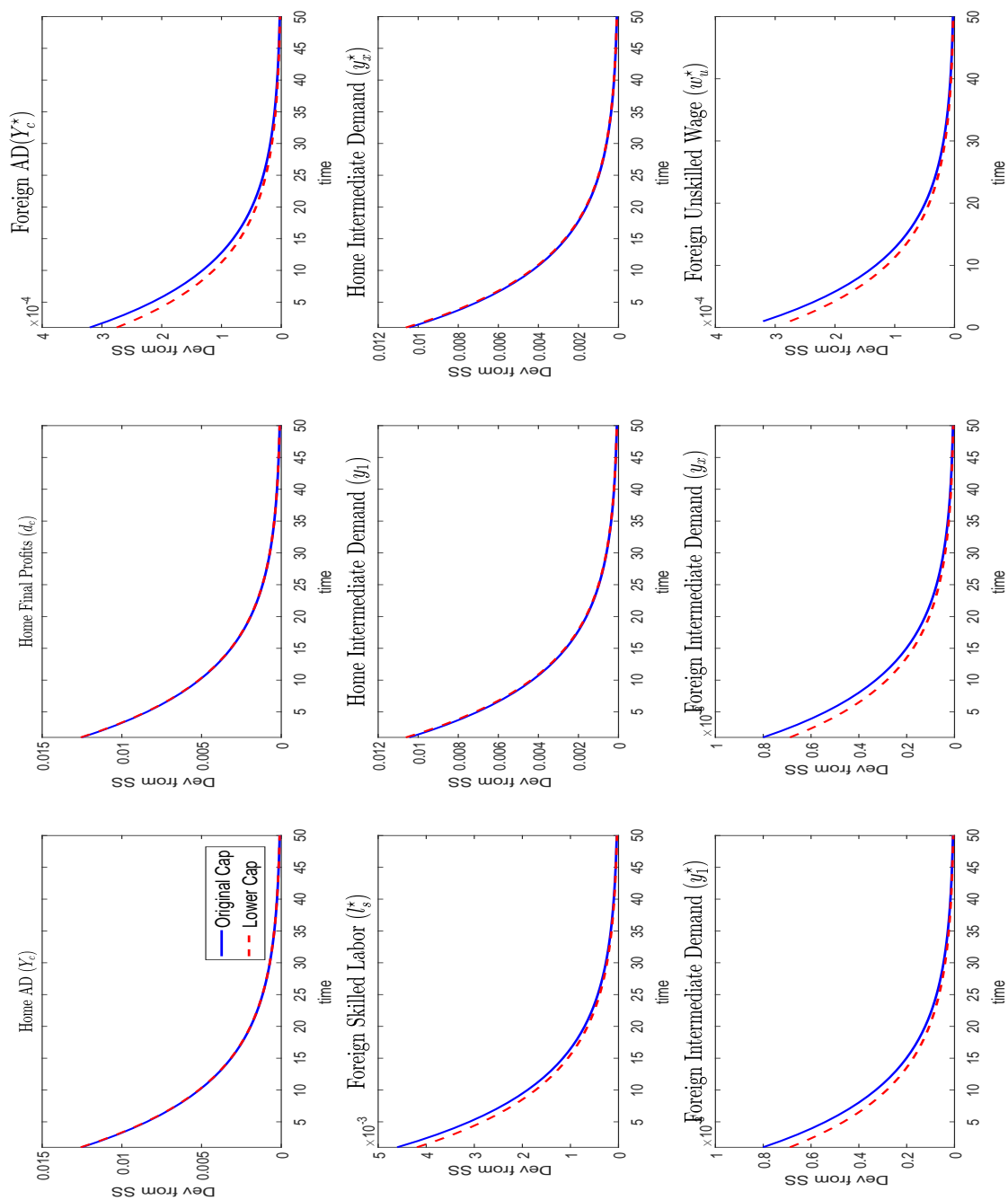


Figure C.6: Response to a 1 Standard Deviation Increase in Home Productivity in Baseline Model versus Lower Cap

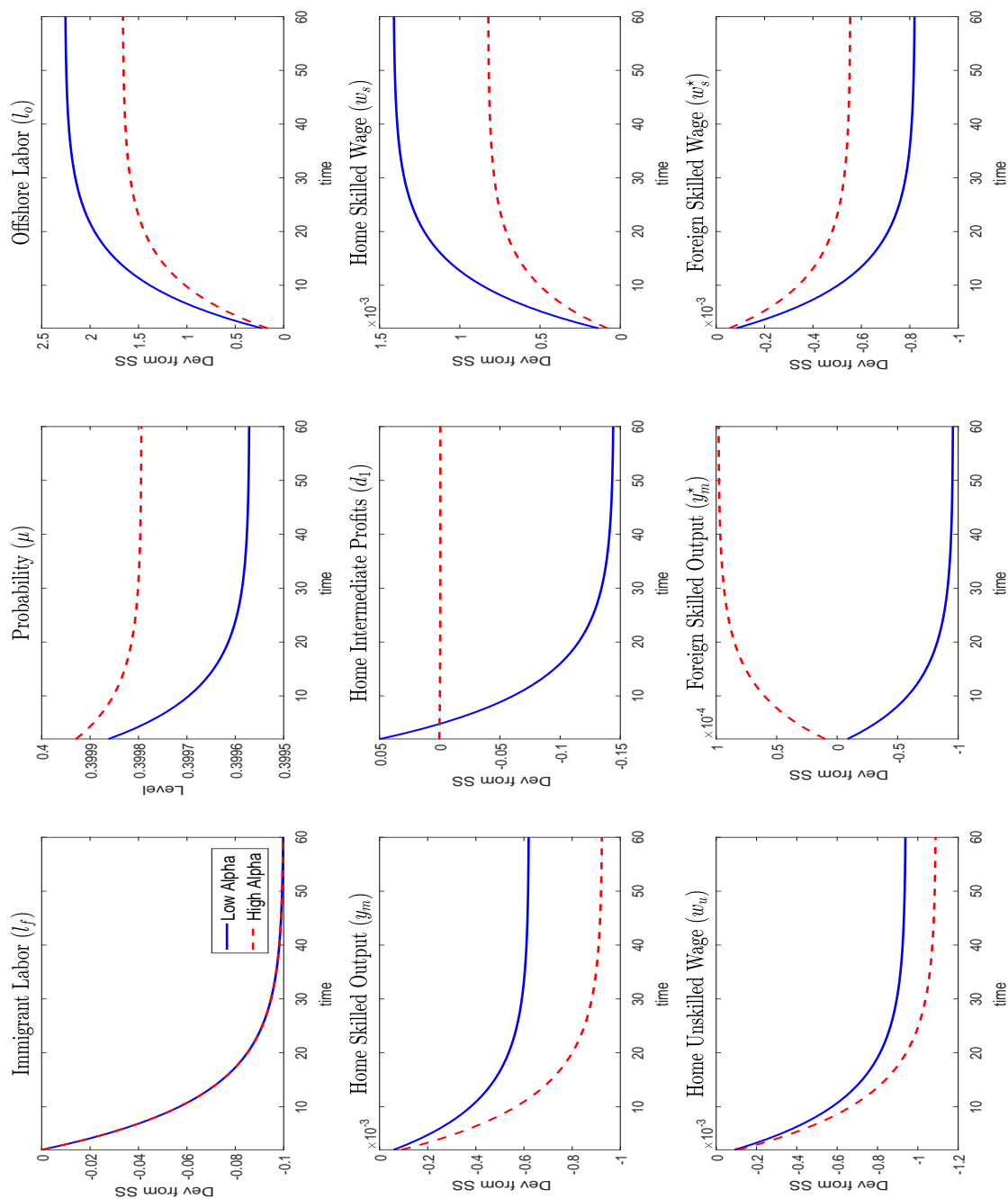


Figure C.7: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus Higher Alpha

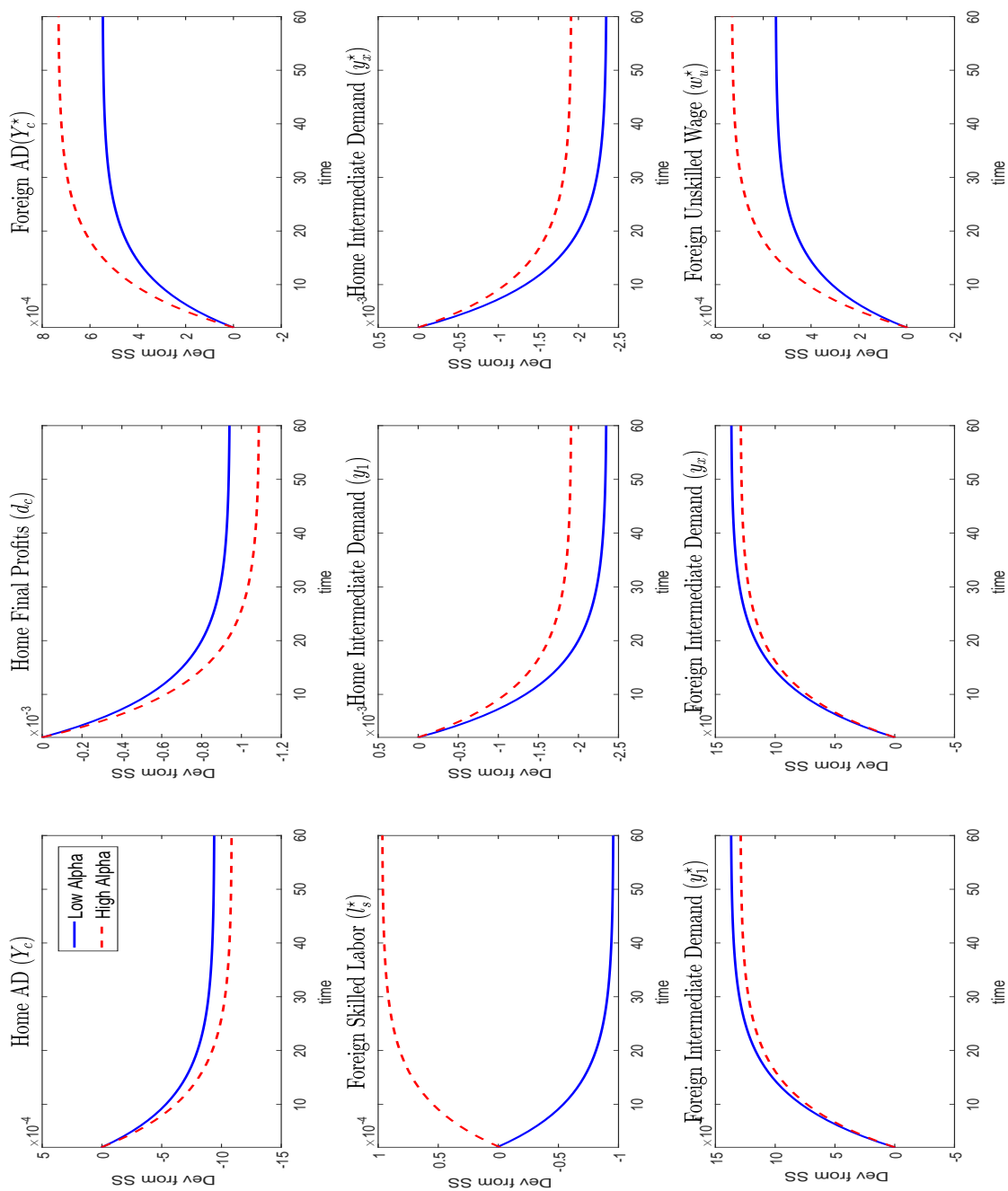


Figure C.8: Response to a 10 Percent Immigration Cap Reduction in Baseline Model versus Higher Alpha