Globalization, Monetary Policy and Labor Market Dynamics

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Boston College Electronic Thesis or Dissertation, 2016

GLOBALIZATION, MONETARY POLICY AND LABOR MARKET DYNAMICS

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A Dissertation

submitted to the Faculty of

the department of Economics

in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

Boston College

Morrissey College of Arts and Sciences

Graduate School

April, 2016

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This dissertation consists of three essays that examine macroeconomic implications of trade liberalization. There has been a long-lasting debate on how trade openness influences the effectiveness of monetary policy. The first two essays provide a novel empirical and theoretical investigation into this issue. Motivated by recent new phenomena in U.S. labor market, the third essay is a work in progress that seeks to explore the evolution of U.S. manufacturing employment structural dynamics, and its connection with import competition.

The first essay uses annual data of US manufacturing industries at 4-digit SIC level from 1972 to 2005 to conduct the empirical analysis. It shows that trade openness is negatively associated with industry-level effect of monetary policy, and at a given degree of trade openness, industries that involve in offshoring don't necessarily exhibit weaker responses. These empirical findings are hard to reconcile with the implications of standard open economy New Keynesian model, which indicates that trade openness strengthens the effectiveness of monetary policy and doesn't model offshoring separately.

The second essay provides a new open economy New Keynesian model that can explain the empirical findings in the first essay. The model features endogenously

determined international trade pattern based on Ricardian trade theory, and one-way offshoring from the advance economy to the less developed one. This model highlights a new channel through which trade openness influences the monetary transmission mechanism: a decline in both trade and offshoring costs raises labor demand elasticity. Trade openness weakens the effects of monetary policy changes on output and inflation by dampening the responses of the domestic labor market. The calibrated model indicates that, when the economy moves from trade and financial autarky to a modern trade regime with an incomplete international financial market, the monetary policy shocks have 22% less of an effect on real GDP and consumer price inflation.

The third essay provides the motivation on why to explore the evolution of U.S. manufacturing employment structural dynamics, introduces the methodology, and describes the dataset as well as future works.

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Acknowledgments

I am grateful to my doctoral advisor, Peter Ireland, who has been an excellent professional role model. His advice and encouragement have enormously influenced my personal development, which includes but goes far beyond this dissertation. I am also deeply grateful to Zhijie Xiao, who has given me guidance and support since before the graduate school. I thank him for constantly sharing research experience, and also for his kindness. I appreciate Fabio Schiantarelli and Jaromir Nosal for their advice along the way. Lastly, I would mention that I benefit a lot from the valuable comments from my peers in the economics department.

To my parents, for their love, support and patience!

CHAPTER 1

Trade Liberalization and Effectiveness of Monetary Policy: Industry-Level Evidence

1. Introduction

The monetary transmission mechanism is one of the most studied topics in monetary economics. It describes how the monetary policy induced changes in money stock or federal funds rate influence real economic activities and inflation. Recent empirical literature indicates that the monetary policy transmission mechanism in the US has changed. The monetary policy disturbances have had a weaker effect on output and inflation after 1980 when compared to the effects before 1980 (see Boivin, Kiley, and Mishkin (2010) and the references therein). The literature has investigated the sources of this evolution of monetary transmission mechanism. Boivin and Giannoni (2006) and Clarida, Galí, and Gertler (2000) attribute this to the shift in the systematic component of monetary policy.[1], while having witnessed the striking growth in trade during 1972 to 2005, many have asked whether globalization can be an important factor that stabilizes the responses of output and inflation to monetary

[1] Boivin and Giannoni (2006) and Clarida et al. (2000) shows that US economy has entered a new monetary policy regime in post 1980s, where the interest rule is more sensitive to inflation fluctuations. Since the new rule induces a greater procyclical movement of real interest rate, it's more stabilizing. The literature also relates the changed monetary transmission mechanism to the decline in the volatility of unemployment rate and inflation in US economy since 1980, which are together referred to as Great Moderation. The evolution of monetary transmission mechanism has induced recent literature another major explanation is the time varying structural disturbance variances, e.g. Sims and Zha (2006) and Primiceri (2005)

disturbances.[2] Since the latter argument still lacks explicit empirical evidence, this paper contributes to the literature in this direction.

This paper investigates the relationship of trade openness and the industry-level effect of monetary policy. A large literature has studies the connection of trade openness and the advanced economy's labor market outcomes, and recently an increasing number of empirical studies have found that trade liberalization - especially the import competition from low wage countries - has significant effect on the employment and labor wages in the advanced economies.[3] Given the important role of labor market outcomes in determining output and inflation dynamics,[4] a trade liberalization induced structural change in the labor market can potentially alter the monetary transmission mechanism.

A significant feature of recent wave of trade liberalization is the increased global production network. Due to revolutionary advances of transportation and communication technology, intermediate products can be moved quickly and cheaply across

[2]Share of import in GDP has increased from 5% to 15.5% in US during this period. Rogoff (2003) is one of the first to argue the disinflationary effect of globalization: Since the globalization raises market competition and leads to greater goods and labor mobility, it reduces the inflation-output tradeoff. Central bank engage less in creating inflation surprise, leading to a lower equilibrium inflation. In contrast, Ball (2006) argues that globalization has little impact on inflation dynamics, and questions Rogoff (2003)s argument by showing the inflation-output tradeoff has increased with the globalization process. There's still no consensus on the connection of trade openness and the effectives of monetary policy.

[3]Empirical literature shows that increase in offshoring activities raises the demand elasticity of unskilled labor in US, e.g. Senses (2010), aggravates income inequality in U.S Feenstra and Hanson (1999), reduces manufacturing employment in U.S. Acemoglu, Autor, Dorn, Hanson, and Price (2016), and increases job displacement in Germany, e.g. Geishecker (2008).

[4]Labor market outcome is important for output since payment to labor accounts for over 50% of value added output. Labor market outcomes is important for inflation dynamics since modern macro theory indicates that prices are set at constant markup over real marginal cost and the payment to labor is the largest component of real marginal cost.

borders, and the output of many production processes can be monitored electronically, facilitating firms in advanced economies to offshoring labor intensive production, or routine service jobs to low-wage countries. Hence, in addition to the standard trade openness measure, this paper uses offshoring as an alternative measure of trade openness, and examines how industries' offshoring status influences the industry-level effect of monetary policy.

The empirical analysis uses annual data of US manufacturing industries at 4-digit SIC level from 1972 to 2005. It begins with an estimation of sectoral vector auto-regressions (VARs) that contain common and industry specific variables. The model is specified so that the identified monetary policy shocks are identical across industries, while the shock response functions can vary freely across industries. The monetary policy shock is identified using the standard recursive identification scheme following Sims (1980). The next step is to examine the relationship between the impulse response functions of manufacturing industries' output and the trade openness measures using heteroscedasticity-robust regression.

The cross section analysis reveals that the trade openness measures are negatively associated with the effect of monetary policy on industry-level output, and at given degree of trade openness, industries that involve in offshoring don't necessarily exhibit weaker responses to monetary policy changes. To the best of my knowledge, this result is new in the literature, and imposes a challenge to the quantitative implications of existing open economy New Keynesian models, i.e. Clarida, Galí, and Gertler (2002) and Galí and Monacelli (2005). With standard calibration choices or estimated parameter values, these models indicate little or positive connection of trade openness and effects of monetary policy changes, and they don't distinguish offshoring from rest of the international trade activities.

This paper is related to at least three strands of literature. Firstly, the empirical analysis is closely connected to Dedola and Lippi (2005) and Peersman and Smets (2005), which explore how industry characteristics influence diverse industry-level responses to monetary policy. The first paper focuses on twenty industries in five OCED countries, and finds industry-level effect of monetary policy is systematically affected by industry's output durability, borrowing capacity measures, and financing requirement measures. The second paper studies the effect of monetary policy of eleven industries of seven euro-area countries, and shows an important role of industries' financial structure, in particularly average firm size and financial leverage ratio, in determining business cycle asymmetry in industry-level effect of monetary policy. Different from the existing literature, this paper investigates the relationship of industry-level trade openness measures and the industry-level effect of monetary policy in U.S.

Secondly, this paper is connected with the earlier empirical literature that explores how trade openness influences inflation. Romer (1993) provides cross-country evidence on the negative relationship between trade openness and inflation level, and argues that trade openness reduces sacrifice ratio based on time-inconsistency model of Barro and Gordon (1983). Daniels, Nourzad, and Vanhoose (2005) and Badinger (2009) find that, once central independence is controlled for, trade openness raises sacrifice ratio, and uses New Keynesian framework to reconcile this finding and the negative relationship between trade openness and inflation level. These empirical findings focus solely on the relationship between inflation level and trade (or financial) openness, instead of the connection of trade openness and the responsiveness of inflation as well as output. Guerrieri et al. (2010) estimate a New Keynesian Philips Curve (NKPC henceforth) based on a New Keynesian model that features variable demand elasticity, they find that foreign competition is quantitatively important in explaining U.S. traded goods' inflation dynamics. Empirical works by Monacelli and Sala (2009) and Bianchi and Civelli (2015) show that international factors can affect inflation dynamics in many countries.

Thirdly, the empirical findings in this paper is related to the implications of existing open economy New Keynesian model. Woodford (2007), based on Clarida et al. (2002), examines several channels through which trade and financial openness can potentially affect monetary transmission mechanism, and finds little evidence for openness to be the causes of weaker effect of monetary policy shocks. Milani (2012) estimates a small open economy version of Clarida et al. (2002) and finds little effects of degree of openness on transmission of monetary policy shock. Cwik, Mller, and Wolters (2011) estimate a model which features none constant demand elasticity following Gust et al. (2010). The producers' mark-up vary with real exchange rate and there is strategic complementarity of exporters' price setting. They find greater openness leads to more effective monetary policy.

2. Econometric Model

This section provides empirical evidence on the role of trade openness in determining the effects of monetary policy changes on manufacturing industry-level output. I measure the industry-level output using total value added from the NBER-CES

Manufacturing Industry Database, which provides annual data for 459 industries at the 4-digit SIC level from 1958 to 2009. The sample period in this paper is from 1972 to 2005. The following analysis uses two openness measures, import penetration ratio following Bernard, Jensen, and Schott (2006) and the measure of offshoring following Senses (2010) and Schott (2004). Both measures are constructed using data from NBER International Finance and Trade Data. The details of constructing offshoring measure are given in the Appendix A.7.

The summary statistics of the openness measures are given in Table 1.1. The average import penetration ratio is 0.163 and the average offshoring measure is 0.044. These two measures are dispersed across industries. The standard deviation of the import penetration ratio is 0.175, and the the standard deviation of the offshoring measure is 0.101. Figure 1.1 plots the cross industry average of the two openness measures from 1972 to 2005. The import penetration ratio has increased from 0.059 to 0.29 and the offshoring measure has almost tripled.

2.1. Panel VAR Model. The effects of monetary policy shocks on manufacturing industry-level output are estimated using structural autoregression models. Let

$$X_t = [Y_t, \pi_t, R_t, Y_{i,t}]' \tag{2.1}$$

be a vector that contains time t value of real GDP, Y_t, PCE inflation, π_t,[5] Federal Funds Rate, R_t, total value added of industry i deflated using GDP deflator, $Y_{i,t}$.

[5]As a part of the robustness check, I tried to use GDP deflator inflation or the combination of GDP deflator inflation and commodity price instead of the benchmark specification. The results are qualitatively not affected. An advantage of using PCE inflation is that it does not generate price puzzle.

Variables are annual from 1972 to 2005. Real GDP and industry-level output are in log levels, PCE inflation is the difference of two consecutive log levels of the PEC index and the Federal Funds Rate is in percentage levels. Assume that X_t has a moving average representation, which is given by

$$X_t = \alpha + A(l)\epsilon_t, \qquad A(0) = A_0 \tag{2.2}$$

where α is a 4×1 vector of constant terms, and $A(l)$ is a 4×4 matrix, which is an infinite order matrix lag polynomial. $\epsilon_t = [\epsilon_Y, \epsilon_\pi, \epsilon_R, \epsilon_{Y_i}]$ is a vector of structural disturbances. The elements of ϵ_t are three common shocks, aggregate output shock, ϵ_Y, inflation shock, ϵ_π and the monetary policy shock, ϵ_R, and an industry-level shock, ϵ_{Y_i}. These shocks are mutually uncorrelated, and follow normal distribution with zero mean and

$$E[\epsilon_t \epsilon_t'] \equiv \Sigma \tag{2.3}$$

where Σ is a 4×4 matrix in which the variance of structural disturbances are along its diagonal and the zeros are elsewhere.

The estimated reduced form vector autoregression model that is associated with equation 2.2 and 2.3 is given by

$$X_t = \beta + B(l)\mu_t, \qquad B(0) = I \quad \text{and} \quad E[\mu\mu'] = \Omega \tag{2.4}$$

where β is a 4×1 vector of constant terms, and $B(l)$ is a 4×4 matrix, which is an infinite order matrix lag polynomial, and can be recovered from the estimated coefficients of the VAR representation of X_t. μ_t is a vector of reduced form innovation terms.

The reduced form VAR is estimated with restrictions on B,[6] which are given by

$$b_{i,j}(l) = 0, \qquad i \in \{1,2,3\} \quad \text{and} \quad j = 4 \quad \text{for all } l \tag{2.5}$$

where $b_{i,j}(l)$ is the element at row i and column j at lag l of B. These restrictions rule out the possibility for industry-level output to affect variables in the common subsystem. This specification assumes that the identified monetary policy shocks are common across manufacturing industries. At the same time, the last row of B can vary freely across industries. In the next step, these heterogeneous responses of industry-level output can be related to industry-level openness measures.

A comparison of equations 2.2, 2.3 and 2.4 indicates that $\mu_t = A_0\epsilon_t$, $\alpha = \beta$, and $A(l) = B(l)A_0$, so that the matrix A_0 provides the link between structural and reduced form VAR models. The standard recursive identification scheme is adopted to get matrix A_0, following Sims (1980). Cholesky decomposition of the covariance matrix of the innovations from reduced from model, Ω, provides the lower triangular matrix A_0, which satisfies $A_0 \Sigma A_0' = \Omega$. With variables in order shown in equation 2.1, when the third element is interpreted as monetary policy shock, the identification scheme assumes that monetary policy responds to aggregate output and inflation contemporaneously, and industry-level output has no effect on monetary policy.

[6] Davis and Haltiwanger (2001) also placed restrictions on the reduced form VAR to get common shocks, but their focus is effect of oil shock's on manufacturing jobs. I estimated the VAR model without restrictions as the robustness check, and results are not qualitatively affected.

Since the recursive identification scheme gives the exactly identified structural model, equation 2.2, I can use it to compute the impulse responses of the industry-level output to identified expansionary monetary policy shock. Two measures are chosen for the industry-level impulse responses, 1) the maximum elasticity, $\hat{Y}_{i,M}$, and 2) the average first three-year elasticity, $\hat{Y}_{i,A}$.[7] The summary statistics of these two elasticities are given in Table 1.1. The mean of the maximum elasticity, $\hat{Y}_{i,M}$, is 2.045, and the mean of the three year average elasticity, $\hat{Y}_{i,A}$, is 0.745. The three-year average elasticities vary within a wide range, from -14.959 to 10.519, and their standard deviation is at 2.362. The maximum elasticities are also dispersed across industries, ranging from -2.571 to 11.917, and their standard deviation is at 2.311.

2.2. Cross-Section Regression. In the regression analysis that follows, I estimate:

$$\hat{Y}_{i,j} = c + \gamma_1 \text{Openness Measures}_i + \eta_i \qquad j \in \{A, M\} \tag{2.6}$$

where $\hat{Y}_{i,e}$ is the industry i's output elasticity and c is a constant term. Openness Measures in this paper are the industry-level import penetration ratio, and the offshoring measure is used as robustness check. These two measures are entered one at a time in the regression model, equation 2.6. To examine whether the relationship between industry-level output elasticity and trade openness is affected by industry's

[7]The average of first three year elasticity is the average 2nd to 4th impulse responses. Including the 1st impulse response into this average elasticity measure doesn't affect the result.

involving in offshoring activities or not, I also estimate:

$$\hat{Y}_{i,j} = c + \gamma_2 \text{Import Penetration}_i + \gamma_3 \text{Offshoring Dummy}_i$$
$$\gamma_4 \text{Import Penetration}_i \times \text{Offshoring Dummy}_i + \xi_i \quad j \in \{A, M\} \quad (2.7)$$

where the offshoring dummy of industry i takes the value 1 if industry i imports non-energy intermediate inputs. I use offshoring dummy instead of value-added offshoring in order to avoid the multi-collinearity problem. I estimate both regression models with 2 digit SIC level industry dummies, in order to control industry-specific factors that may affect how industry-level output react to monetary policy shocks, e.g. industry specific financial characteristics. The regression uses heteroscedasticity robust standard error.

3. Empirical Results

Table 1.2 presents the regression results. According to the estimated results from equation 2.6, the trade openness -measured by import penetration ratio or offshoring- is negatively associated with the industry-level output elasticities. These results are highly significant, and they are not affected by whether or not the industry dummies are included. The coefficient of the import penetration ratio for the maximum elasticity regression with industry dummies indicates that when import penetration increase by 10%, the peak of impulse responses of industry-level output will be lowered by 0.18. This corresponds to a 9% decrease in industry-level output maximum elasticities from their mean level. Using offshoring measure, the estimated effect is larger. A 10% increase in offshoring is associated with a 15.78% decrease in industry-level output maximum elasticities from their mean level. The estimated results from the three-year average elasticities with industry dummies are striking. Using import penetration and offshoring as openness measures indicates respectively 41.2% and 24.2% decrease in three year average elasticities from their mean levels.

The estimation results of equation 2.7 reveal a negative and significant relationship between import penetration and industry-level output elasticities. Yet, whether output elasticities of industries that import non-energy intermediate inputs are more severely affected by trade openness is ambiguous: The coefficients in front of the import penetration and offshoring dummy interaction terms in maximum elasticity regressions as well as those coefficients in the three-year average elasticity regression without industry dummies are negative but not highly significant, and the coefficients of the interaction term in the three-year average elasticity regression with industry dummies is positive and not significance. The coefficients in front of offshoring dummy are all positive and not significant, implying that given import penetration ratio at its mean level, switching from non-offshoring to offshoring magnifies the effect of monetary policy on industry-level output.

A possible explanation for the negative relationship of trade openness and industry-level effect of monetary policy involves two channels: the demand spillover channel and the labor demand elasticity channel. Greater trade openness strengthens the linkage of domestic consumption and foreign production, which leads to a greater demand spillover effect. The greater trade openness, which is associated with a lower trade friction, provides producers a greater ease to substitute between domestic and foreign produced goods, driving up labor demand elasticity. Under greater trade openness regime, a given monetary expansion has a weaker stimulative effect on domestic labor demand, and due to the increased labor demand elasticity, a given increase in labor demand raises labor wage by less. Hence, under greater trade openness, a given monetary expansion has a weaker effect on domestic output and inflation. The intuition for the ambiguous effect of offshoring on the relationship of trade openness and industry-level effect of monetary policy can be related to the offshoring induced productivity effect, which strengthens the comparative advantage of domestic produces and offsets the effect of trade openness on labor demand elasticity and demand spillover.

4. Robustness with Evidence on Price

This section examines whether the findings on the relationship of trade openness and the effect of monetary policy on industry-level output hold, when the vector of variables in equation 2.1 is augmented with industry-level prices. The measure of industry-level prices is the deflator of total value of shipment. This alternative specification also provides evidence on the relationship of trade openness and the effect of monetary policy on industry-level prices.

The estimation procedure is the same as that is used to estimate the baseline specification. The first step is to estimate the restricted VAR model for all the industries, in the sense that the industry-level output and price measures have no effect on aggregate variables, while aggregate variables have contemporaneous effect on industry-level output and price measures. The second step is to regress the elasticities of industry-level output and price with respect to monetary policy shocks on the industry-level trade openness measures. The summary statistics of variables that are used in second stage regression are given in Table 1.3, and the results are given in Table 1.4 and 1.5.

Table 1.4 indicates that the qualitative results of the baseline specification still holds for the alternative specification: trade openness weakens the effect of monetary policy on industry-level output, and at given degree of trade openness, offshoring has an ambiguous effect on industry-level effect of monetary policy. As for the relationship of trade openness and the effect of monetary policy on industry-level prices, Table 1.5 provides a less clear result. Although the coefficients in front of offshoring are all negative and some are highly significant, some coefficients in front of the import penetration measures are positive. A possible reason for this ambiguous effect is that, when trade openness promotes product market competition, which lowers the markup of the monopolistic pricing, it strengthens the responsiveness of industry-level prices to monetary policy induced demand changes. This effect offsets the effect associated with increased demand spillover and strengthened factor market competition, which stabilizes the marginal costs' responsiveness to monetary policy induced demand changes.

5. Conclusion

This paper provides a novel empirical evidence on how trade openness and industries' offshoring status influence the industry-level effect of monetary policy. This empirical evidence challenges the standard open economy New Keynesian model's implication for how trade openness is associated with the effectiveness of monetary policy, which suggests that more research can be done in this direction.

One caveat of this paper is that the industry-level output and price measures are annual-level, which leads the estimated elasticities of these two measures with respect to monetary policy shocks imprecise. The current result holds under the assumption that measurement errors are independently associated with trade openness measures. Data with higher frequency are desirable to validate the findings in this paper.

TABLE 1.1. Summary Statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Import Penetration Ratio	0.163	0.175	0	0.864
Offshoring	0.044	0.101	0	0.889
Offshoring Dummy	0.432	0.496	0	1
Maximum Elasticity	2.045	2.311	-2.571	11.917
Three Year Average Elasticity	0.745	2.362	-14.959	10.519
Number of Observations		417		

Note: Summary statistics of variables in baseline regressions.

FIGURE 1.1. Openness Measures.

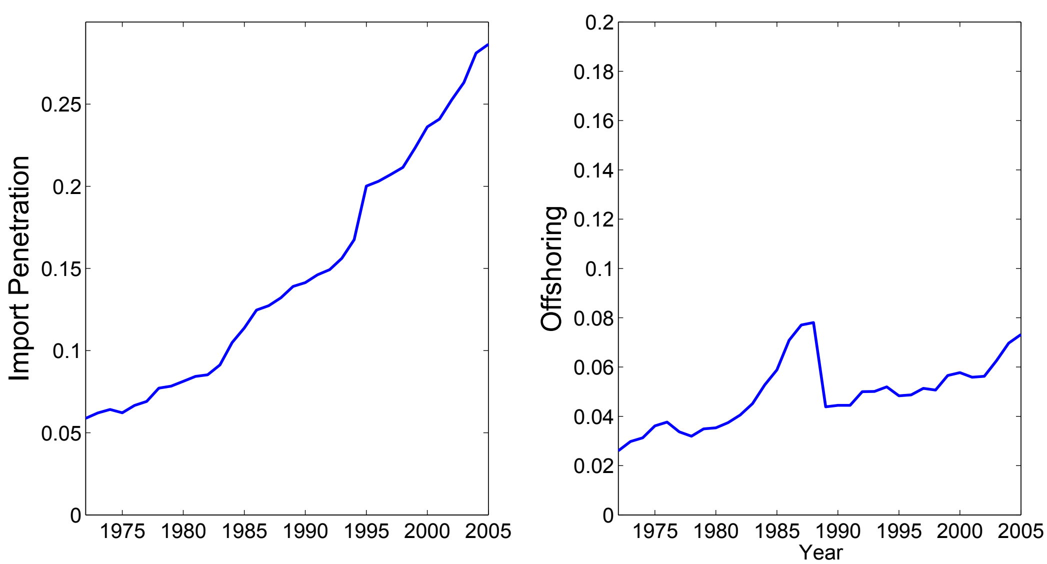


TABLE 1.2. Openness and Industry-Level Effect of Monetary Policy

	Maximum Elasticity						Average Elasticity					
	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$
Import Penetration	-2.756***		-1.833*	-1.800**		-1.014	-3.572***		-3.971***	-3.126***		-3.572***
	(0.629)		(1.006)	(0.754)		(0.992)	(0.575)		(0.777)	(0.746)		(0.885)
Offshoring		-3.116***			-3.225***			-2.340***			-1.801*	
		(0.790)			(1.032)			(0.733)			(1.067)	
Offshoring Dummy			0.527			0.299			0.475			0.309
			(0.334)			(0.341)			(0.348)			(0.389)
Import Penetration×Offshoring Dummy			-2.290*			-1.730			-0.0179			0.589
			(1.383)			(1.303)			(1.212)			(1.280)
Industry Dummies				yes	yes	yes				yes	yes	yes
R^2	0.044	0.018	0.051	0.303	0.304	0.307	0.070	0.010	0.079	0.267	0.234	0.272

Note: This table reports the heteroscedasticity robust regression results of regressing the industry-level output elasticities on the openness measures for the baseline specification. Import Penetration Ratio is measured as the (sum of Imports over the sample period) / (the sum of Shipments-Exports+Imports over the sample period). $\hat{Y}_M$ stands for the maximum elasticity. $\hat{Y}_A$ stands for the average of impulse response of first three years. Standard deviation is in parentheses. Offshoring is measured as the sum of Intermediate Imports over sample period / the sum Material Cost over sample period. The Offshoring Dummy is 1, if the industry participates in offshoring activities. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 1.3. Summary Statistics: Robustness

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Import Penetration Ratio	0.163	0.175	0	0.864
Offshoring	0.044	0.101	0	0.889
Offshoring Dummy	0.432	0.496	0	1
Maximum Elasticity of Output	2.045	2.311	-2.571	11.917
Three Year Average Elasticity of Output	0.745	2.362	-14.959	10.519
Maximum Elasticity of Price	0.502	0.876	-1.801	6.135
Three Year Average Elasticity of Price	-0.944	0.917	-5.038	4.68
Number of Observations		383		

Note: Summary statistics of variables in robustness check regressions.

TABLE 1.4. Openness and Industry-Level Effect of Monetary Policy: Robustness I

	Average Elasticity Maximum							Elasticity				
	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_A$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$	$\hat{Y}_M$
Import Penetration	-3.109*** (0.598)		-3.841*** (0.726)	-3.198*** (0.743)		-3.842*** (0.917)	-2.044*** (0.619)		-1.604* (0.892)	-1.723** (0.739)		-1.115 (1.009)
Offshoring		-1.838** (0.749)			-1.705 (1.094)			-2.260*** (0.800)			-2.809*** (1.025)	
Offshoring Dummy			0.564 (0.371)			0.454 (0.439)			0.636* (0.360)			0.390 (0.365)
Import Penetration×Offshoring Dummy			0.390 (1.250)			0.780 (1.423)			-1.681 (1.359)			-1.487 (1.372)
Industry Dummies				yes	yes	yes				yes	yes	yes
R^2	0.051	0.006	0.067	0.248	0.213	0.256	0.025	0.011	0.033	0.260	0.258	0.263

Note: This table reports the heteroscedasticity robust regression results of regressing the industry-level output elasticities on the openness measures for the alternative specification in Robustness section. Import Penetration Ratio is measured as the (sum of Imports over the sample period) / (the sum of Shipments-Exports+Imports over the sample period). $\hat{Y}_M$ stands for the maximum elasticity. $\hat{Y}_A$ stands for the average of impulse response of first three years. Standard deviation is in parentheses. Offshoring is measured as the sum of Intermediate Imports over sample period / the sum Material Cost over sample period. The Offshoring Dummy is 1, if the industry participates in offshoring activities. * p<0.10, ** p<0.05, *** p<0.01

TABLE 1.5. Openness and Industry-Level Effect of Monetary Policy: Robustness II

	Average Elasticity						Maximum Elasticity					
	$\hat{P}_A$	$\hat{P}_A$	$\hat{P}_A$	$\hat{P}_A$	$\hat{P}_A$	$\hat{P}_A$	$\hat{P}_M$	$\hat{P}_M$	$\hat{P}_M$	$\hat{P}_M$	$\hat{P}_M$	$\hat{P}_M$
Import Penetration	-0.169 (0.244)		0.0222 (0.360)	-0.495* (0.279)		-0.527 (0.491)	-0.397 (0.242)		0.0312 (0.309)	-0.169 (0.275)		0.0144 (0.454)
Offshoring		-0.428 (0.344)			-0.740* (0.384)			-0.734** (0.315)			-0.381 (0.410)	
Offshoring Dummy			0.259* (0.134)			-0.0442 (0.113)			-0.0355 (0.118)			-0.00359 (0.110)
Import Penetration × Offshoring Dummy			-0.703 (0.503)			0.0994 (0.576)			-0.665 (0.489)			-0.337 (0.569)
Industry Dummies				yes	yes	yes				yes	yes	yes
R^2	0.001	0.002	0.010	0.224	0.222	0.224	0.006	0.007	0.017	0.172	0.173	0.173

Note: This table reports the heteroscedasticity robust regression results of regressing the industry-level output elasticities on the openness measures for the alternative specification in Robustness section. Import Penetration Ratio is measured as the (sum of Imports over the sample period) / (the sum of Shipments-Exports+Imports over the sample period). $\hat{Y}_M$ stands for the maximum elasticity. $\hat{Y}_A$ stands for the average of impulse response of first three years. Standard deviation is in parentheses. Offshoring is measured as the sum of Intermediate Imports over sample period / the sum Material Cost over sample period. The Offshoring Dummy is 1, if the industry participates in offshoring activities. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

CHAPTER 2

Globalization, Offshoring and Monetary Control

1. Introduction

Recent empirical evidence reveals that monetary transmission mechanism has changed: output and inflation in the U.S. economy exhibit weaker responses to identified monetary policy changes in post 1980 than they did in pre 1980. The first chapter in this dissertation finds that trade openness can weaken the effectiveness of monetary policy. In addition, motivated by the recent boom of offshoring activities, it explores how industry's offshoring status influence its output responsiveness to monetary policy changes, and shows that at a given degree of trade openness, industries that involve in offshoring don't necessarily exhibit weaker responses to monetary policy changes.

These findings are hard to reconcile with the quantitative implications of existing open economy New Keynesian models, i.e. Clarida, Galí, and Gertler (2002) and Galí and Monacelli (2005). With standard calibration choices or estimated parameter values, these models indicate little negative connection of trade openness and effects of monetary policy changes.[1] In addition, existing open economy New Keynesian models

[1] Woodford (2007), based on Clarida et al. (2002), examines several channels through which trade and financial openness can potentially affect monetary transmission mechanism, and finds little evidence for openness to be the causes of weaker effect of monetary policy shocks. Milani (2012) estimates a small open economy version of Clarida et al. (2002) and finds little effects of degree of openness on transmission of monetary policy shock. Cwik, Mller, and Wolters (2011) estimate a model which features none constant demand elasticity following Gust et al. (2010). The producers' mark-up vary

characterize trade openness using the home bias parameter in consumer preference or the parameter that determines the share of imported inputs in production. Despite its indisputable merits, this specification confounds the changes in preference or technology with the real causes of trade openness, and thereby limits the model's ability to evaluate the effects of offshoring activities and growth in general imports separately.

The contribution of this paper is to provide a New Keynesian open economy stochastic dynamic general equilibrium model that features one-way offshoring from an advanced economy to a less developed economy. This model is based on the static model in Rodrguez-Clare (2010). The model features tradable-goods' producers with heterogeneous technology in both countries, and the trade pattern is determined by the Ricardian trade theory, following Eaton and Kortum (2002). The tradable-goods' producers in the advanced economy have a higher average technology level than their counterparts do in the less developed economy. This generates a wage gap between the two countries, thereby providing the advanced economy's tradable-goods' producers an incentive to offshore a fraction of the production process to the less developed economy. In the baseline model, the international financial market is incomplete, in the sense that two countries trade risk-free nominal bonds. Since the international financial market structure crucially determines the relationship of real exchange rate and macro fundamentals,[2] an alternative structure - Financial Autarky -

with real exchange rate and there is strategic complementarity of exporters' price setting, They find greater openness leads to more effective monetary policy.

[2]Under financial autarky, the real exchange rate is pinned down by the trade balance condition, and under incomplete international financial market, it's governed by the Uncovered Interest Rate Parity condition.

is also considered. The calibrated baseline model shows that when the economy moves from trade autarky to a trade regime, in which import to GDP ratio and offshoring to import ratio are at 2005 levels, the effects of monetary policy shock on real GDP and inflation are lowered by 15%. When the trade liberalization process is accompanied by the international financial market moving from autarky to the incomplete market case, the effects of monetary policy shock on real GDP and inflation are lowered by 22%.

The quantitative model highlights three channels through which trade openness affects the monetary transmission mechanism. Greater trade openness increases the exposure of consumer price to foreign production cost, which is the composition effect.[3] Greater trade openness strengthens the linkage of domestic consumption and foreign production, which is the demand spillover effect. These two channels have been extensively studied in the existing literature. Increasing general imports and offshoring activities magnifies the effects of both channels. The third channel relies on the fact that greater trade openness raises labor demand elasticity (see Senses (2010)), which has not been explored in the literature that focuses on the connection of trade openness and monetary transmission mechanism. Decline in trade cost boosts general imports and promotes product market competition, raising labor demand elasticity. Decline in offshoring cost increases the chance to substitute domestic labor with imported goods and services, while reducing the production cost of domestic tradable-goods' producers. This strengthens their comparative advantage, which

[3]It is a common feature of open economy New Keynesian Phillips Curve that greater trade openness strengthens the connection of CPI inflation and foreign factors (foreign slackness or imported goods' prices), e.g. Benigno and Faia (2010), Razin and Loungani (2005), Sbordone (2008) and Guerrieri et al. (2010).

in turn increases the demand of domestic labor and reduces labor demand elasticity. The latter is reminiscent of the productivity effect in the offshoring literature.[4] The net effect of the offshoring activities on labor demand elasticity depends on the degree of trade openness and the calibration choice of trade elasticity.

The intuition for the interactions of the three channels to generate the observed result is as follows. The greater demand spillover stabilizes the effect of a given monetary expansion on hours worked. With a larger labor demand elasticity, a given increase in labor demand boosts domestic real wage by less. The combined effect of these two channels is that a given monetary expansion has a weaker effect on domestic real wage and hours worked, while it has a magnified effect on foreign real wage and hours worked. When the trade friction is realistically high, domestic production cost plays a dominating role in determining domestic consumer price inflation dynamics. Greater trade openness reduces the effect of monetary policy shock on inflation and output.

How can the structure of the international financial market influence the monetary transmission mechanism? The calibrated model indicates that a given monetary expansion depreciates the real exchange by less under the incomplete international financial market than it does under financial autarky. Real exchange rate depreciation induces an expenditure switching effect, putting an upward pressure on domestic real

[4]Recent papers that study the implications of offshoring activities are Baldwin and Robert-Nicoud (2014), Rodrguez-Clare (2010) and Grossman and Rossi-Hansberg (2008). These papers focus on the medium to long run effects on the labor market. Grossman and Rossi-Hansberg (2008) highlights the positive productivity effect associated with increased exposure to cheap imports. It reduces the production cost and promote middle skilled workers to upgrade their skills level. As a consequence, expansion in offshoring activities benefits workers in all skill levels. Baldwin and Robert-Nicoud (2014) and Rodrguez-Clare (2010) argue the possible negative effect of offshoring activities on domestic wage since the terms of trade deterioration may dominate the positive productivity effect in medium run.

wage and hours worked. Liberalizing the international financial market dampens the expenditure switching effect. As a consequence, it reduces the stimulative effect of a given monetary expansion on real wage and hours worked, and leads to subdued responses of consumer price inflation and real GDP. Under financial autarky, the trade balance condition must hold. The final good producers operate as if using only locally produced inputs regardless of trade openness regime. International demand spillover is negligible. Since the expenditure switching effect dominates the other aforementioned channels, trade openness moderately strengthens the effectiveness of monetary policy.

In terms of business cycle properties, this model can generate two business cycle patterns identified in SVAR studies, which most international business cycle and New Keynesian open economy models fail to capture. Firstly, domestic technology progress leads an appreciation in real exchange rate, which is consistent with the findings of Enders, Mller, and Scholl (2011) and Corsetti, Dedola, and Leduc (2014) for the US.[5] The core of the model that generates this pattern is the presence of an endogenously determined non-traded sector. When positive technology shock raises the production cost of domestic non-traded goods relative to that of foreign non-traded goods, the domestic consumption goods become more expensive than the foreign ones, leading to the appreciation of real exchange rate. The second pattern is that domestic technology progress has contractionary effects on domestic hours worked, which is widely documented in the literature, e.g. Galí (1999) and Kimball, Fernald, and Basu (2006). This result is also driven by the same mechanism. Since positive technology

[5] Corsetti et al. (2008) shows that, for international macro model with incomplete international financial market, positive productivity shock can lead real exchange rate to appreciate, when trade elasticity is low or the productivity shocks are persistent enough.

shock leads real exchange rate to appreciate, the induced expenditure switching effect dominates the strengthened absolute advantage effect, leading to a decrease in the demand of domestic labor.

This paper is related to the existing open economy New Keynesian models, i.e. Clarida et al. (2002), Galí and Monacelli (2005) and Erceg, Gust, and Lpez-Salido (2007). Clarida et al. (2002), Galí and Monacelli (2005) identify two channels through which trade openness influences the monetary transmission mechanism: the terms of trade (defined as the ratio of import price over export price, TOT henceforth) channel and the marginal utility channel. When expansionary monetary policy shock depreciates domestic currency, which raises TOT, foreign goods become more expensive. The global demand shifts toward domestic goods and raises the domestic labor wage, putting upward pressure on the domestic GDP deflator. On the other hand, domestic currency depreciation has negative wealth effect on households and raises the marginal utility, putting downward pressure on the domestic GDP deflator. Greater openness strengthens the effects of both channels. The net effect of the influence of greater openness on the effectiveness of monetary policy shock depends on model calibration, i.e. the degree of substitutability of domestic and imported goods, and the degree of risk aversion. Erceg et al. (2007) concludes that trade openness mainly influences the composition of the consumption basket and the consumer price, rather than stabilizes the responses of output and inflation.

In terms of model elements, this paper is related to the literature that incorporates heterogenous firms (following Melitz (2003)) into international macro model and examine its implications on monetary policy. Schwerhoff and Sy (2014) highlights the disinflationary effect of the positive productivity effect associated with trade liberalization. Cacciatore and Ghironi (2013) incorporates labor market frictions into Ghironi and Melitz (2005). They show how the degree of trade integration influences the incentive of optimal monetary policy: the trade liberalization induced productivity effect reduces the incentive to create positive inflation, which is necessary to correct labor market distortions when trade integration is low.

Since this paper emphasize outsourcing a fraction of production to low wage country, it is related to Arkolakis and Ramanarayanan (2009), Burstein, Kurz, and Tesar (2008), Johnson (2014), which use cross-country input trade linkages to solve the trade-comovement puzzle. That is, country pairs, that are more integrated in trade, exhibit higher output correlation. Among these papers, the closest to this one in terms of model elements choice is Arkolakis and Ramanarayanan (2009), which is built on Eaton and Kortum (2002), and Yi (2003), and extends the standard international macro model with input trade across multiple stages of production. However, these authors find little dependence of business cycle synchronization on trade intensity under complete market.

The rest of the paper is organized as follows. Section 2 presents the model. The model calibration and business cycle properties are given in section 3. Section 4 analyzes the channels through which the trade openness and the financial openness influence the monetary transmission mechanism, and conducts quantitative exercises with the calibrated model. Section 5 concludes the paper.

2. Model

This section presents a dynamic, two-country model in a stochastic environment. The two countries are asymmetric in the sense that the Home manufacturing sector has a higher average technology level than the Foreign manufacturing sector does, and Home manufacturing firms can fragment the production into a continuum of tasks and offshore a fraction of them to Foreign, while Foreign manufacturing firms use only domestic labor as inputs. The production structure of both countries is similar to that in Obstfeld (2003), which features two-stage production. The first stage produces traded manufactured goods and the second stage produces non-traded final goods using manufactured goods as inputs. This paper builds on Eaton and Kortum (2002)'s Ricardian trade model, where both comparative and absolute advantage play a role in determining international trade pattern. The presence of absolute advantage, a higher average technology level in the Home manufacturing sector, leads to a wage gap between Home and Foreign, and generates the incentive for Home manufacturing firms to offshore. Comparative advantage is the driving force of trade in absence of fragmentation of production. The model of one-way offshoring is based on Grossman and Rossi-Hansberg (2008) and Rodrguez-Clare (2010), where expansion of offshoring activities is driven by decline in the cost of importing intermediate goods.

In the model, Home and Foreign are identical except for the production technology of the manufacturing sectors. Each country is populated by a continuum of households of measure one, and consists of a representative retailer, a continuum of final-good-producing firms indexed by $i \in [0, 1]$, a continuum of manufacturing firms indexed by $j \in [0, 1]$, and a central bank. During each period, $t = 0, 1, 2, ...$, manufacturing firm j produces a distinctive perishable intermediate good j and the final-good-producing firm i produces a distinct, perishable final good i using Home and imported Foreign manufactured goods as inputs. The retailer assembles final goods into consumption goods.

In this section, except for the manufacturing sector, I describe the behavior of each agent focusing mainly on Home country, with the understanding that the Foreign economy can be characterized using similar expressions. I mark the Foreign variables with asterisk to distinguish them from Home variables. In the baseline model, the two countries trade risk free bond. In order to analyze the effect of financial openness, financial autarky is introduced at the end of this section.[6] The detailed behavior rule of each agent is given as following.

2.1. The Representative Household. At the beginning of each period, $t = 0, 1, 2...$, the household in Home starts with domestic bond B_{t-1}, and international bond $B_{I,t-1}$, where both B_{t-1} and $B_{I,t-1}$ are denominated using Home currency. The household receives $B_{t-1}+B_{I,t-1}$ units of money when the domestic bond and International bond mature. Then, the household uses some money to purchase $B_t+B_{I,t}$ new bond at the cost of $\frac{B_t}{r_t} + \frac{B_{I,t}}{i_t} + \frac{\psi P_t}{2i_t}(\frac{B_{I,t}}{P_t} - \frac{\bar{B}_I}{P})^2$, where r_t is the risk free nominal interest rate between period t and $t+1$ in Home country, and i_t is the risk free nominal interest rate of holding international bond. The quadratic adjustment cost of holding Foreign bond is introduced in order to pin down a well defined steady state for consumption and asset holding, and to ensure the model stationarity, following Benigno (2009) and Ghironi, Lee, and Rebucci (2007). During each period, the household supplies

[6]Since the author's simulation and the quantitative results of Schmitt-Grohé and Uribe (2003) indicate that, under the first order log-linearization, the models under complete and incomplete international financial market have similar implications. Here I omit the complete market scenario.

h_t units of labor to the manufacturing firms, and receives nominal wage W_t. The household also purchases C_t units of consumption goods from retailers at price P_t, and receives a lump-sum transfer T_t, which is the rebate of the international bond trading cost in terms of consumption goods. At the end of each period, the household receives D_t units of real profit from final-good-producing firms.

The household's activities can be characterized by the optimization problem

$$\max_{\{C_t,h_t,B_t,B_{I,t}\}} E\sum_{t=0}^{\infty}\beta^t(\frac{C_t^{1-\sigma}}{1-\sigma}-\frac{h_t^\eta}{\eta})$$

$$s.t. \qquad C_t+\frac{B_t}{r_tP_t}+\frac{B_{I,t}}{i_tP_t}+\frac{\psi}{2i_t}(\frac{B_{I,t}}{P_t}-\frac{\bar{B}_I}{P})^2\leq\frac{W_t}{P_t}h_t+\frac{B_{t-1}}{P_t}+\frac{B_{I,t-1}}{P_t}+T_t+D_t$$

where $0<\beta<1$ is the discount factor, $\sigma\geq 1$ measures the degree of risk aversion, $\eta>1$ measures the elasticity of labor supply, and ψ measures the degree of frictions in international financial intermediation. $\bar{B}_I$ is the steady state holdings of international bond, and P is the steady state price level.

The optimality conditions of the household include two inter-temporal optimality conditions

$$\beta E[(\frac{C_{t+1}}{C_t})^{-\sigma}\frac{r_t}{\pi_{t+1}}]=1 \tag{2.1}$$

$$\beta E[(\frac{C_{t+1}}{C_t})^{-\sigma}\frac{i_t}{\pi_{t+1}}]=1+\psi(\frac{B_{I,t}}{P_t}-\frac{\bar{B}_I}{P}) \tag{2.2}$$

which links the household's marginal rate of substitution to the real interest rates of holding domestic bond and international bond, and one intra-temporal optimality condition

$$h_t^{\eta-1}C_t^{\sigma} = \frac{W_t}{P_t} \tag{2.3}$$

which links the household's marginal rate of substitution between consumption and working hours to the real wage. The optimality conditions also include the budget constraint with equality.

Similarly, Foreign household faces the budget constraint, which is given by

$$C_t^* + \frac{B_t^*}{r_t^* P_t^*} + \frac{B_{I,t}^*}{i_t P_t^* \mathcal{E}_t} + \frac{\psi}{2i_t}(\frac{B_{I,t}^*}{P_t^* \mathcal{E}_t} - \frac{\bar{B}_I^*}{P^* \mathcal{E}})^2 \leq \frac{W_t^*}{P_t^*}h_t^* + \frac{B_{t-1}^*}{P_t^*} + \frac{B_{I,t-1}^*}{P_t^* \mathcal{E}_t} + T_t^* + D_t^* \tag{2.4}$$

where $\mathcal{E}_t$ is nominal exchange rate, calculated as units of home currency per unit of Foreign currency. The optimality conditions of holding domestic and international bonds for Foreign household are given by

$$\beta E[(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}\frac{r_t^*}{\pi_{t+1}^*}] = 1 \tag{2.5}$$

$$\beta E[(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}\frac{i_t}{\pi_{t+1}^*}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}] = 1 + \psi(\frac{B_{I,t}^*}{\mathcal{E}_t P_t^*} - \frac{\bar{B}_I^*}{P^* \mathcal{E}}) \tag{2.6}$$

Due to the friction of trading international bond, the Uncovered Interest Rate Parity is violated when the real holding of international bond deviates its steady state level:

$$E_t[(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}(\frac{i_t}{\pi_{t+1}^*}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} - \frac{r_t^*}{\pi_{t+1}^*})] = \psi(\frac{B_{I,t}^*}{\mathcal{E}_t P_t^*} - \frac{\bar{B}_I^*}{P^* \mathcal{E}}) \tag{2.7}$$

2.2. The Representative Retailer. During each period $t = 0, 1, 2...$, the representative retailer purchases $Y_t(i)$ units of each type of final good at nominal price $P_t(i)$ to produce Y_t units of the homogeneous consumption goods with constant return to scale technology, which is given by

$$Y_t = [\int_0^1 Y_t(i)^{\frac{\gamma-1}{\gamma}} di]^{\frac{\gamma}{\gamma-1}} \tag{2.8}$$

where $\gamma > 1$ measures the elasticity of substitution between different final goods. The retailer sells the consumption goods in competitive market and maximizes profit by choosing

$$Y_t(i) = [\frac{P_t(i)}{P_t}]^{-\gamma} Y_t \qquad \text{for } i \in [0,1],\ t = 0,1,2... \tag{2.9}$$

The perfect competition drives the profit to zero, determining the price index

$$P_t = [\int_0^1 P_t(i)^{1-\gamma} di]^{\frac{1}{1-\gamma}} \qquad \text{for all t= 0, 1, 2...} \tag{2.10}$$

2.3. The Representative Final-Good-Producing Firm. During each period, the final good producer i purchases $y(i,j)$ units of manufactured good j from perfect competitive international manufactured goods' market, at nominal price $p_m(j)$ to produce $Y_t(i)$ units of final good i with the constant return to scale technology

$$Y_t(i) = [\int_0^1 y_t(i,j)^{\frac{\mu-1}{\mu}} dj]^{\frac{\mu}{\mu-1}} \tag{2.11}$$

where $\mu > 1$ measures the elasticity of substitution of manufactured goods. The final good producer minimizes cost by choosing

$$y_t(i,j) = [\frac{p_{m,t}(j)}{P_{m,t}}]^{-\mu} Y_t(i) \qquad \text{for } i,j \in [0,1] \text{ and } t = 0,1,2... \tag{2.12}$$

where $P_{m,t}$ is the nominal price of the intermediate input bundle. The perfect competition in the international manufactured goods' market drives the profit of the manufacturing firms to zero, determining the nominal price of the Home manufactured goods' bundle, which is given by

$$P_{m,t} = [\int_0^1 p_{m,t}(j)^{1-\mu} dj]^{\frac{1}{1-\mu}} \tag{2.13}$$

Since the final goods are imperfect substitutes in producing the consumption goods, final goods are sold in monopolistic competitive market: During period t, the final good producer i set price $P(i)$ subjecting to the demand of the retailer at the given price. The final good producer i sets price facing the Rotemberg (1984) type of quadratic adjustment cost measure by the consumption goods, which is given by

$$\frac{\phi}{2}[\frac{P_t(i)}{P_{t-1}(i)\tilde{\Pi}} - 1]^2 Y_t \tag{2.14}$$

where ϕ measures the magnitude of cost in response to the price adjustment, and $\tilde{\Pi}$ is the steady state level of inflation set by the central bank.

The final good producer i maximizes the market value of the firm by choosing the nominal price $P_t(i)$

$$\max_{P_t(i)} E[\sum_{t=0}^{\infty} \beta^t \frac{D_t(i)}{C_t^\sigma}] \tag{2.15}$$

where $\beta^t \frac{1}{C_t^\sigma}$ the household's marginal utility gain from one unit of real profit. With the demand of final good i equation 2.12, and the real marginal cost of the final good producer i, $\frac{P_{m,t}}{P_t}$, the expression of the real profit is given by

$$D_t(i) = [\frac{P_t(i)}{P_t}]^{1-\gamma}Y_t - \frac{P_{m,t}}{P_t}[\frac{P_t(i)}{P_t}]^{-\gamma}Y_t - \frac{\phi}{2}[\frac{P_t(i)}{P_{t-1}(i)\tilde{\Pi}} - 1]^2 Y_t \tag{2.16}$$

The first order condition of optimally setting price is

$$\begin{aligned}(\gamma-1)[\frac{P_t(i)}{P_t}]^{-\gamma}\frac{Y_t}{P_t} =& \gamma\frac{P_{m,t}}{P_t}[\frac{P_t(i)}{P_t}]^{-\gamma-1}\frac{Y_t}{P_t} - \phi[\frac{P_t(i)}{P_{t-1}(i)\tilde{\Pi}} - 1]\frac{Y_t}{\tilde{\Pi}P_{t-1}(i)} + \\ & \beta\phi E[(\frac{C_{t+1}}{C_t})^{-\sigma}[\frac{P_{t+1}(i)}{P_t(i)\tilde{\Pi}} - 1]\frac{P_{t+1}(i)}{P_t(i)\tilde{\Pi}}\frac{Y_{t+1}}{P_t(i)}] \end{aligned} \tag{2.17}$$

2.4. The Representative Manufacturing Firm. During each period, $t = 0, 1, 2...$, representative Home manufacturing firm j fragments its production of manufactured good $y_{m,t}(j)$ into a continuum of task, $t(j,k)$ indicated by $k \in \Omega_j$. Ω_j is the set of all the tasks involved to produce good j, and it's indexed by j to allow for the variability of tasks cross manufacturing firms. The production function is given by

$$y_{m,t}(j) = z_t(j)\int_{\Omega_j} t_t(j,k)dk \tag{2.18}$$

where $z_t(j)$ is the idiosyncratic technology shock to firm j. Following Eaton and Kortum (2002), I assume $z_t(j)$ is a random draw from the Frechet distribution

$$F(z) = e^{-Z_t z^{-\theta}} \tag{2.19}$$

where θ measures the dispersion of the idiosyncratic technology, and it's the measure of the comparative advantage within the continuum of manufactured goods: A lower value of θ generates larger heterogeneity in terms of idiosyncratic technology within a country, and the comparative advantage effect is greater. Z_t is country specific aggregate technology shock, and determines the location of the idiosyncratic technology shock's distribution. Higher Z_t implies that the idiosyncratic technology draw is likely to be better, and it affects the share of goods in which Home has comparative advantage relative to Foreign across the continuum of goods. It follows a stationary autoregressive process:

$$\ln(Z_t) = (1 - \rho_z)\ln(\mu_z) + \rho_z \ln(Z_{t-1}) + \epsilon_{z,t} \tag{2.20}$$

where $0 < \rho_z < 1$. μ_z is the steady state value of aggregate technology, Z_t, and it governs the average realization of idiosyncratic technology shocks, $z_t(j)$. $\epsilon_{z,t}$ is serial uncorrelated and follows the normal distribution with zero mean and standard deviation σ_z.

Foreign representative manufacturing firm j hires $h_t^*(j)$ units labor from the representative household to produce $y_{m,t}^*(j)$ units of good j with the constant return to scale technology

$$y_{m,t}^*(j) = z_t^*(j) h_t^*(j) \tag{2.21}$$

where $z_t^*(j)$ is the idiosyncratic productivity of firm j and it's a random draw from Frechet distribution with aggregate technology, Z_t^*. With the assumption, $\mu_z > \mu_z^*$, Home manufacturing firms have absolute advantage over their Foreign counterparts, hence Home has higher wage than Foreign does, $W_t > W_t^* \mathcal{E}_t$.

For Home manufacturing firm j, each task k can either be implemented by domestic labor or by offshoring. Following Rodrguez-Clare (2010), offshoring task k involves an iceberg cost, $\zeta_t(k)$, which is an independent draw from an exponential distribution with parameter λ, and a mass point at 1. Formally, given constant $\bar{\zeta} \geq 1$, the probability that the offshoring cost of task k is greater than $\bar{\zeta} \geq 1$ is

$$P(\zeta_t(k) \leq \bar{\zeta}) = F(\bar{\zeta}, \lambda) = 1 - \exp(-\lambda\bar{\zeta}) \tag{2.22}$$

where $\lambda > 0$. Higher λ implies a lower average offshoring cost. Let $C_t(\mathbf{W_t}, k)$ denote the unit nominal cost of task k as a function of nominal wages, $\mathbf{W_t} \equiv (W_t, W_t^*\mathcal{E}_t)$. It is given by

$$C_t(\mathbf{W_t}, k) = \begin{cases} W_t & \zeta_t(k) > \frac{W_t}{W_t^*\mathcal{E}_t} \\ \zeta_t(k)W_t^*\mathcal{E}_t & 1 \leq \zeta_t(k) \leq \frac{W_t}{W_t^*\mathcal{E}_t} \\ W_t^*\mathcal{E}_t & \zeta_t(k) < 1 \end{cases}$$

Home manufacturing firm j will choose to offshore when offshoring cost is below $\frac{W_t}{W_t^*\mathcal{E}_t}$, and the lowest possible offshoring cost is 1. With unit cost of each task, $C_t(\mathbf{W_t}, k)$ specified, the nominal unit input cost of the representative manufacturing firm j is given by

$$C_t(\mathbf{W_t}) = W_t^*\mathcal{E}_t F(1, \lambda) + \int_{W_t^*\mathcal{E}_t}^{W_t} x dF(x, \frac{\lambda}{W_t^*\mathcal{E}_t}) + W_t[1 - F(W_t, \frac{\lambda}{W_t^*\mathcal{E}_t})] \tag{2.23}$$

which indicates that firm j's unit input cost is a weighted sum of Home labor cost, W_t and Foreign labor cost, $W_t^*\mathcal{E}_t$, and hence $W_t > C_t(\mathbf{W_t}) > W_t^*\mathcal{E}_t$. Higher λ shifts greater weight towards $W_t^*\mathcal{E}_t$.

Since both Home and Foreign manufacturing firms are able to produce all the variety of manufactured goods, and Home made and Foreign made manufactured goods j are perfect substitutes in producing the final goods, the manufactured goods are sold in perfectly competitive international market. For Home final good producers, the available nominal prices of manfactured good j are

$$\begin{cases} \text{Home} & p_{h,m,t}(j) = \frac{C_t(\mathbf{W_t})}{z_t(j)} \\ \text{Foreign} & p_{f,m,t}(j) = \frac{W_t^* \tau \mathcal{E}_t}{z_t^*(j)} \end{cases}$$

where $\tau > 1$ for $t = 0, 1, 2, ...$ is the iceberg trade cost. Due to the costly trade, Purchasing Power Parity doesn't hold in this model.

As the representative Home final good producer always chooses the cheaper source of manufactured good j, the nominal price of the manufactured good j in Home country is $p_{m,t}(j) = \min\{p_{h,m,t}(j), p_{f,m,t}(j)\}$ for all $j \in [0, 1]$ and $t = 0, 1, 2....$ Following Eaton and Kortum (2002)'s probabilistic approach, the nominal price index of manufactured goods' bundle $P_{m,t}$ is given by

$$P_{m,t} = [Z_t C_t(\mathbf{W_t})^{-\theta} + Z_t^*(W_t^* \tau \mathcal{E}_t)^{-\theta}]^{-\frac{1}{\theta}} [\Gamma(\frac{1 - \mu + \theta}{\theta})]^{\frac{1}{1-\mu}} \tag{2.24}$$

where $[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}} > 0$ is a constant. Recall that $P_{m,t}$ is the representative final good producer j's nominal marginal cost. Due to international trade, the Home final good producer's marginal cost depends on: 1) Home labor cost, W_t, and aggregate technology, Z_t; 2) Foreign labor cost denominated in Home currency $W_t^* \mathcal{E}_t$ and aggregate technology, Z_t^* and 3) the trade cost τ. Progress in aggregate technology in either country or decline in trade or labor cost in either country leads to a lower nominal marginal cost in Home. As the trade cost declines, the Foreign factors has greater effect on Home final-good producers marginal cost, and on Home CPI inflation as well.

Since there are a continuum ex ante identical manufacturing firms $j \in [0,1]$, by Law of Large Numbers, the fraction of the manufactured goods that the Home final good producers purchase from Home manufacturing firms, $S_{h,t}$, is the same as the probability that the representative Home manufacturing firm j serves Home market, that is the probability that firm j provides a lower price in Home market than the Foreign manufacturing firm j does. $S_{h,t}$ is given by

$$S_{h,t} = \frac{Z_t C_t(\mathbf{W_t})^{-\theta}}{Z_t C_t(\mathbf{W_t})^{-\theta} + Z_t^*(W_t^*{}_t \tau \mathcal{E}_t)^{-\theta}} \tag{2.25}$$

Similarly, the Home intermediate-good-producing firms' market share in Foreign market, $S_{f,t}$ is given by

$$S_{f,t} = \frac{Z_t[C_t(\mathbf{W_t})\tau/\mathcal{E}_t]^{-\theta}}{Z_t[C_t(\mathbf{W_t})\tau/\mathcal{E}_t]^{-\theta} + Z_t^* W_t^{*-\theta}} \tag{2.26}$$

The above two equations imply that raising the Home marginal cost relative to Foreign marginal cost evaluated using the same currency shifts the global demand towards Foreign intermediate good. A lower trade cost promotes international trade, by reducing the price charged by exporters abroad, and hence expanding the range of traded goods in both countries. With lower θ, the dispersion of idiosyncratic productivities among intermediate good producers is greater in both countries, leading to a greater comparative advantage effect to keep the trade pattern stable.

The perfect competition drives the profit of Home manufacturing firms to zero, determining Home manufactured goods' market clear condition:

$$P_{m,t} S_{h,t} Y_t + P_{m,t}^* S_{f,t} Y_t^* \mathcal{E}_t = C_t(\mathbf{W_t}) \frac{h_t}{1 - F(W_t, \frac{\lambda}{W_t^* \mathcal{E}_t})} \tag{2.27}$$

which implies that the revenue of Home manufacture sector equals to the sum of the payment to domestic labor and offshored labor services.

Foreign manufacturing goods' market clear condition is given by

$$P_{m,t}(1-S_{h,t})Y_t + P^*_{m,t}\mathcal{E}_t(1-S_{f,t})Y^*_t = W^*_t h^*_t \mathcal{E}_t + W_t h_t - C_t(\mathbf{W_t})\frac{h_t}{1-F(W_t, \frac{\lambda}{W^*_t\mathcal{E}_t})} \quad (2.28)$$

which implies that Foreign manufacturing firms revenue is equal to the payment to Foreign labor net the payment to offshored labor services.

2.5. Central Bank. In each country, the central bank conduct monetary policy following standard Taylor rule proposed by Taylor (1993), augmented by the lagged nominal interest rate.[7]

$$\ln(r_t) - \ln(r) = \rho_r[\ln(r_{t-1}) - \ln(r)] + \Phi_Y E_t[\ln(Y_{GDP,t}) - \ln(Y_{GDP})] + \Phi_\pi E_t[\ln(\Pi_t]) - \ln(\tilde{\Pi})] + \epsilon_{r,t}$$

where $\epsilon_{r,t}$ is unforecastable random variable, which is interpreted as unexpected monetary policy shock to period t nominal interest rate. $\epsilon_{r,t}$ is serially uncorrelated and it follows zero mean normal distribution with standard deviation σ_{ϵ_r}. ρ_r measures the persistency of the nominal interest rate and $0 < \rho_r < 1$.

The policy rule implies Home central bank adjusts the short term nominal interest rate according to the last period nominal interest rate, the expected deviation of real GDP from its steady state level and the expected deviation of inflation from the desired level. The monetary authority chooses magnitude of interest rates' response to inflation, measured by Φ_π, the magnitude of interest rates' response to output, measured by Φ_Y. The $\frac{\Phi_\pi}{1-\rho_r} > 1$ is a sufficient condition to ensure existence of a unique nonexplosive rational expectation equilibrium.

[7]The federal funds rate is well-known for its persistency. This phenomenon may arise as Fed's interest rate smoothing motivation, or reflect the optimal policy under commitment

2.6. Symmetric Equilibrium. In equilibrium, all the final-good-producing firms behave in the identical way, therefore $Y_t(i) = Y_t$, $P_t(i) = P_t$ and $D_t(i) = D_t$ for all $i \in [0,1]$ and $t = 0, 1, 2...$; and all the manufacturing firms behave in the same way ex ante, $h_t(j) = h_t$, $t(j,k) = t_t$, and their expected market shares in the global market are the same. Denote real wage $w_t = \frac{W_t}{P_t}$, real input cost of Home manufacturing firms, $c_t(\mathbf{w}) = \frac{C_t(\mathbf{W})}{P_t}$, real marginal cost of final good producers, $p_{m,t} = \frac{P_{m,t}}{P_t}$, real domestic bond holdings $b_t = \frac{B_t}{P_t}$ and real international bond holding $b_{I,t} = \frac{B_{I,t}}{P_t}$. The aggregate resource constraint can be written as

$$C_t + \frac{b_{I,t}}{i_t} = w_t h_t + b_{I,t-1} + Y_t - p_{m,t} Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}} - 1)^2 Y_t \tag{2.29}$$

and the consumption goods' market clear condition is given by

$$C_t = Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}} - 1)^2 Y_t \tag{2.30}$$

In equilibrium, the domestic bond is in zero net supply: $b_t = 0$, and so is the international bond: $b_{I,t} + b^*_{I,t} = 0$. By definition, current account, ca_t is the sum of the trade balance and net international investment income, which is given by

$$ca_t = \frac{b_{I,t}}{i_t} - \frac{b_{I,t-1}}{i_t} = (1 - \frac{1}{i_t}) b_{I,t-1} + w_t h_t - p_{m,t} Y_t \tag{2.31}$$

The bond market equilibrium condition implies that $ca_t = ca^*_t Q_t$. Hence, the current account can also be expressed as

$$\frac{b_{I,t}}{i_t} - b_{I,t-1} = \frac{w_t h_t - w^*_t h^*_t Q_t - p_{m,t} Y_t + p^*_{m,t} Y^*_t Q_t}{2} \tag{2.32}$$

2.7. Financial Autarky. Since the international financial market structure crucially affects the determination of real exchange rate, I also consider financial autarky case, where there's no international borrowing or lending between Home and Foreign. Only domestic bond is traded in each country. The Home household's budget constraint becomes,

$$C_t + \frac{b_t}{r_t} \leq w_t h_t + b_{t-1} + D_t \tag{2.33}$$

The inter-temporal optimality condition is the standard close economy Euler equation.

$$\beta E[(\frac{C_{t+1}}{C_t})^{-\sigma} r_t \frac{P_t}{P_{t+1}}] = 1 \tag{2.34}$$

Under Financial autarky, the inability to trade inter-temporally imposes that the value of the imports must equal to the value of exports evaluated using the same currency:

$$p^*_{m,t} Q_t S_{f,t} Y^*_t = p_{m,t}(1 - S_{h,t}) Y_t + c_t(\mathbf{w_t}) \frac{h_t}{1 - F(w_t, \frac{\lambda}{w^*_t Q_t})} - w_t h_t \tag{2.35}$$

in which the left-hand side term is Foreign imports, the first term on the right-hand side is Home imports of manufactured goods, and the last two terms on the right-hand side measures the imports of offshored products. This trade balance condition determines the the movement of real exchange rate.

The definition of equilibrium, the calculation of steady state and the log-linearized model are given in Appendix A.3, A.4 and A.5.

3. Calibration and Macro Dynamics

This section presents the impulse responses of the key macro variables in the model to unexpected transitory technology shock and to unexpected transitory monetary policy shock. To this end, I calibrate the parameters in the model, compute the implied steady state values of the endogenous variables, and solve the first order log-linearized model following Schmitt-Grohe and Uribe (2004). The detailed analysis is given as follows.

3.1. Calibration. Model calibration follows the standard choices from the literature. Periods are interpreted as quarters. The discount factor is set at $\beta = 0.99$ and the inverse of the inter-temporal elasticity of substitution $\sigma = 1$, which are standard in quarterly business cycle models. I set $\eta = 5$ to match Frisch elasticity of aggregate hours of 0.25, which is within the reasonable range of Frisch elasticity estimates suggested in Chetty, Guren, Manoli, and Weber (2011). The international financial intermediate friction parameter is set at $\psi = 0.01$, in order to induce the model stationarity, and to ensure a small enough effect of asset adjustment on the model dynamic. I use the estimated value for trade elasticity from Simonovska and Waugh (2014), to set the trade elasticity $\theta = 4$. The elasticity of substitution of final goods and the elasticity of intermediate goods are set using the estimated value from Bernard, Eaton, Jensen, and Kortum (2003), $\gamma = \mu = 3.8$.[8] The adjustment cost

[8]As in Eaton and Kortum (2002), the model contains two parameters related to the elasticity of substitution between the trade goods from two sources. μ governs substitutability in the intensive margin within goods that are continuously traded, θ governs the heterogeneity in production technology across goods, and hence determines the extent to which the extensive margin of trade in new goods responds to variations in production cost or trade costs. The role of the parameter μ in determining the elasticity of trade is concealed by the role of θ. In our model, only θ influences the model dynamics.

parameter is set at $\phi = 33$ to match the price adjustment frequency about one year, which is the standard choice in models with sticky price, e.g. the Calve model. The steady state inflation is set $\tilde{\Pi} = 1.0086$, which implies a annual inflation of 3.48% following Ireland (2004). The stance of monetary policy are set at $\Phi_\pi = 1.5$ and $\Phi_Y = 0.5$ following Taylor (1993), and set the persistency of nominal interest rate, $\rho_i = 0.76$, and the persistency of the technology shock, $\rho_z = 0.83$, according to the estimated values in Lubik and Schorfheide (2006). The trade cost τ and offshore cost λ are set to match steady state import to GDP ratio at 17% and the ratio of material offshore to import at 30% in Home country.[9] The steady state values of Home aggregate technology, μ_z is set at 1 and steady state values of Foreign aggregate technology, μ_z^* is set at 0.07 in order to target the ratio of real GDP between Home and Foreign at 2.[10]

3.2. Real GDP and Productivity in the Model. Before proceeding to showing the impulse responses of productivity and monetary policy shocks, let's take a detour to define the real GDP and the measured productivity (or TFP) in this model. It's necessary, because unlike the standard international business cycle models, in which all value added is created in one-stage production, this model features two stages of production. The real GDP is defined as the total real value of gross output of each sector less the total real value of expenditure on intermediate inputs. The

[9]The measure of material offshore can be estimated following Feenstra and Hanson (1999, 1996). 30% is within the reasonable range of the ratio of intermediate imports to non-energy imports in US manufacture sector.

[10] It's consistent with the ratio of GDP per capita in US to the mean of US dollar valued GDP per capita in US top twenty five trade partners in 2000 according to the World Bank data.

expression of real GDP is given by

$$Y_{\text{GDP,t}} = (1 - p_{m,t})Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}} - 1)^2 Y_t + w_t h_t \tag{3.1}$$

where the first two terms on right hand side of the equation are the real value added of the final good sector, and the last term is the real value added of the manufacture sector. That is, the real GDP is the sum of real value of the profit from the final-good-producing sector, and the real wage payment to domestic households.

The average labor productivity is defined as the ratio of real GDP over labor input:

$$A_t = \frac{Y_{\text{GDP,t}}}{h_t} \tag{3.2}$$

The movement of the measured productivity comes from three sources: 1) technology progress in manufacture sector; 2) reallocation of resources among the manufacturing firms with heterogeneous technology levels; 3) the variation of the manufactured input bundle's price, which influences the final-good-producing firms production cost. The first channel is straightforward. The second channel arises because reallocation of resources among firms with different technology shifts the size distribution of manufacturing firms, hence changes the average technology level of intermediate good sector. The third channel is associated with the offshoring induced productivity effect, which is analyzed in Grossman and Rossi-Hansberg (2008) and Rodrguez-Clare (2010). The following analysis provides concrete examples on how these three channels interact.

3.3. Macro Dynamics.

3.3.1. *Positive Technology Shock.* Figure 2.1 shows the impulse responses of variables to an unexpected positive technology shock (positive one percent deviation) in Home manufacturing sector, reflecting the increase in the average realization of the idiosyncratic technology shocks of Home manufacturing firms. The blue solid lines are the impulse responses of Home variables; the red dashed lines are impulse responses of Foreign variables. In line with Galí and Monacelli (2005), technology progress moves prices and quantities in opposite directions: real GDP and consumption rise, while CPI inflation falls in Home. The Home monetary authority reacts to the falling inflation by providing an easing monetary condition from the second period onward. The lagged response of nominal interest rate leads to the hump-shaped response of real GDP and consumption. Consistent with the empirical literature, e.g. Kimball et al. (2006), the positive technology shock has a contractionary effect on hours, since the improved production efficiency is more than sufficient to meet the short run moderate increase in demand. The puzzling decline in Home real wage in the first period is due to lack of nominal wage rigidity. The insufficient labor demand leads nominal wage to fall. Given the presence of price stickiness, the real wage falls correspondingly.

Consistent with the recent empirical evidence, e.g. Enders et al. (2011) and Corsetti et al. (2014), technology progress leads real exchange rate to appreciate. The intuition is that a positive technology shock reduces the average production cost of Home manufacturing firms, which facilitate them to expand Home and Foreign market shares. This, in turn, increases the demand of Home labor relative to the demand of Foreign labor, which raises Home labor wages above Foreign labor wages, as evaluated with Home currency. The positive technology shock, on the other hand, reduces the share of non-traded manufacturing-good-producing firms, leaving their average technology level less affected by the positive technology shock. Consequently, the average production cost of Home non-traded manufacturing goods rises relative to that of Foreign non-traded manufacturing goods. Hence, Home consumption goods become more expensive than Foreign ones.[11]

Home technology shock has a negative spillover effect on the Foreign economy in terms of real GDP, hours and real wage. It also leads to a temporary deflation. In reaction, the Foreign central bank lowers the nominal interest rate and Foreign consumption rises. Since the Foreign central bank lowers the nominal interest rate by less than the Home central bank does, a capital inflow into Foreign occurs, which causes Foreign consumption to rise more than the Home consumption does in the initial one and a half years.

3.3.2. *Expansionary Monetary Policy Shock.* Figure 2.2 shows the impulse responses to unexpected expansionary monetary policy shock (negative one percent deviation in nominal interest rate) in Home. The blue solid lines are the impulse responses of Home variables; the red dashed lines are impulse responses of Foreign variables. Expansionary monetary policy raises Home CPI inflation and consumption demand. To accommodate the rising aggregate demand, Home final good producers expand production, and Home aggregate hours and real GDP increase. Notably, for one percent decrease in Home nominal interest rate, the Home real wage rises by nearly six percent, which is larger than what structural VAR model suggests. This large response of real wages is caused mainly by a lack of real wage rigidity, as well as

[11] This mechanism is in the same spirit as Ghironi and Melitz (2005): with an endogenously determined non-traded sector, when positive technology shock in Home raises Home labor wage relative to Foreign labor wage, it raises Home non-traded goods prices above Foreign non-traded goods prices, leading to real exchange rate appreciation.

the relatively low labor supply elasticity of the model calibration choice. Moreover, the expansionary monetary policy shock raises domestic average labor productivity.[12] It raises domestic labor wage relative to Foreign labor wage, hence stimulates offshoring activities, thus enhancing Home average labor productivity.

Expansionary monetary policy shock in Home has a negligible effect on Foreign consumption and nominal interest rate, but has a positive spillover effect on Foreign real GDP, hours and real wages. The positive demand shock in Home raises the demand of Foreign manufactured good, driving up Foreign hours and real wage; while raising the cost of manufacturing input bundle, thus driving down their profit. The former channel dominates, and Foreign real GDP rises. Given the high persistence of Foreign nominal interest rates and a moderate increase in Foreign CPI inflation, Foreign nominal interest rate rises by a negligible amount, which boosts Foreign consumption by little.

4. Globalization, Offshoring and Effectiveness of Monetary Policy

This section explores the mechanisms through which manufactured goods importation increases, offshoring activities expansion, and international financial market liberalization influence the monetary transmission mechanism. The model is simulated to quantify the combined effects of financial market liberalization and trade liberalization on monetary transmission mechanism. Counterfactual analysis is conducted to examine the interactions of different channels. Sensitivity analysis is presented at the end of this section.

[12] Basu (1995) provides a close economy model, which features using intermediate inputs in final good's production, monopolistic competition and sticky price to generate pro-cyclical productivity effect with demand shock.

4.1 The Mechanism: Role of Trade Integration

For simplicity, the technology shocks are shut off. The role of trade openness in determining inflation dynamics can be analyzed with the New Keynesian Philips Curve (NKPC henceforth), i.e. the log-linearized first order condition of final-good-producing firms' optimally choosing their target prices (equation 2.17). The percentage deviation of a variable from its steady state value is denoted by the variable with hat. The expression of the NKPC is given by

$$\hat{\Pi}_t = \beta E[\hat{\Pi}_{t+1}] + \frac{\gamma - 1}{\phi}[\frac{\hat{c}_t(\mathbf{w_t})}{1+\tau^{-\theta}} + \frac{\tau^{-\theta}}{1+\tau^{-\theta}}(\hat{w}_t^* + \hat{Q}_t)] \tag{4.1}$$

which implies that Home CPI inflation, $\hat{\Pi}_t$, depends on the joint dynamics of unit input cost of Home manufacturing firms, $\hat{c}_t(\mathbf{w})$, and that of Foreign manufacturing firms, $\hat{w}_t^* + \hat{Q}_t$. It differs from the standard close economy NKPC, since Foreign labor cost affects Home CPI inflation. Given $\frac{d(\frac{1}{1+\tau^{-\theta}})}{d\tau} > 0$, as trade cost τ falls, the Home production cost has weaker effects on domestic CPI inflation.[13] Moreover, the log-linearized unit input cost of Home manufacturing firms is given by

$$\hat{c}_t(\mathbf{w_t}) = \frac{we^{-\frac{\lambda w}{w^*Q}}}{c(\mathbf{w})}\hat{w}_t + \frac{w^*Q(1-e^{-\lambda} - \lambda e^{-\lambda}) + \int_{w^*Q}^{w}(\frac{\lambda x}{w^*Q})e^{-\frac{\lambda x}{w^*Q}}(\frac{\lambda x}{w^*Q}-1)dx + \frac{\lambda w^2}{w^*Q}e^{-\frac{\lambda w}{w^*Q}}}{c(\mathbf{w})}(\hat{w}_t^* + \hat{Q}_t) \tag{4.2}$$

It shows that the unit input cost of Home manufacturing firms is the weighted sum of Home and Foreign real wages, and that the weights depend on the offshoring cost measure, λ. Recall that λ governs the average realization of the idiosyncratic offshoring

[13]Recent literature studying the open economy New Keynesian Philips Curve also find that openness weakens the connection of domestic inflation and domestic production cost (Benigno and Faia (2010), Guerrieri et al. (2010) and Razin and Loungani (2005)).

costs, and higher λ indicates a lower average offshoring cost. The relationship between trade openness, which is governed by trade cost, τ, as well as offshoring cost, λ, and the elasticities of Home manufacturing firms' unit input cost and Home CPI inflation with respect to Home and Foreign real wages is given in Figure 2.3. These two figures imply that decline in offshoring cost reduces the impact of Home real wages on Home manufacturing firms' unit input cost, and the simultaneous decline in offshoring and trade costs weakens its effects on Home CPI inflation. This trade openness induced change in consumer price composition is referred to as the cost composition effect, which is the first channel through which trade openness influences the monetary transmission mechanism.

Since the NKPC indicates that the effect of monetary policy shock on inflation depends on how Home and Foreign labor costs reaction to monetary policy disturbances, the analysis proceeds with a focus on the labor market. The log-linearized Home (Foreign) manufactured goods' market clear condition yields the Home (Foreign) labor demand condition. The derivation is given in the Appendix A.6. Home and Foreign hours worked depend on domestic and foreign real wages, real exchange rate and global consumption demand. Figure 2.4 shows how trade openness influences the elasticities of Home and Foreign labor demand with respect to these four variables. Greater trade integration, measured by the simultaneous decline in trade cost and offshoring cost, raises the labor demand elasticities with respect to Home and Foreign real wage, and strengthens the global demand spillover. These are the second and third channels, through which trade openness influences the monetary transmission mechanism. The effects of trade integration on labor demand elasticities are asymmetric between Home and Foreign: The less developed country is more severely affected.

It is straightforward that greater trade openness induced by falling trade cost or offshoring cost leads to greater demand spillover effect, since both changes strengthen the linkage of domestic demand and foreign production. A trade cost decline and an offshoring cost decline have different implications for labor demand elasticities. A trade cost decline promotes product market competition, thus raising labor demand elasticity. An offshoring cost decline raises labor demand elasticity by facilitating domestic producers to substitute domestic labor with imported goods and services. At the same time, it also enhances domestic producers competitiveness in global market by reducing their production cost, which in turn raises their willingness to hire domestic labor to expand production. This efficiency gain effect reduces labor demand elasticity, and also dampens the demand spillover effect induced by the offshoring cost reduction.

Figure 2.5 reveals the quantitative implications of offshoring-induced productivity effect. The first row compares two scenarios of the effects of trade openness on the labor demand elasticities with respect to the four variables: 1) trade growth driven by the simultaneous declines of trade and offshoring costs, and 2) trade growth driven by the decline of trade cost only. Under both scenarios, greater trade openness drives up labor demand elasticities with respect to domestic wage, and leads to greater international demand spillover. These effects are dampened by the offshoring-induced productivity effect. The second and third rows of Figure 2.5 compare the effects of offshoring on the labor demand elasticities with respect to the four variables under two trade openness regimes. When the trade openness is low (high trade cost), the offshoring cost decline raises labor demand elasticity, but when trade openness is high (low trade cost), the offshoring cost decline reduces labor demand elasticity. The lower trade cost promotes the manufactured goods' market competition, hence magnifies the productivity effect associated with offshoring activities.

Since greater trade openness raises labor demand elasticity with respect to domestic labor wage and enhances international demand spillover, it lowers the effects of demand shock on domestic real wage and hours worked. Intuitively, this labor demand elasticity increase implies that for a given increase in hours worked, the real wages rise by less. The greater demand spillover indicates that, for a given monetary expansion, the given increase in consumption demand in Home has weaker effects on Home hours worked. The combined effect of increased labor demand elasticity and strengthened effects of global demand spillover lead to subdued responses of real wage and hours worked to domestic demand shock.

4.2 Role of Financial Market Integration

International financial market integration reduces the responses of real exchange rate to exogenous disturbances, thereby dampening the effects of demand shock on domestic real wages and hours worked. To be more specific, when Home monetary expansion depreciates real exchange rate, the final-good producer level expenditure switching effect puts an upward pressure on Home real wage and hours worked. International financial market liberalization weakens the expenditure switching effect, hence lowers the upward pressure of monetary expansion on real wages and hours worked.

In sum, the above analysis indicates that international financial market and trade market integration reduces the effects of demand shock on domestic real wage and hours worked, while strengthening this integration's effects on Foreign real wage and hours worked. The cost composition effect implies that trade integration reduces the CPI inflation's exposure to domestic real wage, while raises its exposure to foreign real wage. The following analysis quantifies the interactions of these channels.

4.3 Quantitative Results

Figure 2.6 presents the impulse responses of the model to expansionary monetary policy shock (a negative one percent deviation in nominal interest rate) in Home under two extreme trade and international financial market openness regimes: The economy moves from nearly trade trade autarky and financial autarky to post 2005 trade regime and incomplete international financial market.[14] Increased international trade and financial openness weakens the effects of monetary policy disturbances on domestic inflation, real GDP, hours worked and real wages, and magnifies its effects on Foreign variables. The case 1 column in the upper left section of Table 2.1 quantifies the percentage changes of the peaks of impulse responses of these four variable. When trade liberalization is accompanied by international financial market liberalization, effects of monetary policy changes on output and inflation are dampened by 22%.

The other three columns in the upper left section of Figure 2.1 report the percentage changes of the peak impulse responses of output, inflation, real wages and hours worked from low trade openness regime to high trade openness regime under three

[14]Under post 2005 trade regime, values of trade cost τ, and the offshoring cost λ are chosen to match the import to GDP ratio at 17% and the intermediate imports to general imports at 30%, which corresponds to US trade pattern in 2005.

scenarios. Case 2 implies that under an incomplete international financial market, when the simultaneous decline in trade and offshoring costs moves the economy from nearly trade autarky to post 2005 trade regime, the effects of monetary policy shock on output and inflation are 15% lower. In case 3, the growth of trade is driven by the decline in trade cost alone. Comparing the results from case 2 and case 3 reveals that due to the induced productivity effect, offshoring can weaken the effects of trade openness on the output elasticity with respect to monetary policy shock. Yet, under baseline calibration, this effect is quantitatively small. Case 4 shows that under financial autarky, the effects of trade openness on the output elasticity with respect to monetary policy shock are negligible.

4.4 Robustness

Table 2.1 reports the quantitative results of the aforementioned four groups of exercise under three alternative sets of calibrations, with one parameter value changed in each set. The changed parameters are labor supply elasticity, the household's risk aversion coefficient and the trade elasticity, since the labor supply elasticity and the household's risk aversion coefficient affect the responsiveness of real wage and hours worked to demand changes, and trade elasticity affects the responsiveness of trade flow to relative production costs between two countries. These alternative parameter choices are given by: $\sigma = 6.37$ following Woodford (2007), $\eta = 2.33$ following Chetty et al. (2011), and $\theta = 1$ given that international macro literature tends to choose a low trade elasticity.

The model's qualitative implications on the connection of trade openness and effectiveness of monetary policy are not affected by these changed calibration choices.

The greater risk aversion and higher labor supply elasticity leads to lower volatility of the economy in response to demand shocks, hence the differences of the impulse responses to monetary shocks are smaller. With the changed risk aversion and labor supply elasticity, the decline in offshoring cost still weakens the effects of trade openness on output elasticity with respect to monetary policy shocks, since according to the first two rows of Figure 2.7, trade openness that involves offshoring leads labor demand elasticity to increase by less and a weaker international demand spillover.

The relative quantitative effects of the trade openness induced by falling trade cost, and the trade openness induced by falling offshoring cost can, nevertheless, differ according to the choice of trade elasticity. Under low trade elasticity, a simultaneous decline in trade cost and offshoring cost is more stabilizing for both output and inflation than the decline in trade cost alone does, since low trade elasticity implies greater complementarity among traded goods. Exporters' market shares are less affected by relative production cost, thereby limiting the offshoring cost reduction induced efficiency gain effect on output. The third row of Figure 2.7 provides the supportive evidence for this analysis, by showing that, under lower trade elasticity, trade openness that involves offshoring leads to a greater increase in labor demand elasticity and a greater demand spillover. When trade elasticity is low, the decline in offshoring cost magnifies the effects of trade openness on output elasticity with respect to monetary policy shocks.

5. Conclusion

This paper establishes a new fact that greater trade openness weakens the effects of the monetary policy changes on the industry-level output. The empirical analysis also suggests that the involvement of offshoring activities doesn't necessarily strengthens the impact of trade openness on the the effects of monetary policy changes. Based on these evidence, this paper provides an open economy New Keynesian model, which features heterogeneous manufacturing firms and one-wage offshoring from the advanced economy to the less developed one. The model implies that trade openness weakens the effects of monetary policy changes through dampening the responses of domestic labor market to monetary policy shocks. A simultaneous decline in trade cost and offshoring raises labor demand elasticity, while due to the offshoring induced productivity effect, when trade cost is low enough, the decline in offshoring cost alone reduces labor demand elasticity. This provides a possible explanation for the ambiguous role of offshoring status in determining the strength of the effects of trade openness on the effectiveness of monetary policy. The calibrated model shows that trade openness or financial openness weakens the effects of monetary policy changes, and the general equilibrium effect of the offshoring induced productivity effect is small.

FIGURE 2.1. Impulse responses of the model in response to unexpected positive technology shock.

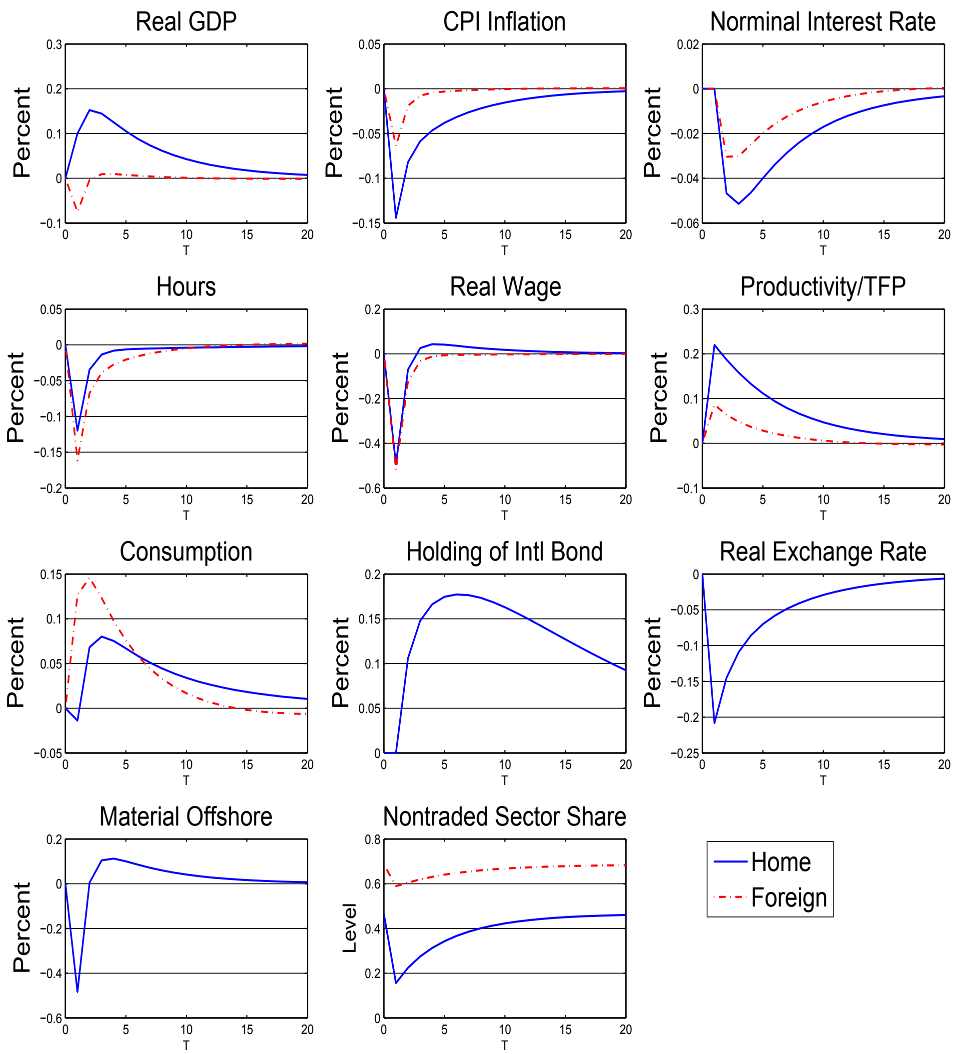


Figure 2.2. Impulse responses of the the model in response to unexpected expansionary monetary policy shock.

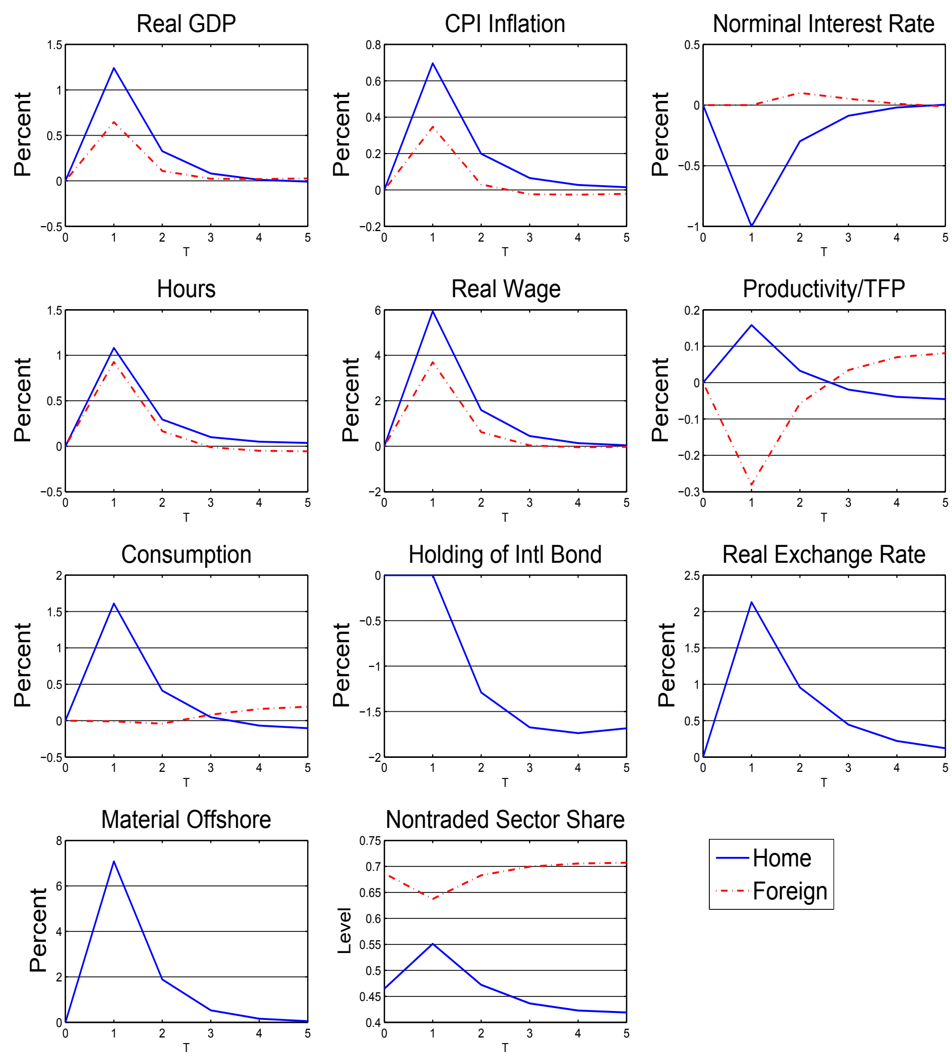
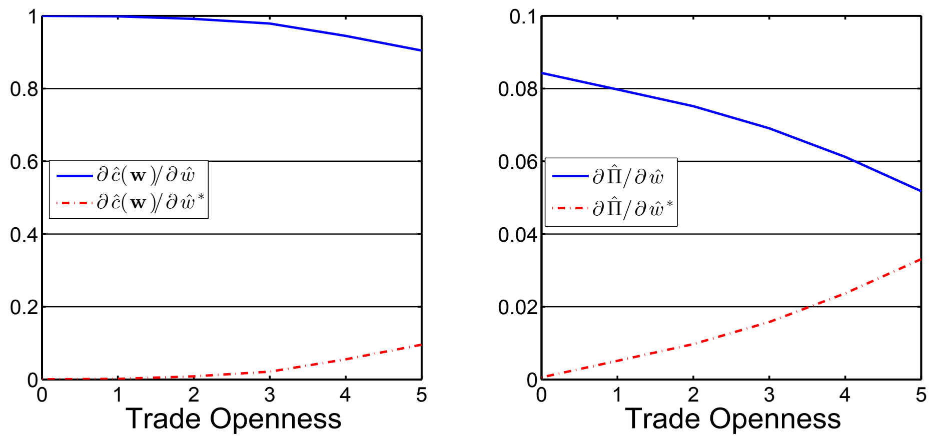
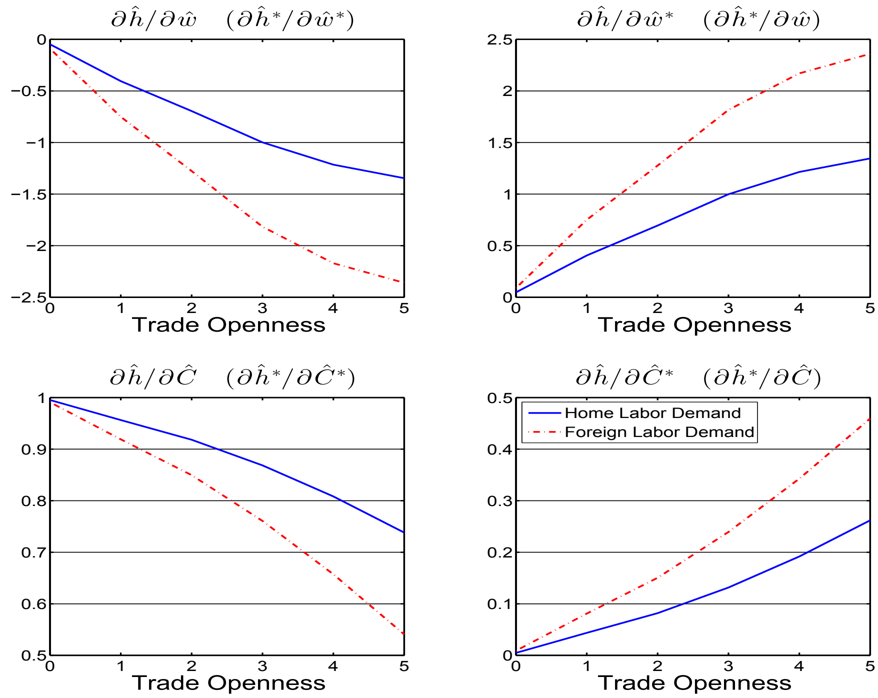


FIGURE 2.3. Elasticity of CPI Inflation w.r.t. Domestic and Foreign Labor Costs



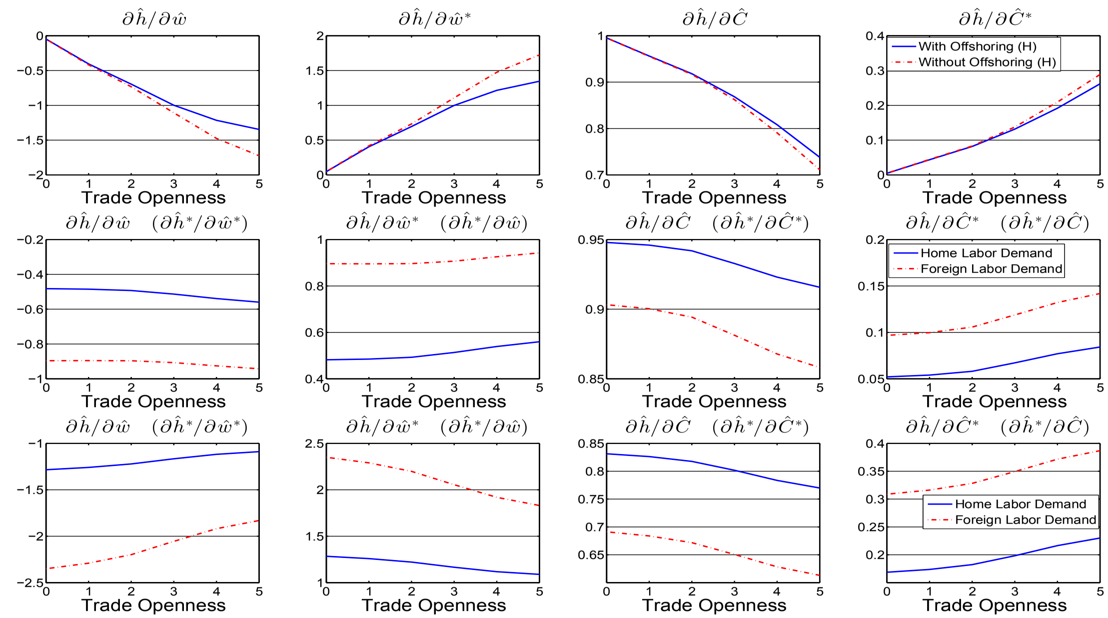
Note: The figure on the left shows the elasticity of Home manufacturing firms' unit input cost with respect to Home and Foreign real wages as functions of trade cost and offshoring cost. The figure on the right shows the elasticity of Home CPI inflation with respect to Home and Foreign real wages as functions of trade cost and offshoring cost. The X axis ticks from 0 to 5 correspond to six combinations of import to real GDP ratio and intermediate imports to total imports ratio, [(0.5%,0.5%), (3%, 3%), (6%, 12%), (10%, 17%), (15%, 28%), (21%, 37%)].

FIGURE 2.4. Labor Demand Elasticities: Baseline



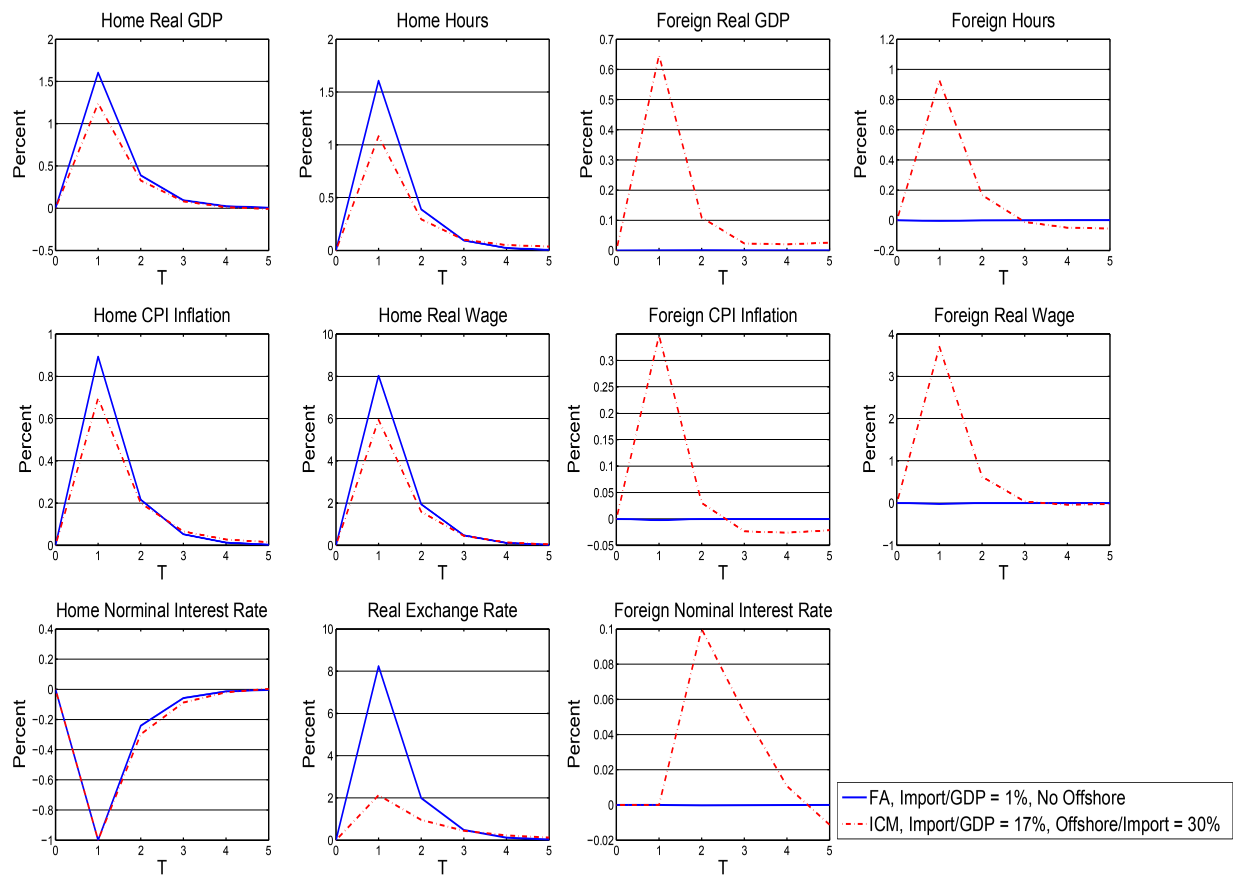
Note: This plot shows the elasticity of labor demand with respect to Home and Foreign real wage and Home and Foreign consumption demand at different trade openness regimes. The X axis ticks from 0 to 5 correspond to six combinations of import to real GDP ratio and intermediate imports to total imports ratio, [(0.5%,0.5%), (3%, 3%), (6%, 12%), (10%, 17%), (15%, 28%), (21%, 37%)].

FIGURE 2.5. Labor Demand Elasticities: Baseline Counterfactuals



Note: This figure shows the relationship between labor demand elasticities and trade cost as well as offshoring cost. The four panels in the first row compare the case 1, in which growth of trade is driven by decline in trade cost alone, and the case 2 in which growth of trade is trade by both decline in trade cost and offshoring cost. For case 1, X axis ticks from 0 to 5 correspond to import to GDP ratio [0%, 3%, 6%, 10%, 15%, 21%], while for case 2, X axis ticks from 0 to 5 correspond to six combinations of import to real GDP ratio and the ratio of intermediate imports to total imports, [(0%, 0%), (3%, 3%), (6%, 12%), (10%, 17%), (15%, 28%), (21%, 37%)]. The eight panels in the second and the third row compare the case 3, in which, given a high trade cost, the growth of trade is driven by decline in offshoring cost alone, and the case 4, in which given a low trade cost, the growth of trade is driven by decline in offshoring cost alone. For case 3, X axis ticks from 0 to 5 correspond to six combinations of import to real GDP ratio and the ratio of intermediate imports to total imports, [(4%,0%), (4%, 7%), (4.3%, 20%), (5%, 40%), (6%, 56%), (7%, 64%)], and for case 4, they correspond to [(12%,0%), (13%, 7%), (14%, 20%), (16%, 40%), (18%, 56%), (20%, 64%)].

FIGURE 2.6. Impulse Responses: Alternative International Financial Market



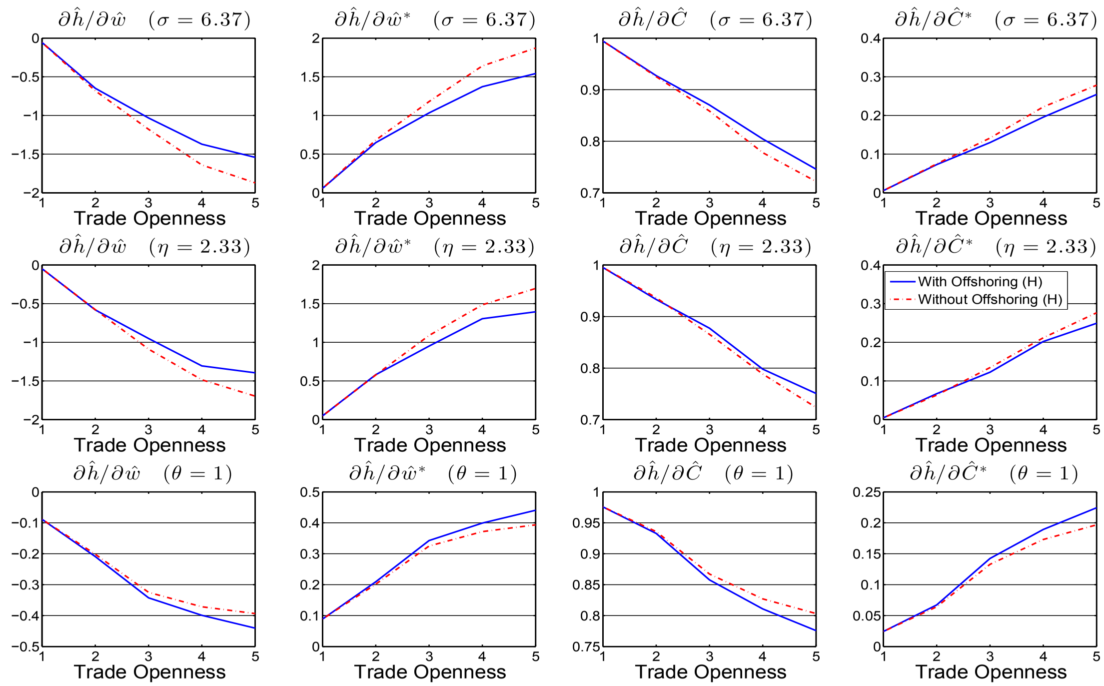
Note: Impulse responses of the model under trade autarky and under financial autarky, and the model under incomplete international financial market and modern trade regime in response to 1% unexpected expansionary monetary policy shock.

Table 2.1. Quantitative Results Table

	Baseline				$\sigma = 6.37$			
Variables	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
Output Y	-0.2249	-0.1515	-0.1546	-0.0011	-0.1312	-0.0955	-0.097	-0.0021
Inflation Π	-0.2203	-0.1468	-0.1452	0.0387	-0.1384	-0.0773	-0.0764	0.0141
Hours Worked h	-0.3271	-0.2272	-0.2256	0.0441	-0.0679	-0.0606	-0.0695	0.0388
Real Wage w	-0.2597	-0.1738	-0.1725	0.0351	-0.1489	-0.0891	-0.0873	0.0137
	$\eta = 2.33$				$\theta = 1$			
Variables	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
Output Y	-0.2005	-0.1644	-0.1674	-0.001	-0.1539	-0.1089	-0.0915	-0.0037
Inflation Π	-0.1307	-0.1005	-0.1025	0.0383	-0.1379	-0.0758	-0.0595	0.1717
Hours Worked h	-0.2709	-0.2264	-0.2278	0.043	-0.212	-0.129	-0.1033	0.2021
Real Wage w	-0.1649	-0.1306	-0.1313	0.0241	-0.1677	-0.0994	-0.0795	0.1611

Note: This table reports the percentage changes of the listed variables' peak impulse responses from low trade openness regime to high trade openness regime. The exercise is conducted using four different sets of calibrations: the baseline calibration and changing the calibrated values of risk aversion coefficient σ, the measure of labor supply elasticity η, and the trade elasticity θ, one for each time. 'Case 1' compares the results of the model under financial autarky and import to GDP ratio at 1% as well as no intermediate imports, and the results of the model under incomplete market and import to GDP ratio at 17% as well as the intermediate imports to total imports ratio at 30%. 'Case 2' compares the results of the model under incomplete market and import to GDP ratio at 1% as well as no intermediate imports, and the results of the model under incomplete market and import to GDP ratio at 17% as well as the intermediate imports to total imports ratio at 30%. 'Case 3' compares the results of the model under incomplete market and import to GDP ratio at 1% as well as no intermediate imports, and the results of the model under incomplete market and import to GDP ratio at 17% as well as no intermediate imports. 'Case 4' corresponds to model under financial autarky and import to GDP ratio at 1% as well as no intermediate imports, and the results of the model under financial autarky and import to GDP ratio at 17% as well as the intermediate imports to total imports ratio at 30%.

FIGURE 2.7. Labor Demand Elasticities: Robustness



Note: This figure shows the relationship between Home labor demand elasticities and trade cost as well as offshoring cost from the model under three sets of calibrations, with one parameter value changing from baseline scenario each time. Each row reports the results of the model under one set of parameterization, and it compares the Home labor demand elasticities computed from model, in which the decline of trade cost drives the growth of trade, and the Home labor demand elasticities computed from model, in which the decline of trade cost and the decline of offshoring cost drive the growth of trade. For the former scenario, X axis ticks from 1 to 5 correspond to five combinations of import to real GDP ratio and the ratio of intermediate imports to total imports, [(0%, 0%), (5%, 0%), (10%, 0%), (15%, 0%), (20%, 0%)]. For the latter scenario, X axis ticks from 1 to 5 correspond to five combinations of import to real GDP ratio and the ratio of intermediate imports to total imports, [(0%, 0%), (5%, 7%), (10%, 14%), (15%, 21%), (20%, 28%)].

CHAPTER 3

Import Competition and Changing U.S. Manufacturing Employment Structural Dynamics

1. Introduction

U.S. labor market during the past three recessions has witnessed two new phenomena. Firstly, job losses mainly concentrate among the middle-skill workers, while the recovery of the middle-skill jobs is slow and a large fraction of the losses is permanent, e.g. Foote and Ryan (2015) and Jaimovich and Siu (2012). Secondly, the recovery of employment is slower than that in previous cases, e.g. Galí, Smets, and Wouters (2012). Both phenomena suggest that U.S. labor market may undergo structural changes.

As an important component of U.S. labor force, manufacturing employees have experienced similar changing dynamics since 1990. Figure 3.1 shows the total manufacturing employees, production-nonsupervisory employees and total employees minus production-nonsupervisory employees from 1959 to 2015. This paper refer the last group as non-production employees, which include low-skilled service employees and managerial employees. Both types of manufacturing employees experienced rapid recovery in pre-1990 recessions, while their recovery is much slower in post-1990 recessions, and the recovery has never been fully achieved. In addition, starting from early

2000s the total manufacturing employees exhibit a significant downward trend which is mainly driven by the decline in the production and nonsupervisory employees.

This paper seeks to provide a detailed analysis of the evolution of the manufacturing employment's structural dynamics. It estimates the time-varying elasticities of industry-level employees, production and non-production employees with respect to demand, supply as well as monetary policy shocks, and relates these elasticities to industry characteristics in order to further explore the determinants of the structural dynamics of industry-level employees.

The empirical model is a factor augmented structural vector autoregressive model with time-varying parameters and stochastic volatility (TVP-FAVAR). The model specification is essentially the same as that in Baumeister, Liu, and Mumtaz (2013) and Ellis, Mumtaz, and Zabczyk (2014), while these two papers focus mainly on disaggregate price dynamics in U.S. (Baumeister et al. (2013)) and U.K. (Ellis et al. (2014)).

This paper estimates the TVP-FAVAR model instead of the TVP-VAR model for two reasons. Firstly, as it is stated in Bernanke, Boivin, and Eliasz (2005)(BBE henceforth) and Benati and Surico (2009), omitted-variable problem can potentially lead to a substantial bias in estimating the effect of monetary policy changes on the real economy using a small or medium scale VAR model. In addition, the measurement error associated with the variables included in the VAR system can also reduce the precision of the estimated dynamic relationships. FAVAR framework provides a possible solution to these problems by incorporating extra information to the VAR system in the form of common factors, which extracts information from a large panel of economic data. Secondly, the specification of the FAVAR provides a convenient framework to analyze structural dynamics of industry-level data.

There has been a growing literature that scrutinizes various aspects of changing structural dynamics of the U.S. economy. Cogley and Sargent (2005) and Primiceri (2005) estimated small scale time-varying parameter VAR models, which include inflation, unemployment and short-term interest rate. Both find clear evidence that the autoregression coefficients, and the variance of the disturbances have changed. Cogley and Sargent (2005) shows that the inflation persistency has increased. Primiceri (2005) finds monetary policy has reacted more aggressively to fluctuations in macro fundamentals, but plays a minor role in explaining the less effectiveness monetary policy since 1980s, when compared with changing volatility of structural shocks. Galí and Gambetti (2009) documents the changed structural dynamics of hours and labor productivity to technology shocks and non-technology shocks. All this evidence on the changing structural dynamics of aggregate macro series motivates this paper to estimate FAVAR with time varying parameters instead of constant ones.

In terms of methodology, this paper is related with Negro and Otrok (2008), which is the first to incorporate time-varying factor loadings and stochastic volatility into a dynamic factor model. They use the model to study the evolution in international business cycles, and report a decline in the volatility across a panel of 19 countries. Benati and Surico (2009) uses time-varying parameter FAVAR to explore the evolution of inflation in thirteen industrial countries.

The organization of the rest of the paper is as follows. Section 2 presents the econometric model and its estimation algorithm. Section 3 lists the sources of the data. Section 4 discusses the directions of future works.

2. Empirical Methodology

This section describes the TVP-FAVAR model, the structural shocks' identification strategy and the estimation procedures.

2.1. The Empirical Model. The time-varying parameter FAVAR model has the standard state space representation. The observation equation relates the vector of informational variables, X_t, to the vector of common factors, C_t, which is given by

$$X_t = \Phi C_t + \theta_t \tag{2.1}$$

where X_t is an $N \times 1$ vector. The informational variables include measures on real activities, asset prices, inflation and industry-level employment in U.S. manufacturing sector. The vector of common factors C_t is $(K+1)\times 1$, and it contains K latent factors $F_t = [F_{1,t}, \cdots, F_{K,t}]^T$, and an observable factor, Y_t. As in BBE, the observable factor is the federal funds rate, since both the econometrician and the monetary authority can observe the federal funds rate, and regard it as a measurement of monetary policy stance. That is $C_t = [F_{1,t}, \cdots, F_{K,t}, Y_t]^T$. Φ is a $N\times(K+1)$ matrix of factor loadings. The error term θ_t is a $N \times 1$ vector that follows a multivariate normal distribution $N(0, G)$. Since $\theta_{i,t}$, for $i = 1, \cdots, N$, are assume to be independent across equations, G is a diagonal matrix.

The transitional equation is a second order VAR with time varying parameters and a time varying variance covariance matrix for the innovation terms, which is given by

$$C_t = \beta_{1,t}C_{t-1} + \beta_{2,t}C_{t-2} + \mu_t \tag{2.2}$$

where $\beta_{i,t}$, for $i = 1$ and 2, are $(K+1)\times(K+1)$ matrices of time varying coefficients. μ_t is a $(K+1)\times 1$ vector of heteroskedastic shocks with time varying variance covariance matrix Ω_t, which can be factorized as

$$\Omega_t = A_t^{-1}\Sigma_t\Sigma_t'(A_t^{-1})' \tag{2.3}$$

where A_t is a lower triangular matrix with ones along its diagonal, and Σ_t is a diagonal matrix with standard deviation of structural disturbances along its diagonal and zeros elsewhere. With this decomposition, the transition equation can be rewritten as

$$C_t = \beta_{1,t}C_{t-1} + \beta_{2,t}C_{t-2} + A_t^{-1}\Sigma_t\epsilon_t \tag{2.4}$$

Let B_t be a $2(K+1)^2 \times 1$ vector that collects all the elements in $\beta_{i,t}$ for $i = 1$ and 2, α_t be a $\frac{K(K+1)}{2} \times 1$ vector that collects all the non-zero elements of A_t, and σ_t be a $(K+1) \times 1$ vector that collects the diagonal elements of Σ_t. Following Primiceri (2005), these time varying parameters evolve as random walks

$$B_t = B_{t-1} + \nu_t \tag{2.5}$$

$$\alpha_t = \alpha_{t-1} + \xi_t \tag{2.6}$$

$$\log(\sigma_t) = \log(\sigma_{t-1}) + \eta_t \tag{2.7}$$

All the innovations in equations 2.1 2.4 2.5 2.6 and 2.7 are assumed to be serially uncorrelated and jointly normally distributed with the variance covariance matrix given by

$$V = \text{var}\left(\begin{bmatrix} \theta_t \\ \epsilon_t \\ \nu_t \\ \xi_t \\ \eta_t \end{bmatrix}\right) = \begin{bmatrix} G & 0_{N\times(K+1)} & 0_{N\times M} & 0_{N\times(K+1)} & 0_{N\times(K+1)} \\ 0_{(K+1)\times N} & I_{K+1} & 0_{(K+1)\times M} & 0_{(K+1)\times(K+1)} & 0_{(K+1)\times(K+1)} \\ 0_{M\times N} & 0_{M\times(K+1)} & Q & 0_{M\times(K+1)} & 0_{M\times(K+1)} \\ 0_{(K+1)\times N} & 0_{(K+1)\times(K+1)} & 0_{(K+1)\times M} & S & 0_{(K+1)\times(K+1)} \\ 0_{(K+1)\times N} & 0_{(K+1)\times(K+1)} & 0_{(K+1)\times M} & 0_{(K+1)\times(K+1)} & W \end{bmatrix}$$

where $0_{m,n}$ is $m \times n$ dimension matrix of zeros, $M = 2(K+1)^2$, and I_{K+1} is a $K+1$ dimension identity matrix. G, Q, S and W are positive semidefinite matrices. The assumptions on S and W are the same as those in Primiceri (2005): S is block diagonal and W is a diagonal matrix.

2.2. Estimation Procedure. The model estimation uses standard MCMC techniques, and it takes three steps. The first step is to take factors as given and estimate the transition equation 2.4. This boils down to estimating a time-varying parameter VAR using the method that is outlined in Primiceri (2005). The coefficients of the transition equation, B_t, and the off-diagonal elements of the covariance matrix, α_t are simulated using multi-move Gibbs sampling method, that is developed in Carter and Kohn (1994). The simulation of the volatility parameters follows Kim et al. (1998), using seven mixture of normals to approximate the log of Chi-squared distribution of the residual terms in the transformed observation equation.

The next step is to draw the hyperparameters $\{\Phi, G, Q, S, W\}$ from their respective posterior distributions. Φ follows normal distribution, G follows inverse Gamma distribution, and Q, S, W follow inverse-Wishart Distribution. The last step is to simulate factors in line with BBE and Kim and Nelson (1999).

2.3. Identification of Structural Shocks. Given the estimated time-varying VAR equation 2.4, one can calculate the monthly impulse responses of common factors $C_t = [F_{1,t}, \cdots, F_{K,t}, Y_t]^T$, which are denoted as $\hat{C}^J_{t+s} = [\hat{F}^J_{1,t+s}, \cdots, \hat{F}^J_{K,t+s}, \hat{Y}^J_{t+s}]^T$, where s is the horizon and J indicates the type of structural shock. Once these are available, it's straightforward to compute the time-varying impulse responses of all the informational variables with the observation equation 2.1, which is given by

$$\begin{pmatrix} \hat{X}^J_{1,1,t+s} \\ \vdots \\ \hat{X}^J_{N,1,t+s} \\ \hat{Y}^J_{t+s} \end{pmatrix} = \begin{bmatrix} \Phi_{1,1} & \cdots & \Phi_{1,K+1} \\ \vdots & \ddots & \vdots \\ \Phi_{N,1} & \cdots & \Phi_{N,K+1} \\ & 0_{1,K+1} & 1 \end{bmatrix} \times \begin{pmatrix} \hat{F}^J_{1,t+s} \\ \vdots \\ \hat{F}^J_{K,t+s} \\ \hat{Y}^J_{t+s} \end{pmatrix}$$

Due to the presence of time-varying parameters in the VAR equation, the computation of the impulse responses has to take into account the uncertainty associated with drifting parameters in the VAR equation over the impulse response horizon. The formula to compute impulse response of the variables in the transition equation is given by

$$E[C_{t+s}|\Theta_{t+s}, \delta^J_t] - E[C_{t+s}|\Theta_{t+s}] \tag{2.8}$$

where $\Theta_t = \{B_t, \alpha_t, \sigma_t, Q, S, W\}$ contains all the parameters in the VAR equation, and δ^J is a type J structural shock. Equation 2.8 computes the expectation of the deviation of endogenous variable C driven by structural shock δ^J_t conditional on time-varying parameters. The conditional expectations are calculated using Monte Carlo integration for 1,000 replications of Gibbs sampler, which is outlined in Koop et al. (1996).

This paper uses sign-restriction identification scheme to identify three structural shocks: an aggregate demand shock, an aggregate supply shock, and a monetary policy shock. As a structural shock identification strategy, sign restrictions were first introduced by Faust (1998) and Uhlig (2005) to identify monetary policy shocks, and is widely used in more recent literature to identified other types of shocks, such as aggregate supply shocks, oil shocks, and exchange rate shocks, e.g. Peersman and Straub (2009) and Hau and Rey (2004).

The theoretical motivation of the sign restriction in this paper is a standard NK model, which is estimated using maximum likelihood, as described in Ireland (2004). The model implied restrictions on the contemporaneous impulses of the model to three structural shocks are: 1) positive aggregate demand shocks raise the growth of industrial production, CPI inflation and federal funds rate; 2) positive supply shocks raise the growth of industrial production, while drives down CPI inflation, which results in an ambiguous effect on federal funds rate; 3) Expansionary monetary policy shocks, which leads to a decrease in federal funds rate has positive effect on the growth of industrial production and CPI inflation. These sign restrictions are summarized in Table 3.1.

The way to apply these sign restrictions is as following. We can draw a $(K+1)\times(K+1)$ matrix from multivariate normal distribution $N(0_{K+1,1}, I_{(K+1)\times(K+1)})$, and take a QR decomposition of this matrix to get a orthonormal rotation matrix P that satisfies $PP' = I$. Let $\tilde{A}_t = A_t^{-1}P$. Given equation 2.3, we now have $\Omega_t = \tilde{A}_t\Sigma_t\Sigma_t'(\tilde{A}_t)'$. This household transformation provides an infinite many candidate impulse responses. We can examine if these impulse responses satisfy sign restrictions.

If they do, the rotation matrix P_t will be stored. This procedure is repeated until we have collect 100 rotation matrices.

3. Data Description

This paper uses two balanced monthly panel data of U.S. economy to estimate the time-varying parameter FAVAR model. The data series run from January 1990 to October 2005. The choice of the starting date reflects the date, from which most of the monthly industry-level employment data become available. The ending date is confined by the availability of macro indicators that are used in BBE. All the data are transformed into stationary time series.

BBE contains 111 series of macro indicators, which include measures on output, employment, asset prices and interest rates. The two datasets expand BBE by including industry-level employee data in Employment, Hours and Earnings dataset, which is collected by BLS Current Employment Statistics (CES) program, and can be downloaded from Econ Stats website. The first dataset augment BBE macro indicators with 24 'All Employees' data series, and in total, it has 135 series. The 24 'All Employees' data series cover 60% of manufacturing sector employees over the sample period. The second dataset adds 18 'Production and Nonsupervisory Employees' series, and 18 non-production employee series to BBE macro indicators, and it totally includes 147 data series. The detailed list of the data series is given in the Appendix C.

The data that are used to construct industry characteristic measures, i.e. capital stock and capital expenditure, are obtained from NBER-CES dataset. The industry-level openness measures are obtained from NBER international trade and finance dataset.

4. Future Works

A possible direction of future work is to compare the evolution of structural dynamics of production employees and non-production employees, since job polarization literature, e.g. Foote and Ryan (2015) and Jaimovich and Siu (2012) as well as the rough Figure 3.1 reveals that these two types of employees exhibit different dynamic pattern. Since industry characteristic crucially determines the nature of the structural changes an industry experiences, these potential diverse responses of industry-level production and non-production employees with respect to structural shocks can be related to industry characteristic measures.

Figure 3.2, 3.3 and 3.4 present an example on how labor-intensity[1] influences the dynamics of total, production as well as non-production employees. For all types of employees, employees in labor-intensive industries tend to exhibit more dramatic changes in dynamic pattern over the sample period than those in capital intensive industries do. This echoes the findings in recent empirical literature, that import competition from China has induced plants to shift from labor-intensive industries to capital intensive ones, and in the meanwhile removes middle-skill jobs, Pierce and Schott (2012).

[1]The detailed list of industries that belong to labor intensive industries is given in Table C.1

TABLE 3.1. Sign Restrictions

Shocks	IP Growth	CPI Growth.	Federal Funds Rate.
Demand Shocks	+	+	+
Supply Shocks	+	-	
Monetary Policy Shocks	+	+	-

Note: IP stands for Industrial Production.

FIGURE 3.1. Manufacturing Employees

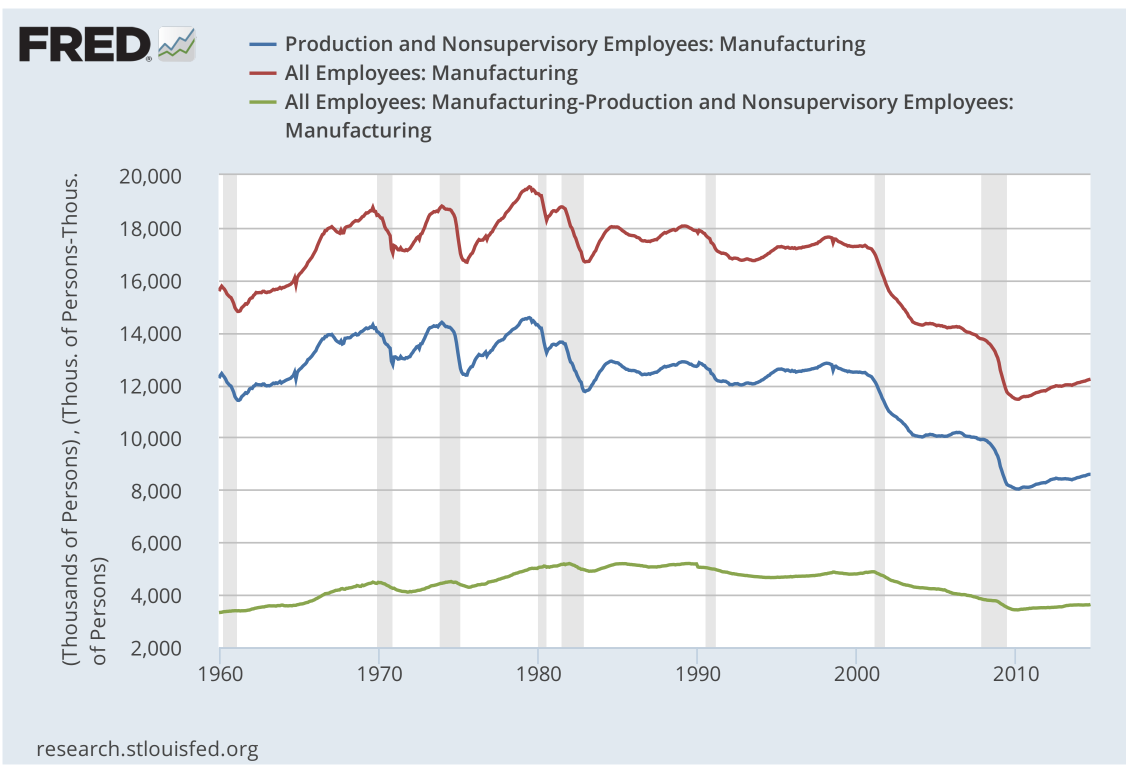


FIGURE 3.2. Manufacturing Total Employees

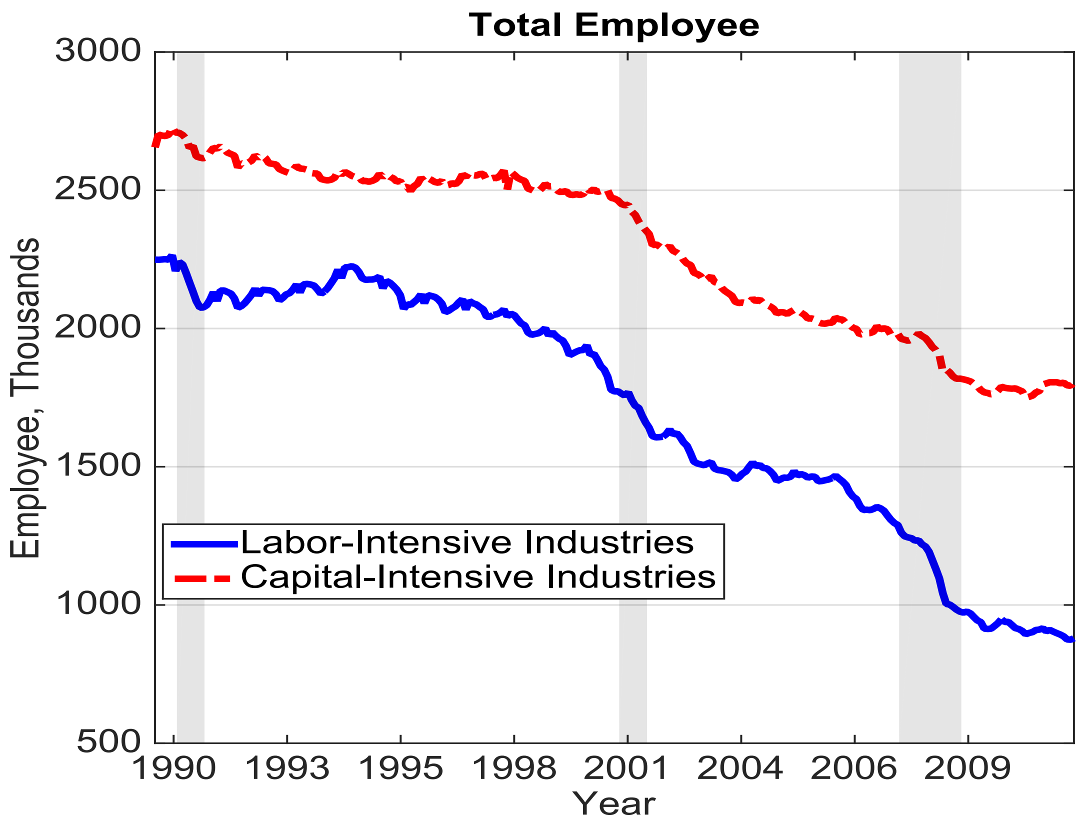


FIGURE 3.3. Manufacturing Production Non-supervisory Employees

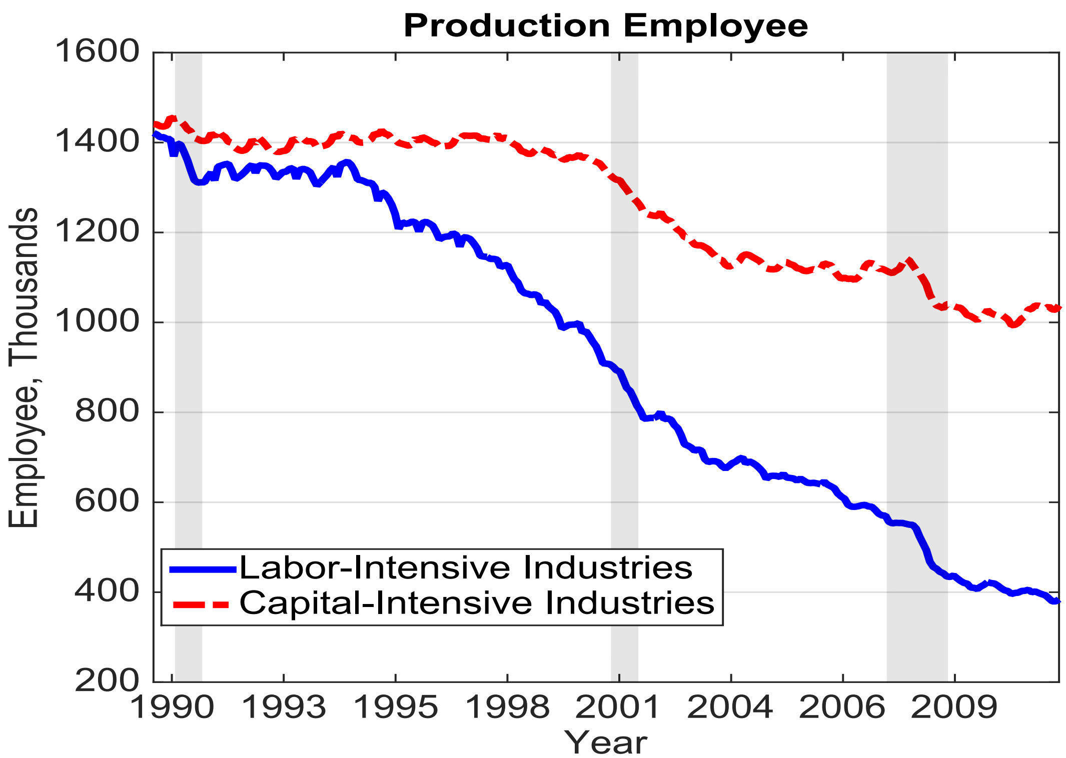
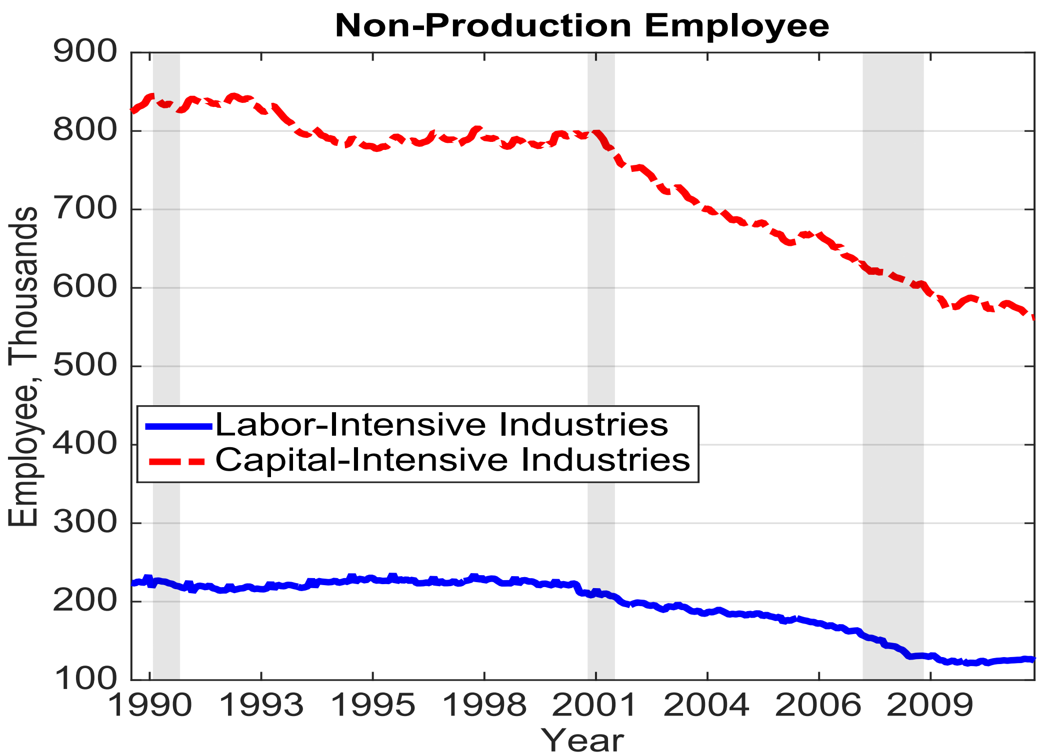


FIGURE 3.4. Manufacturing Non-production Employees



APPENDIX A

Trade Liberalization and Effectiveness of Monetary Policy: Industry-Level Evidence

1. Data Description

The industry-level output measure is the industry-level total value added from NBER-CES Manufacturing Industry Database, which provides annual data for 459 industries at the 4-digit SIC level for the sample period in this paper, from 1972 to 2005. To construct the measure of offshoring, this paper also uses material cost of each sector from this dataset. The two openness measures are

$$\text{Import Penetration Ratio}_i = \frac{\sum_t \ \text{Imports}_{i,t}}{\sum_t \ \text{Shipments}_{i,t} - \text{Exports}_{i,t} + \text{Imports}_{i,t}}$$

$$\text{Offshoring}_i = \frac{\sum_t \ \text{Non-energy Intermediate Imports}_{i,t}}{\sum_t \ \text{Material Cost}_{i,t}}$$

where subscript i indicates industry i and subscript t indicates year t.

The measures for imports, value of shipments and exports are available for 458 industries at the 4-digit SIC level in 'low-age country share' dataset on Peter Schott's website. The non-energy intermediate imports' measure is constructed following Schott (2004) using 10 digit HS level U.S. import data.

The summary statistics of the openness measures are given in Table 1.1. The reason why the sample size is smaller than 458 is that industries that have 1) intermediate imports more than total imports, 2) exports larger than value of shipment and 3) non-stationary estimated VAR are dropped from the sample. The remaining sample accounts for around 95% of total manufacturing employment.

APPENDIX B

Globalization, Offshoring and Monetary Control

1. Trade Pattern and Intermediate Good Price Index

Given intermediate-good producers' idiosyncratic productivity following Frechet distribution, I can get that a home intermediate good producer j presents domestic market with the price distribution $G_{h,t}(p)$:

$$\begin{aligned} G_{h,t}(p) &= \Pr\{p_{h,m,t} < p_t\} \\ &= \Pr\{\frac{C_t(\mathbf{W_t})}{Z_t z_t(i)} < p_t\} \\ &= 1 - e^{-Z_t[\frac{C_t(\mathbf{W_t})}{p_t}]^{-\theta}} \end{aligned}$$

The price distribution of Foreign good i in home market is given by

$$G_{f,t}(p_t) = 1 - e^{-Z_t^*[\frac{W_t^* \mathcal{E}_t \tau}{p_t}]^{-\theta}}$$

Given that $p_t(i)$ is the price of good i in home market unless both sources charge price higher than $p_t(i)$, the price distribution of good i in home market is

$$\begin{aligned} G_t(p) &= [1 - G_{h,t}(p)][1 - G_{f,t}(p)] \\ &= e^{\{-Z_t[\frac{C_t(\mathbf{W_t})}{p}]^{-\theta} - Z_t^*[\frac{W_t^* \mathcal{E}_t \tau}{p}]^{-\theta}\}} \\ &= e^{-\phi_t [p]^{\theta}} \end{aligned}$$

where $\phi_t = Z_t C_t(\mathbf{W_t})^{-\theta} + Z_t^*(W_t^*\tau\mathcal{E}_t)^{-\theta}$. ϕ is critical to subsequent analysis. It summarizes how 1) labor costs, 2) technology statuses, and 3) trade costs in both countries affect price distribution of home intermediate goods. International trade provides a channel for Foreign factors to influence domestic prices.

Recall that the price index $P_{m,t}$ given by equation 2.24,

$$\begin{aligned}
P_{m,t} &= [\int_0^1 p_{m,t}(j)^{1-\mu}dj]^{\frac{1}{1-\mu}} \\
&= [\int_0^\infty p^{1-\mu}dG_t(p)]^{\frac{1}{1-\mu}} \\
&= [\int_0^\infty p^{1-\mu}de^{-\phi_t[p]^\theta}]^{\frac{1}{1-\mu}} \\
&= [\int_0^\infty p^{1-\mu+\theta}(-\phi_t)e^x\frac{dx}{x}]^{\frac{1}{1-\mu}} \\
&= [\int_0^\infty \phi_t^{\frac{\mu-1}{\theta}} x^{\frac{1-\mu+\theta}{\theta}} e^x\frac{dx}{x}]^{\frac{1}{1-\mu}} \\
&= \phi_t^{-\frac{1}{\theta}}\Gamma(\frac{1-\mu+\theta}{\theta})^{\frac{1}{1-\mu}}
\end{aligned}$$

where $x = -\phi_t p^\theta$, and $\Gamma() > 0$ is Gamma function,[1] and $\Gamma(\frac{1-\mu+\theta}{\theta})$ is a constant.

I can get the Foreign material good bundle in the similar way, which is given by

$$P_{m,t}^* = [Z_t C_t(\mathbf{W_t})^{-\theta} + Z_t^*(W_t^*\tau\mathcal{E}_t)^{-\theta}]^{-\frac{1}{\theta}}[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}}$$

Since there are a continuum of intermediate goods/ producers, the probability that a home producer provides the lower price in home (Foreign) market is the same as the home producer's share in home (Foreign) market. Then the home producers'

[1]The expression of Gamma function is $\Gamma(t) = \int_0^\infty x^t e^x \frac{dx}{x}$

domestic market share $S_{h,t}$ is

$$\begin{aligned} S_{h,t} &= \Pr\{p_{h,m,t} < p_{f,m,t}\} \\ &= \int_0^\infty [1 - G_{f,t}(p)] dG_{h,t}(p) \\ &= \int_0^\infty e^{-\phi_t} Z_t C_t(\mathbf{W_t})^{-\theta} dp_t^\theta \\ &= \frac{Z_t C_t(\mathbf{W_t})^{-\theta}}{\phi_t} \end{aligned}$$

Home firm's Foreign market share is given by

$$S_{f,t} = \frac{Z_t[C_t(\mathbf{W_t})\tau/\mathcal{E}_t]^{-\theta}}{Z_t[C_t(\mathbf{W_t})\tau/\mathcal{E}_t]^{-\theta} + Z_t^* W_t^{*-\theta}}$$

2. Calibration Table

Table B.1. Calibration

Preference Parameters	Value
β: household's discount factor	0.99
η: $\frac{1}{\eta-1}$ is the Frisch labor supply elasticity	5
σ: risk aversion coefficient	1
Technology Parameters	**Value**
ψ: international financial intermediation cost	0.01
ϕ: measures the magnitude of price adjustment cost	33
μ: elasticity of substitution between different variety of manufactured input	3.8
θ: trade elasticity	4
γ: elasticity of substitution between final goods	3.8
ρ_z: persistency of technology shock	0.83
Monetary policy	**Value**
$\tilde{\Pi}$: steady state inflation	1.0086
ρ_ν: persistency of monetary policy shock	0.76
Φ_π: stance of monetary policy with respect to inflation	1.5
Φ_Y: stance of monetary policy with respect to real GDP	0.5
$\mu_z = 1$ and $\mu_z^* = 0.07$: Home and Foreign steady state values of aggregate technology	

3. The Full Model

Incomplete Market

The equilibrium conditions of the model under incomplete market are listed as following, which include twenty-two equations in twenty-two endogenous variables

$$C_t, C_t^*, r_t, r_t^*, i_t, h_t, h_t^*, \Pi_t, \Pi_t^*, w_t, w_t^*, c_t(\mathbf{w_t}), Y_t, Y_t^*, Y_{GDP,t}, Y_{GPD,t}^*, p_{m,t}, p_{m,t}^*, S_{h,t}, S_{f,t}, b_{I,t}, Q_t$$

among which there are three pre-determined variables $b_{I,t}, r_t, r_t^*$.

Euler Equation (Domestic Bond)

$$\beta E[(\frac{C_{t+1}}{C_t})^{-\sigma}\frac{r_t}{\Pi_{t+1}}] = 1 \qquad \text{and} \qquad \beta E[(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}\frac{r_t^*}{\Pi_{t+1}^*}] = 1$$

Euler Equations (International bond)

$$\beta E[(\frac{C_{t+1}}{C_t})^{-\sigma}\frac{i_t}{\pi_{t+1}}] = 1 + \psi(b_{I,t} - \bar{b}_I)$$

$$\beta E[(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}\frac{i_t}{\pi_{t+1}}\frac{Q_t}{Q_{t+1}}] = 1 + \psi(\frac{-b_{I,t}}{Q_t} - \bar{b}_I)$$

Labor Supply

$$h_t^{\eta-1} = \frac{w_t}{C_t^\sigma} \qquad \text{and} \qquad h_t^{*\eta-1} = \frac{w_t^*}{C_t^{*\sigma}}$$

Home Manufacturing Sector Input Cost

$$c_t(\mathbf{w_t}) = w_t^* Q_t F(1,\lambda) + \int_{w_t^* Q_t}^{w_t} x dF(x, \frac{\lambda}{w_t^* Q_t}) + w_t[1 - F(w_t, \frac{\lambda}{w_t^* Q_t})]$$

Manufactured Good Price Index

$$p_{m,t} = [Z_t c_t(\mathbf{w_t})^{-\theta} + Z_t^*(w_t^* \tau Q_t)^{-\theta}]^{-\frac{1}{\theta}}[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}}$$

$$p^*_{m,t} = \{Z_t[\frac{c_t(\mathbf{w_t})\tau}{Q_t}]^{-\theta} + Z^*_t w^{*-\theta}_t\}^{-\frac{1}{\theta}}[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}}$$

Home Manufacturing Firms' Market Shares

$$S_{h,t} = \frac{Z_t c_t(\mathbf{w_t})^{-\theta}}{Z_t c_t(\mathbf{w_t})^{-\theta} + Z^*_t(w^*_t Q_t\tau)^{-\theta}} \quad \text{and} \quad S_{f,t} = \frac{Z_t[\frac{c_t(\mathbf{w_t})\tau}{Q_t}]^{-\theta}}{Z^*_t w^{*-\theta}_t + Z_t[\frac{c_t(\mathbf{w_t})\tau}{Q_t}]^{-\theta}}$$

Labor Demand conditions

$$p_{m,t}S_{h,t}Y_t + p^*_{m,t}S_{f,t}Y^*_t Q_t = c_t(\mathbf{w_t})\frac{h_t}{1-F(w_t, \frac{\lambda}{w^*_t Q_t})}$$

$$p_{m,t}(1-S_{h,t})Y_t + p^*_{m,t}Q_t(1-S_{f,t})Y^*_t = w^*_t h^*_t Q_t + w_t h_t - c_t(\mathbf{w_t})\frac{h_t}{1-F(w_t, \frac{\lambda}{w^*_t Q_t})}$$

New Keynesian Philips Curve

$$1 = \frac{\gamma}{\gamma-1}p_{m,t} - \frac{\phi}{\gamma-1}(\frac{\Pi_t}{\Pi}-1)\frac{\Pi_t}{\Pi} + \beta\frac{\phi}{\gamma-1}E[(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{\Pi_{t+1}}{\Pi}-1)\frac{\Pi_{t+1}}{\Pi}\frac{Y_{t+1}}{Y_t}]$$

$$1 = \frac{\gamma}{\gamma-1}p^*_{m,t} - \frac{\phi}{\gamma-1}(\frac{\Pi^*_t}{\Pi}-1)\frac{\Pi^*_t}{\Pi} + \beta\frac{\phi}{\gamma-1}E[(\frac{C^*_{t+1}}{C^*_t})^{-\sigma}(\frac{\Pi^*_{t+1}}{\Pi}-1)\frac{\Pi^*_{t+1}}{\Pi}\frac{Y^*_{t+1}}{Y^*_t}]$$

Monetary Policy Rules

$$\ln(r_t) - \ln(r) = \rho_i[\ln(r_{t-1}) - \ln(r)] + \Phi_Y[\ln(Y_{GDP,t}) - \ln(Y_{GDP})] + \Phi_\pi[\ln(\Pi_t]) - \ln(\Pi)] + \epsilon_{r,t}$$

$$\ln(r^*_t) - \ln(r^*) = \rho_i[\ln(r^*_{t-1}) - \ln(r^*)] + \Phi_Y[\ln(Y^*_{GDP,t}) - \ln(Y^*_{GDP})] + \Phi_\pi[\ln(\Pi^*_t]) - \ln(\Pi^*)] + \epsilon_{r^*,t}$$

GDP

$$Y_{GDP,t} = (1-p_{m,t})Y_t + w_t h_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}}-1)^2 Y_t$$

$$Y^*_{GDP,t} = (1-p^*_{m,t})Y^*_t + w^*_t h^*_t - \frac{\phi}{2}(\frac{\Pi^*_t}{\tilde{\Pi}^*}-1)^2 Y^*_t$$

Final Goods Market Clear

$$C_t = Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}}-1)^2 Y_t \quad \text{and} \quad C^*_t = Y^*_t - \frac{\phi}{2}(\frac{\Pi^*_t}{\tilde{\Pi}}-1)^2 Y^*_t$$

In addition, the model features two structural shock series following $AR(1)$ process with i.i.d error term: $\ln(\Upsilon_t) = (1-\rho_z)E[\ln(\Upsilon_t)] + \rho_z \ln(\Upsilon_{t-1}) + \epsilon_{\Upsilon,t}$, where index $\Upsilon = \{Z_t, Z_t^*\}$ stand for technology shocks in Home and Foreign countries.

Financial Autarky

Under financial autarky, the equilibrium conditions include twenty equations in twenty endogenous variables.

$$C_t, C_t^*, r_t, r_t^*, h_t, h_t^*, \Pi_t, \Pi_t^*, w_t, w_t^*, c_t(\mathbf{w_t}), Y_t, Y_t^*, Y_{GDP,t}, Y_{GPD,t}^*, p_{m,t}, p_{m,t}^*, S_{h,t}, S_{f,t}, Q_t$$

among which there are two pre-determined variables, r_t, r_t^*.

Among the twenty equations, seventeen of them are the same as those in incomplete market: Euler equations of holding domestic bond, the labor supply equations, Home manufacturing sector input cost, the price index of manufactured goods, the Home producers' market shares, New Keynesian Philips Curve, the definition of real GDP, final goods market clear and the monetary policy rules. The remaining three equations are given as following.

Labor Demand Conditions

$$p_{m,t}Y_t = w_t h_t \qquad \text{and} \qquad p_{m,t}^* Y_t^* = w_t^* h_t^*$$

Trade Balance

$$p_{m,t}^* Q_t S_{f,t} Y_t^* = p_{m,t}(1 - S_{h,t}) Y_t$$

4. Steady State Allocation

Since the holdings of international assets are zero at steady state, the trade balance condition holds, and the model under incomplete international financial market and the model under financial autarky have identical steady state allocations. I use variables without time subscript to denote the steady state value of that variable. At steady state, $\Pi = \Pi^* = \tilde{\Pi}$, $r = r^* = i = \frac{\tilde{\Pi}}{\beta}$, $b_I = 0$, $p_m = p_m^* = \frac{\gamma-1}{\gamma}$ and $C = Y$, $C^* = Y^*$.

With labor supply conditions, I can express the steady state values of Home consumption, C, and Foreign consumption C^* as functions of Home and Foreign wages:

$$C = (\frac{\gamma - 1}{\gamma} w^{\frac{\eta}{1-\eta}})^{\frac{1-\eta}{\sigma+\eta-1}} \qquad C^* = (\frac{\gamma - 1}{\gamma} w^{*\frac{\eta}{1-\eta}})^{\frac{1-\eta}{\sigma+\eta-1}}$$

The manufactured goods' market clear conditions for both countries are given by

$$\frac{\gamma - 1}{\gamma} C = wh \qquad \frac{\gamma - 1}{\gamma} C^* = w^* h^*$$

from which I can express the steady state values of Home hours worked, h, and Foreign hours worked, h^* in terms of Home and Foreign consumption and Home and Foreign wages.

Since Home and Foreign have different average technology levels, Home variables and Foreign variables have different steady state solutions, and steady state values of most variables don't have analytical expressions. I can solve $c(\mathbf{w})$, w, w^* and Q jointly from the expressions of Home and Foreign manufactured goods' price index, the Home manufacturing firm's unit input cost and the Home labor market clear condition, which are given by

$$[c(\mathbf{w})^{-\theta} + (w^*\tau Q)^{-\theta}]^{-\frac{1}{\theta}}[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}} = \frac{\gamma-1}{\gamma}$$

$$\{[\frac{c(\mathbf{w})\tau}{Q}]^{-\theta} + w^{*-\theta}\}^{-\frac{1}{\theta}}[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}} = \frac{\gamma-1}{\gamma}$$

$$c(\mathbf{w}) = w^*QF(1,\lambda) + \int_{w^*Q}^{w} xdF(x,\frac{\lambda}{w^*Q}) + w[1-F(w,\frac{\lambda}{w^*Q})]$$

$$p_mS_hY + p_m^*S_fY^*Q = c(\mathbf{w})\frac{h}{1-F(w,\frac{\lambda}{w^*Q})}$$

I use the MATLAB routine to solve this group of nonlinear equations. With the steady state values of $c(\mathbf{w})$, w^* and Q, I can solve for the Home manufacturing firms' market shares, $S_{h,t}$, $S_{f,t}$, Home and Foreign consumption, C and C^*, and Home and Foreign hours worked, h and h^*.

With these values, the steady state values of Home and Foreign real GDP, $Y_{GDP,t}$, $Y^*_{GPD,t}$ can be solved accordingly.

5. Log-linearized Model

Incomplete Market

Since at steady state, the international asset holdings are zero, the percentage deviations of bond holdings from the steady state are normalized as $\hat{b}_{I,t} = db_{I,t}$

Euler Equation(Domestic Bond)

$$\hat{C}_t = E[\hat{C}_{t+1}] - \frac{1}{\sigma}(\hat{r}_t - E[\hat{\Pi}_{t+1}]) \quad \text{and} \quad \hat{C}^*_t = E[\hat{C}^*_{t+1}] - \frac{1}{\sigma}(\hat{r}^*_t - E[\hat{\Pi}^*_{t+1}])$$

Euler Equation(International Bond)

$$-\sigma(E[\hat{C}_{t+1}] - \hat{C}_t) + \hat{i}_t - E[\hat{\Pi}_{t+1}] = \psi(\hat{b}_{I,t})$$

$$-\sigma(E[\hat{C}^*_{t+1}] - \hat{C}^*_t) + \hat{i}_t - E[\hat{\Pi}_{t+1}] + \hat{Q}_t - E[\hat{Q}_{t+1}] = \psi(-\hat{b}_{I,t} - \hat{Q}_t)$$

Labor Supply

$$(\eta - 1)\hat{h}_t = \hat{w}_t - \sigma\hat{C}_t \quad \text{and} \quad (\eta - 1)\hat{h}^*_t = \hat{w}^*_t - \sigma\hat{C}^*_t$$

Home Manufacturing Sector Input Cost

$$\hat{c}_t(\mathbf{w_t}) = \frac{we^{-\frac{\lambda w}{w^*Q}}}{c(\mathbf{w})}\hat{w}_t + \frac{w^*Q(1 - e^{-\lambda} - \lambda e^{-\lambda}) + \int_{w^*Q}^{w}(\frac{\lambda x}{w^*Q})e^{-\frac{\lambda x}{w^*Q}}(\frac{\lambda x}{w^*Q} - 1)dx + \frac{\lambda w^2}{w^*Q}e^{-\frac{\lambda w}{w^*Q}}}{c(\mathbf{w})}(\hat{w}^*_t + \hat{Q}_t) \tag{5.1}$$

Manufactured Goods' Price Index

$$\hat{p}_{m,t} = \frac{\hat{c}_t(\mathbf{w_t})}{1 + \tau^{-\theta}} + \frac{\tau^{-\theta}}{1 + \tau^{-\theta}}(\hat{w}^*_t + \hat{Q}_t) - \frac{\hat{Z}_t + \tau^{-\theta}\hat{Z}^*{}_t}{\theta(1 + \tau^{-\theta})} \tag{5.2}$$

$$\hat{p}^*_{m,t} = \frac{\tau^{-\theta}}{1 + \tau^{-\theta}}[\hat{c}_t(\mathbf{w_t}) - \hat{Q}_t] + \frac{\hat{w}^*_t}{1 + \tau^{-\theta}} - \frac{\hat{Z}_t\tau^{-\theta} + \hat{Z}^*_t}{\theta(1 + \tau^{-\theta})} \tag{5.3}$$

Home Manufacturing Firms' Market Shares

$$\hat{S}_{h,t} = \frac{\theta\tau^{-\theta}}{1+\tau^{-\theta}}[\hat{w}_t^* + \hat{Q}_t - \hat{c}_t(\mathbf{w_t}) + \frac{\hat{Z}_t - \hat{Z}_t^*}{\theta}] \tag{5.4}$$

$$\hat{S}_{f,t} = \frac{\theta}{1+\tau^{-\theta}}[\hat{w}_t^* + \hat{Q}_t - \hat{c}_t(\mathbf{w_t}) + \frac{\hat{Z}_t - \hat{Z}_t^*}{\theta}] \tag{5.5}$$

Labor Demand Condition

$$\begin{aligned}&\frac{p_m S_h Y}{Y_M}(\hat{p}_{m,t} + \hat{S}_{h,t} + \hat{Y}_t) + \frac{p_m^* S_f Y^* Q}{Y_M}(\hat{p}_{m,t}^* + \hat{S}_{f,t} + \hat{Y}_t^* + \hat{Q}_t)\\ =&\hat{c}_t(\mathbf{w_t}) + \hat{h}_t + \frac{\lambda w}{w^* Q}(\hat{w}_t - \hat{w}_t^* - \hat{Q}_t)\end{aligned} \tag{5.6}$$

$$\begin{aligned}&\frac{p_m(1-S_h)Y}{Y_M^*}(\hat{p}_{m,t} - \frac{S_h}{1-S_h}\hat{S}_{h,t} + \hat{Y}_t) + \frac{p_m^*(1-S_f)Y^*Q}{Y_M^*}(\hat{p}_{m,t}^* - \frac{S_F}{1-S_f}\hat{S}_{f,t} + \hat{Y}_t^* + \hat{Q}_t)\\ =&\frac{w^*Qh^*}{Y_M^*}(\hat{w}_t^* + \hat{Q}_t + \hat{h}_t^*) - \frac{c(\mathbf{w})he^{\frac{\lambda w}{w^*Q}}}{Y_M^*}[\hat{c}_t(\mathbf{w_t}) + \hat{h}_t + \frac{\lambda w}{w^*Q}(\hat{w}_t - \hat{w}_t^* - \hat{Q}_t)] + \frac{wh}{Y_M^*}(\hat{w}_t + \hat{h}_t)\end{aligned} \tag{5.7}$$

where

$$Y_M = p_m S_h Y + p_m^* S_f Y^* Q$$

$$Y_M^* = p_m(1-S_h)Y + p_m^*(1-S_f)Y^*Q$$

Price Evolution

$$\hat{\Pi}_t = \beta E[\hat{\Pi}_{t+1}] + \frac{\gamma-1}{\phi}\hat{p}_{m,t} \quad \text{and} \quad \hat{\Pi}_t^* = \beta E[\hat{\Pi}_{t+1}^*] + \frac{\gamma-1}{\phi}\hat{p}_{m,t}^*$$

Monetary Policy

$$\hat{r}_t = \rho_i \hat{r}_{t-1} + \Phi_\Pi \hat{\Pi}_t + \Phi_Y \hat{Y}_{GDP,t} + \hat{\epsilon}_{r,t}$$

$$\hat{r}_t^* = \rho_i \hat{r}_{t-1}^* + \Phi_\Pi \hat{\Pi}_t^* + \Phi_Y \hat{Y}_{GDP,t}^* + \hat{\epsilon}_{r,t}^*$$

Final good market clear conditions

$$\hat{C}_t = \hat{Y}_t \quad \text{and} \quad \hat{C}_t^* = \hat{Y}_t^*$$

GDP

$$\hat{Y}_{GDP,t} = -p_m \hat{p}_{m,t} + (1 - p_{m,t})\hat{Y}_t + p_m(\hat{w}_t + \hat{h}_t)$$

$$\hat{Y^*}_{GDP,t} = -p_m^* \hat{p}_{m,t}^* + (1 - p_{m,t}^*)\hat{Y}_t^* + p_m^*(\hat{w}_t^* + \hat{h}_t^*)$$

Current Account

$$\frac{\Pi}{\beta}(\hat{b}_{I,t} - \hat{i}_t) - \hat{b}_{I,t-1} = \hat{w}_t + \hat{h}_t - \hat{w}_t^* - \hat{h}_t^* - \hat{Q}_t - \hat{p}_{m,t} - \hat{Y}_t + \hat{p}_{m,t}^* + \hat{Y}_t^* + \hat{Q}_t$$

Financial Autarky

The log-linearized equilibrium conditions are given as following.

Labor Demand Condition

$$\hat{p}_{m,t} + \hat{Y}_t = \hat{w}_t + \hat{h}_t \quad \text{and} \quad \hat{p}_{m,t}^* + \hat{Y}_t^* = \hat{w}_t^* + \hat{h}_t^*$$

Trade Balance

$$\hat{p}_{m,t}^* + \hat{Q}_t + \hat{S}_{f,t} + \hat{Y}_t^* = \hat{p}_{m,t} + \hat{S}_{h,t} + \hat{Y}_t$$

6. Log-linearized Labor Demand Conditions under Incomplete Market

Given the log-linearized expressions of Home manufactured goods' price index equations, equations 5.2 and 5.3, and Home manufacturing firms's market share, equations 5.4 and 5.5, the log-linearized labor demand conditions can be rewritten as

$$\begin{aligned}
\hat{h}_t =& [\frac{p_m S_h Y}{Y_M}(1-S_h) + \frac{p_m^* S_f Y^* Q}{Y_M}(1-S_f)](1+\theta)[\hat{w}_t^* + \hat{Q}_t - \hat{c}_t(\mathbf{w_t})] \\
& - \frac{\lambda w}{w^* Q}(\hat{w}_t - \hat{w}_t^* - \hat{Q}_t) + \frac{p_m S_h Y}{Y_M}\hat{Y}_t + \frac{p_m^* S_f Y^* Q}{Y_M}\hat{Y}_t^* \\
\hat{h}_t^* =& \frac{Y_M + Y_M^*}{w^* h^* Q}\hat{c}_t(\mathbf{w_t}) + [\frac{p_m Y}{w^* Q h^*}(1-S_h) + \frac{p_m^* Y^* Q}{w^* Q h^*}(1-S_f)][\hat{w}_t^* + \hat{Q}_t - \hat{c}_t(\mathbf{w_t})] \\
& + \frac{p_m Y}{w^* Q h^*}\hat{Y}_t + \frac{p_m^* Y^* Q}{w^* Q h^*}\hat{Y}_t^* - \hat{w}_t^* - \hat{Q}_t - \frac{wh}{w^* Q h^*}(\hat{w}_t + \hat{h}_t)
\end{aligned}$$

With the log-linearized expressions of Home manufacturing sector's input cost equation 5.1

$$\hat{c}_t(\mathbf{w_t}) = \frac{we^{-\frac{\lambda w}{w^* Q}}}{c(\mathbf{w})}\hat{w}_t + \frac{w^* Q(1-e^{-\lambda} - \lambda e^{-\lambda}) + \int_{w^* Q}^{w}(\frac{\lambda x}{w^* Q})e^{-\frac{\lambda x}{w^* Q}}(\frac{\lambda x}{w^* Q} - 1)dx + \frac{\lambda w^2}{w^* Q}e^{-\frac{\lambda w}{w^* Q}}}{c(\mathbf{w})}(\hat{w}_t^* + \hat{Q}_t)$$

and $\hat{C}_t = \hat{Y}_t$ and $\hat{C}_t^* = \hat{Y}_t^*$, Home and Foreign labor demand can be expressed in terms of Home and Foreign real wages, $\hat{w}_t$, $\hat{w}_t^*$, real exchange rate $\hat{Q}_t$, and Home and Foreign consumption demand $\hat{C}_t$ and $\hat{C}_t^*$. The elasticities of Home and Foreign labor demand with respect to these five variables are given by

$$\frac{\partial \hat{h}_t}{\partial \hat{w}_t} = -\Xi_1\Xi_3 - \frac{\lambda w}{w^*Q}$$

$$\frac{\partial \hat{h}_t}{\partial \hat{w}_t^*} = \frac{\partial \hat{h}_t}{\partial \hat{Q}_t} = \Xi_1(1-\Xi_2) + \frac{\lambda w}{w^*Q}$$

$$\frac{\partial \hat{h}_t}{\partial \hat{C}_t} = \frac{p_m S_h Y}{Y_M}$$

$$\frac{\partial \hat{h}_t}{\partial \hat{C}_t^*} = \frac{p_m^* S_f Y^* Q}{Y_M}$$

$$\frac{\partial \hat{h}_t^*}{\partial \hat{w}_t^*} = \frac{\partial \hat{h}_t^*}{\partial \hat{Q}_t} = \frac{Y_M + Y_M^*}{w^*h^*Q}\Xi_2 + \Xi_4(1-\Xi_2) - 1 - \frac{wh}{w^*h^*Q}[\Xi_1(1-\Xi_2) + \frac{\lambda w}{w^*Q}]$$

$$\frac{\partial \hat{h}_t^*}{\partial \hat{w}_t} = (\frac{Y_M + Y_M^*}{w^*h^*Q} - \Xi_4)\Xi_3 - \frac{wh}{w^*h^*Q}(1 - \Xi_1\Xi_3 - \frac{\lambda w}{w^*Q})$$

$$\frac{\partial \hat{h}_t^*}{\partial \hat{C}_t} = \frac{p_m Y}{w^*Qh^*} - \frac{wh}{w^*h^*Q}\frac{p_m S_h Y}{Y_M}$$

$$\frac{\partial \hat{h}_t^*}{\partial \hat{C}_t^*} = \frac{p_m^* Y^* Q}{w^*Qh^*} - \frac{p_m^* S_f Y^* Q}{Y_M}\frac{wh}{w^*h^*Q}$$

where

$$\Xi_1 = [\frac{p_m S_h Y}{Y_M}(1-S_h) + \frac{p_m^* S_f Y^* Q}{Y_M}(1-S_f)](1+\theta)$$

$$\Xi_2 = \frac{w^*Q(1-e^{-\lambda} - \lambda e^{-\lambda}) + \int_{w^*Q}^{w}[(\frac{\lambda x}{w^*Q})^2 e^{-\frac{\lambda x}{w^*Q}} - \frac{\lambda x}{w^*Q}e^{-\frac{\lambda x}{w^*Q}}]dx + \frac{\lambda w^2}{w^*Q}e^{-\frac{\lambda w}{w^*Q}}}{c(\mathbf{w})}$$

$$\Xi_3 = \frac{w e^{-\frac{\lambda w}{w^*Q}}}{c(\mathbf{w})}$$

$$\Xi_4 = \frac{p_m Y}{w^*Qh^*}(1-S_h) + \frac{p_m^* Y^* Q}{w^*Qh^*}(1-S_f)$$

APPENDIX C

Import Competition and Changing U.S. Manufacturing Employment Structural Dynamics

1. List of the Data Series

The labor intensity measure of industry i, LI_i is given by

$$LI_i = \frac{\sum_t \text{Production and Non-Supervisory Employees}_i}{\sum_t \text{Capital Stock}_i}$$

This paper defines labor-intensive industries as the industries with LI_i above 30th percentile, and the capital-intensive industries as the industries with LI_i below the 70th percentile.

The detailed list of industries that are included in the dataset and their labor intensity properties are given in the table in next page.

Table C.1. List of Industries

NAICS	Industry Names	Labor Intensive	Capital Intensive
3352	Household appliances		
3121(p) and 3122(p)	Beverages and tobacco products		CI(E,P)
315(p)	Apparel	LI(E,P)	
316(p)	Leather and allied products	LI(E,P)	
321(p)	Wood products	LI(E)	
324(p)	Petroleum and coal products		CI(E,P)
327(p)	Nonmetallic mineral products		
332991	Ball and roller bearings		
333111	Farm machinery and equipment		
3332	Industrial machinery		
334111	Electronic computers		CI(E)
3342(p)	Communications equipment		CI(E,P)
3361	Automobiles		CI(E)
336211(p)	Motor vehicle bodies	LI(E)	
3379(p)	Other furniture-related products	LI(E,P)	
339(p)	Miscellaneous manufacturing		
311(p)	Food manufacturing		
313(p)	Textile mills		
314(p)	Textile product mills	LI(E,P)	
322(p)	Paper and paper products		CI(E,P)
323(p)	Printing and related support activities		
325(p)	Chemicals		CI(E,P)
326(p)	Plastics and rubber products		
3219(p)	Other wood products	LI(E,P)	

Note: NAICS index with ’p’ in parenthesis indicates that the production and non-production worker series include that industry. LI(E) indicates that the industry is labor-intensive for ’All Employees’ dataset. ’P’ denotes ’Production Nonsupervisory Employees’.

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