Globalization, Offshoring and Monetary Policy Effectiveness

Wen Zhang*

May 2016

Abstract

This paper provides an empirical and theoretical investigation into the relationship between trade openness and the effects of monetary policy changes. Using data from US industries at a 4-digit SIC level from 1972 to 2005, the empirical analysis reveals a negative relationship between trade openness and the effects of identified monetary policy shocks on the output of manufacturing industries. Based on this evidence, the theoretical section develops an open economy New Keynesian model that features heterogeneous manufacturing firms and one-way offshoring from the advanced economy to the less developed one. A simultaneous decline in trade cost and offshoring cost weakens the effect of monetary policy changes on output and inflation by dampening the responses of the domestic labor market: it raises labor demand elasticity and strengthens demand spillover. The calibrated model indicates that, when the economy moves from low trade regime 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 offshoring induced productivity effect can moderately offset the dampening effect of trade openness.

JEL Classification: E52, F41, F62

Key Words: International monetary policy, Trade integration, Financial integration

*Department of Economics, Renmin University of China, 59 Zhongguancun St, Haidian, Beijing, China, 100872 Email: wen.zhang.ruc@gmail.com.

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 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 effect before 1980 (see Boivin, Kiley, and Mishkin (2010) and the references therein). A vast amount of literature has investigated the sources of the 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 since late 1960s, many have asked whether trade openness has changed the dynamics of output and inflation.[2] Since the latter argument lacks explicit empirical evidence and the implications of the existing theoretical literature are ambiguous, this paper contributes to the literature by providing a coherent empirical and theoretical investigation into the effect of trade openness on the monetary transmission mechanism.

A novel feature of this paper is that it examines the roles of offshoring and of regular trade in influencing monetary transmission mechanism separately. Firstly, both regular trade and offshoring can potentially alter the monetary transmission mechanism. Due to revolutionary advances of transportation and communication technology, intermediate products can be moved quickly and cheaply across borders. It leads to a boom of offshoring accompanying recent trade liberalization episodes. The empirical literature shows a significant effect of trade openness - especially the expansion of offshoring - on labor market performance in advanced economies.[3] Given the important role of labor market outcomes in determining output and inflation dynamics,[4] a trade

[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.

[2] 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 banks 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 the argument in Rogoff (2003) by showing the inflation-output tradeoff has increased with the globalization process. However, their focus is on the level of equilibrium inflation, instead of the dynamic responses of inflation and output to monetary policy changes.

[3] Empirical literature shows that increasing offshoring raises the demand elasticity of unskilled labor in US (e.g. Senses (2010)), aggravates income inequality in U.S (e.g. Feenstra and Hanson (1999)) and reduces manufacturing employment in U.S. (e.g. Acemoglu, Autor, Dorn, Hanson, and Price (2016)). Hummels, Munch, and Xiang (2016) provides a comprehensive survey on the implications of offshoring on labor market outcomes.

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

liberalization induced structural change in the labor market can potentially alter the monetary transmission mechanism. Secondly, regular trade and offshoring may have different implications for the monetary transmission mechanism. For example, at a given monetary expansion, increasing regular imports or offshoring crowds out the stimulative effect of monetary policy on domestic output, while increasing offshoring reduces domestic producers' production cost, which magnifies the the stimulative effect of monetary policy on domestic output. The latter is referred to as offshoring induced productivity effect in the literature, e.g. Grossman and Rossi-Hansberg (2008) and Amiti and Konings (2007). This productivity effect leads the net effect of offshoring on the monetary policy effectiveness ambiguous.

The purpose of the empirical analysis is to detect whether increased trade openness can weaken the responses of industry-level output to monetary policy shocks, and how this relationship is affected by the industries' offshoring status. The empirical investigation uses annual data of US manufacturing industries at the 4-digit SIC level from 1972 to 2005. The analysis 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 different trade openness measures using heteroscedasticity-robust regression.

The cross section analysis indicates that the impulse responses of industry-level output are negatively associated with openness measures, and involvement in offshoring doesn't necessarily amplify the effect of trade openness. To the best of my knowledge, this result is new in the literature,[5] and is hard to reconcile with the quantitative implications of existing open economy New Keynesian models, e.g. Clarida, Galí, and Gertler (2002) and Galí and Monacelli (2005). With standard calibration choices or estimated parameter values, these models indicate an ambiguous relationship of trade openness and effects of monetary policy changes.[6] In addition, existing open

[5] Using a similar econometric framework, the literature focuses mainly on how industries' financial charateristics influence industry-level effect of monetary policy e.g. Dedola and Lippi (2005) and Peersman and Smets (2005). The literature, e.g. Guerrieri, Gust, and Lpez-Salido (2010), Monacelli and Sala (2009) and Bianchi and Civelli (2014), has established that trade openness or global factors crucially affect inflation dynamics in many countries, but hasn't shown how trade openness influences the effectiveness of monetary policy.

[6] 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 the weaker effect of monetary policy shocks since early 1980s. Milani (2012) estimates a small open economy version of Clarida et al. (2002) and finds little effect of degree of openness on transmission of monetary policy shock. Cwik, Mller, and Wolters (2011) estimate a model, where the none constant demand elasticity leads producers' mark-up vary with real exchange rate following Gust et al. (2010). They find greater openness leads to more effective monetary policy.

economy New Keynesian models have not formally incorporated firm-level offshoring decisions. The majority of them characterize trade openness using the home bias parameter in consumer preference or the parameter that determines the share of imported inputs in production function. 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 and of regular imports separately.

The main goal of this paper is to provide a New Keynesian open economy stochastic dynamic general equilibrium model. The model features: (1) tradable goods' producers with heterogeneous technology in both countries; (2) the endogenously determined international trade pattern based on the Ricardian trade theory, following Eaton and Kortum (2002); (3) one-way offshoring from an advanced economy (Home) to a less developed economy (Foreign), built on the static model in Rodrguez-Clare (2010); (4) vertical production linkage, in the sense that final-good-producing firms purchase tradable inputs from global market to produce non-tradable final goods for local household; (5) final-good-producing firms set prices facing nominal rigidity, i.e. Rotemberg (1984). 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,[7] an alternative structure - Financial Autarky - is also considered.

In the model, the tradable good producers in Home have an absolute advantage over their counterparts in Foreign. This generates a wage gap between the two countries, thereby providing the Home tradable good producers an incentive to offshore a fraction of the production process to Foreign. Hence, there are two types of exports in Foreign, that is offshoring and regular export. Offshoring is initiated by Home tradable-good-producing firms for the cost saving purpose, and the resulting output is shipped back to these firms. The regular export is driven by the comparative advantage effect.

The calibrated baseline model shows that when the economy moves from low trade regime (import to real GDP ratio at 1%) to a trade regime, in which import to GDP ratio and offshoring to import ratio are at 2005 levels, the effect of monetary policy shocks on real GDP and inflation is lowered by 15%. When this trade liberalization process is accompanied by the international financial market moving from autarky to the incomplete market case, the effect of monetary policy shocks on real GDP and inflation is lowered by 22%. The offshoring induced productivity effect can offset the dampening effect of trade openness (increase both regular imports and offshoring), but its quantitative effect is small.

The model implies that trade openness weakens the effectiveness of monetary policy through

[7] 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.

stabilizing its impact on domestic labor market. Firstly, greater trade openness strengthens the linkage of domestic consumption and foreign production, which is the demand spillover effect. This is a standard channel in the open economy New Keynesian model. Secondly, 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: (1) increases the ease for tradable-good-producing firms to substitute domestic labor with offshoring, raising labor demand elasticity; (2) reduces the production cost of domestic tradable goods' producers, and strengthens their comparative advantage, which in turn increases the demand of domestic labor and reduces labor demand elasticity as well as the demand spillover. The net effect of the offshoring on labor demand elasticity as well as the demand spillover effect depends on the degree of trade openness and the calibration choice of trade elasticity.

The intuition for the interactions of these 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 real wage and hours worked play a dominating role in determining domestic CPI inflation and output dynamics. Hence, 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 rate 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 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.

Comparing the business cycle implications of the baseline model and of the model, where two countries are symmetric and without offshoring, shows that: (1) given technology shocks, offshoring reduces the cross-country output correlation; (2) given monetary policy shocks, offshoring amplifies the cross-country output correlation. This result is related to the research agenda on the relationship of offshoring and international business cycle synchronization, e.g. Burstein, Kurz, and Tesar (2008), Zlate (2016), Kleinert et al. (2015) and Cravino and Levchenko (2015). In particular, the first finding contradicts the implications of the models in Burstein et al. (2008) and Zlate (2016), which find that offshoring amplifies the cross-country output correlation given technology shocks based on models without nominal rigidity. These controversial findings calls for more elaborated empirical investigation as future research. The second finding is new in the literature, since the existing papers are abstract from nominal rigidity, and focuses mainly on whether the presence of offshoring can amplify output comovement in response to technology shock.

Despite the large amount of existing open economy New Keynesian models, few have examined the relationship of trade openness and the effectiveness of monetary policy. Many have focused mainly on the normative analysis: Clarida et al. (2002) and Galí and Monacelli (2005) build on the Armington model, and deliver ambiguous implications for the relationship of trade openness and effectiveness of monetary policy; Cacciatore and Ghironi (2013) incorporates labor market frictions into Ghironi and Melitz (2005), and shows the optimal monetary policy depends on the degree of trade openness. Some papers have examined how trade openness influences the slope of New Keynesian Philips Curve (NKPC): Sbordone (2008) incorporates the variable demand elasticity into a standard New Keynesian model, and does not find strong evidence that the increased traded goods' variety flattens the NKPC; Razin and Loungani (2005) shows trade openness flattens NKPC within the framework based on Armington model. This paper is the first to incorporate offshoring into an open economy New Keynesian model, and studies its implications for the effectiveness of monetary policy.

In terms of model elements, this paper is related to the dynamic models that are built on Eaton and Kortum (2002): Arkolakis and Ramanarayanan (2009) studies the implication of trade openness on international business cycle synchronization; Caliendo and Parro (2015) examines the welfare gains of NAFTA; Eaton, Kortum, Neiman, and Romalis (2011) explores the sources of the dramatic collapse of trade during recent 2008 recession. This paper is the first to incoporate nominal rigidity into the dynamic Eaton-Kortum model.

The rest of the paper is organized as follows. Section 2 shows the empirical analysis on the relationship of trade openness and the industry level effects of monetary policy. Section 3 presents the model. The model calibration and business cycle properties are given in section 4. Section 5 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 6 concludes the paper.

2 Empirical Evidence

This section provides empirical evidence on the role of trade openness in determining the effect 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 Schott (2004). Both measures are constructed using data from NBER International Finance and Trade Dataset. The details on constructing openness measures are given in the Online Appendix.

The summary statistics of the openness measures are given in Table 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 standard deviation of the offshoring measure is 0.101. Both measures have experienced a significant growth over the sample period: The cross industry average of the import penetration ratio has increased from 0.059 to 0.29 from 1972 to 2005, and cross industry average of the offshoring measure has almost tripled over the sample period.

2.1 Econometric Method

2.1.1 Panel VAR Model

The effect of monetary policy shocks on manufacturing industry-level output are estimated using structural autoregression models. Let

$$X_{i,t} = [Y_t, \pi_t, R_t, Y_{i,t}]' \tag{1}$$

be a vector that contains time t value of real GDP Y_t, PCE inflation π_t,[8] Federal Funds Rate R_t, total value added of industry i deflated using GDP deflator $Y_{i,t}$.[9] 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 $X_{i,t}$ has a moving average

[8] As a part of the robustness check, I replaced PCE inflation with GDP deflator inflation or the combination of GDP deflator inflation and commodity price. The results are qualitatively not affected. An advantage of using PCE inflation is that it does not generate price puzzle for this dataset.

[9] The reason for not including industry-level price measures into the VAR is that there is not enough PPI series to match the industry-level output measures for the given sample period.

representation, which is given by

$$X_{i,t} = \alpha + A(l)_i \epsilon_t, \qquad A(0)_i = A_{i,0} \tag{2}$$

where α is a 4×1 vector of constant terms, and $A(l)_i$ is a 4×4 matrix, which is an infinite order matrix lag polynomial. $\epsilon_{i,t} = [\epsilon_Y, \epsilon_\pi, \epsilon_R, \epsilon_{Y_i}]$ is a vector of structural disturbances. The elements of $\epsilon_{i,t}$ are three common shocks, aggregate output shock ϵ_Y, inflation shock ϵ_π, 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

$$E[\epsilon_{i,t}\epsilon'_{i,t}] \equiv \Sigma_i \tag{3}$$

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 and 3 is given by

$$X_{i,t} = \beta_i + B(l)_i \mu_{i,t}, \qquad B(0)_i = I \quad \text{and} \quad E[\mu_i \mu'_i] = \Omega_i \tag{4}$$

where β_i is a 4×1 vector of constant terms, and $B(l)_i$ 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 $X_{i,t}$. $\mu_{i,t}$ is a vector of reduced form innovation terms.

The reduced form VAR is estimated with restrictions on B_i,[10] which are given by

$$b_{p,q}(l)_i = 0, \qquad p \in \{1,2,3\} \quad \text{and} \quad q = 4 \quad \text{for all } l \tag{5}$$

where $b_{p,q}(l)_i$ is the element at row p and column q at lag l of B_i. 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, the differences in shock response functions of industry-level output can be related to industry-level trade openness measures.

A comparison of equations 2, 3 and 4 indicates that $\mu_{i,t} = A_{i,0}\epsilon_{i,t}$, $\alpha_i = \beta_i$, and $A(l))_i = B(l)_i A_{i,0}$, where the matrix $A_{i,0}$ provides the link between structural and reduced form VAR models. In line with Sims (1980), this paper uses standard recursive identification scheme to get

[10] 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.

matrix $A_{i,0}$. Cholesky decomposition of the covariance matrix of the innovations of the reduced form model Ω_i, provides the lower triangular matrix $A_{i,0}$, which satisfies $A_{i,0}\Sigma_i A'_{i,0} = \Omega_i$. With variables in order shown in equation 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.

Since the recursive identification scheme gives the exactly identified structural model (equation 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 $\hat{Y}_{i,A}$.[11] The summary statistics of these two elasticities are given in Table 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.

2.1.2 Cross-Section Regression

In the regression analysis that follows, I estimate:

$$\hat{Y}_{i,j} = c_j + \gamma_{1,j}\text{Openness Measures}_i + \eta_{i,j} \qquad j \in \{A, M\} \tag{6}$$

where $\hat{Y}_{i,j}$ is the industry i's j type output elasticity and c_j is a constant term. Openness Measures in this paper are the industry-level import penetration ratio, and the offshoring measure. To avoid multicollinearity, these measures are entered one at a time in the regression model (equation 6). To examine whether the relationship between industry-level output elasticity and trade openness is affected by industry's involving in offshoring, I also estimate:

$$\begin{aligned}\hat{Y}_{i,j} = c_j + \gamma_{2,j}&\text{Import Penetration}_i + \gamma_{3,j}\text{Offshoring Dummy}_i \\ &\gamma_{4,j}\text{Import Penetration}_i \times \text{Offshoring Dummy}_i + \xi_{i,j} \quad j \in \{A, M\}\end{aligned} \tag{7}$$

where the offshoring dummy of industry i takes the value 1 if industry i imports non-energy intermediate inputs. I also estimate both regression models (equation 6 and 7) 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 estimation uses heteroscedasticity robust standard error.

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

2.2 Results

Table 2 presents the regression results. According to the estimated results of equation 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 percentage-points, the peak of impulse responses of industry-level output will be lowered by 18 percentage-points. 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 percentage-point increase in offshoring measure is associated with a 15.78 percent in industry-level output maximum elasticities from their mean level. The estimated results from the three-year average elasticities with industry dummies are striking: a 10 percentage-point increase in import penetration (offshoring measure) leads to 41.2% (24.2%) decrease in three year average elasticities from their mean levels.

The result from estimating equation 7 reveals 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 significant. Together with the positive but not significant coefficients in front of the offshoring dummy, this result implies that given import penetration ratio at its mean level, switching from non-offshoring to offshoring magnifies the effect of monetary policy shocks on industry-level output. A possible explanation of these results will be discussed in the model mechanism section 5.1.

3 Model

In the model, Home and Foreign are identical except for the production technology of the tradable-good-producing 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 tradable-good-producing firms indexed by $j \in [0, 1]$, and a central bank. Only tradable-good-producing firms in Home have the option to offshore. Offshored production is implemented by Foreign labor. During each period, $t = 0, 1, 2, ...$, the Home tradable-good-producing firm j uses domestic labor and the output of offshored production to produce a distinctive perishable tradable good j. The Foreign tradable-good-producing firm j uses only domestic labor to produce the distinctive perishable tradable good j. In both countries, the final-good-producing firm i produces a distinct, perishable final good i using local and imported tradable goods as inputs. The retailer assembles final goods into consumption goods.

In this section, except for the tradable-good-producing sector, I describe the behavior of each agent focusing mainly on Home, with the understanding that the equilibrium conditions of Foreign can be characterized using similar equations. 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.[12] The detailed behavior rule of each agent is given as follows.

3.1 The Representative Household

At the beginning of each period, $t = 0, 1, 2...$, the household in Home starts with domestic bonds B_{t-1}, and international bonds $B_{I,t-1}$, 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 bonds and international bonds mature. Then, the household uses some money to purchase $B_t + B_{I,t}$ new bonds at the cost of $B_t/r_t + B_{I,t}/i_t + \psi P_t/2i_t(B_{I,t}/P_t - \bar{B}_I/P)^2$, where r_t is the risk free nominal interest rate between period t and $t+1$ of holding domestic bonds, i_t is the risk free nominal interest rate between period t and $t+1$ of holding international bonds, and the last term is the quadratic adjustment cost of holding international bond, which is introduced in order to pin down a well defined steady state for consumption and asset holdings, and to ensure the model stationarity, in line with Benigno (2009). During each period, the household supplies h_t units of labor to the tradable-good-producing firms, and receives nominal wage W_t. The household also purchases C_t units of consumption goods from retailers at the 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 monopolistic final-good-producing firms.

[12] 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 quantitative implications. Here I omit the complete market scenario.

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

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

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

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 nominal international bond, and P is the steady state price level.[13]

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

$$\beta E\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{r_t}{\pi_{t+1}}\right]=1 \tag{8}$$

$$\beta E\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{i_t}{\pi_{t+1}}\right]=1+\psi\left(\frac{B_{I,t}}{P_t}-\frac{\bar{B}_I}{P}\right) \tag{9}$$

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

$$h_t^{\eta-1}C_t^{\sigma}=\frac{W_t}{P_t} \tag{10}$$

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.

The Foreign household faces a similar budget constraint, which is given by

$$C_t^*+\frac{B_t^*}{r_t^*P_t^*}+\frac{B_{I,t}^*}{i_tP_t^*\mathcal{E}_t}+\frac{\psi}{2i_t}\left(\frac{B_{I,t}^*}{P_t^*\mathcal{E}_t}-\frac{\bar{B}_I^*}{P^*\mathcal{E}}\right)^2\leq\frac{W_t^*}{P_t^*}h_t^*+\frac{B_{t-1}^*}{P_t^*}+\frac{B_{I,t-1}^*}{P_t^*\mathcal{E}_t}+T_t^*+D_t^* \tag{11}$$

$\mathcal{E}_t$ is nominal exchange rate, and it is 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

$$\beta E\left[\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\sigma}\frac{r_t^*}{\pi_{t+1}^*}\right]=1 \tag{12}$$

$$\beta E\left[\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\sigma}\frac{i_t}{\pi_{t+1}^*}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right]=1+\psi\left(\frac{B_{I,t}^*}{P_t^*\mathcal{E}_t}-\frac{\bar{B}_I^*}{P^*\mathcal{E}}\right) \tag{13}$$

[13] Note that the nominal international bond holdings $\bar{B}_I$ and the price level P don't have separate steady state values. Instead, the model provides steady state value of the real international bond holdings $\bar{b}_I=\bar{B}_I/P$.

Due to the presence of the friction of trading international bond, the Uncovered Interest Rate Parity is violated when the real value of international bonds $B_{I,t}/P_t$ (or $B^*_{I,t}/P^*_t\mathcal{E}_t$) deviates its steady state level $\bar{B}_I/P$ (or $\bar{B}^*_I/P^*\mathcal{E}$):

$$E_t[(\frac{C^*_{t+1}}{C^*_t})^{-\sigma}(\frac{i_t}{\pi^*_{t+1}}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} - \frac{r^*_t}{\pi^*_{t+1}})] = \psi(\frac{B^*_{I,t}}{P^*_t\mathcal{E}_t} - \frac{\bar{B}^*_I}{P^*\mathcal{E}}) \tag{14}$$

3.2 The Representative Retailer

During each period $t = 0, 1, 2...$, the representative retailer purchases $Y_t(i)$ units of final good i at the 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

$$Y_t = [\int_0^1 Y_t(i)^{\frac{\gamma-1}{\gamma}} di]^{\frac{\gamma}{\gamma-1}} \tag{15}$$

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

$$Y_t(i) = [\frac{P_t(i)}{P_t}]^{-\gamma} Y_t \qquad \text{for } i \in [0, 1],\ t = 0, 1, 2... \tag{16}$$

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

$$P_t = [\int_0^1 P_t(i)^{1-\gamma} di]^{\frac{1}{1-\gamma}} \qquad \text{for all t= 0, 1, 2...} \tag{17}$$

3.3 The Representative Final-Good-Producing Firm

During each period, the final good producer i purchases $y(i, j)$ units of tradable good j from the perfectly competitive tradable goods' market, at the nominal price $p_m(j)$ to produce $Y_t(i)$ units of final good i with the constant return to scale technology

$$Y_t(i) = [\int_0^1 y_t(i, j)^{\frac{\mu-1}{\mu}} dj]^{\frac{\mu}{\mu-1}} \tag{18}$$

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

$$y_t(i, j) = [\frac{p_{m,t}(j)}{P_{m,t}}]^{-\mu} Y_t(i) \qquad \text{for } i, j \in [0, 1] \text{ and } t = 0, 1, 2... \tag{19}$$

where $P_{m,t}$ is the nominal price of the tradable goods' bundle. The perfect competition in the tradable goods' market drives the profit of the tradable good producers to zero, determining the nominal price of the tradable goods' bundle, which is given by

$$P_{m,t} = [\int_0^1 p_{m,t}(j)^{1-\mu} dj]^{\frac{1}{1-\mu}} \tag{20}$$

Since the final goods are imperfect substitutes in producing the consumption goods, final goods are sold at 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 measured by the consumption goods, which is given by

$$\frac{\phi}{2}[\frac{P_t(i)}{P_{t-1}(i)\tilde{\Pi}} - 1]^2 Y_t \tag{21}$$

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 $P_t(i)$

$$\max_{P_t(i)} E[\sum_{t=0}^{\infty} \beta^t \frac{D_t(i)}{C_t^\sigma}] \tag{22}$$

where β^t / C_t^σ is the household's marginal utility gain from one unit of real profit. With the demand of final good i (equation 19), and the real marginal cost of the final good producer i $P_{m,t}/P_t$, the expression of the real profit is given by

$$D_t(i) = [\frac{P_t(i)}{P_t}]^{1-\gamma} Y_t - \frac{P_{m,t}}{P_t}[\frac{P_t(i)}{P_t}]^{-\gamma} Y_t - \frac{\phi}{2}[\frac{P_t(i)}{P_{t-1}(i)\tilde{\Pi}} - 1]^2 Y_t \tag{23}$$

The first order condition of optimally setting price is given by

$$\begin{aligned}(\gamma - 1)[\frac{P_t(i)}{P_t}]^{-\gamma} \frac{Y_t}{P_t} =& \gamma \frac{P_{m,t}}{P_t}[\frac{P_t(i)}{P_t}]^{-\gamma-1} \frac{Y_t}{P_t} - \phi[\frac{P_t(i)}{P_{t-1}(i)\tilde{\Pi}} - 1] \frac{Y_t}{\tilde{\Pi} P_{t-1}(i)} + \\ & \beta\phi E[(\frac{C_{t+1}}{C_t})^{-\sigma}[\frac{P_{t+1}(i)}{P_t(i)\tilde{\Pi}} - 1] \frac{P_{t+1}(i)}{P_t(i)\tilde{\Pi}} \frac{Y_{t+1}}{P_t(i)}]\end{aligned} \tag{24}$$

3.4 The Representative Tradable-Good-Producing Firm

During each period, $t = 0, 1, 2...$, the representative Home tradable-good-producing firm j fragments its production of tradable good $y_{m,t}(j)$ into a continuum of tasks $t(j,k)$, which is indexed by $k \in \Omega_j$. Ω_j is the set of the tasks involved to produce tradable good j, and Ω_j is indexed by j to allow for the variability of tasks cross tradable good producers. The production function is given by

$$y_{m,t}(j) = z_t(j) \int_{\Omega_j} t_t(j,k)dk \tag{25}$$

where $z_t(j)$ is the idiosyncratic technology shock to Home tradable-good-producing firm j.

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

$$y_{m,t}^*(j) = z_t^*(j)h_t^*(j) \tag{26}$$

where $z_t^*(j)$ is the idiosyncratic productivity of Foreign tradable-good-producing firm j.

Following Eaton and Kortum (2002), I assume the idiosynchratic shocks ($z_t(j)$ and $z_t^*(j)$) follow the Frechet distribution

$$F(z) = e^{-Z_t z^{-\theta}} \tag{27}$$

where θ measures the dispersion of the idiosyncratic technology, and it governs the comparative advantage effect: 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 it determines the location of the idiosyncratic technology shocks' distribution. A higher Z_t implies that the idiosyncratic technology draws are likely to be better. Z_t follows a stationary autoregressive process:

$$\ln(Z_t) = (1 - \rho_z)\ln(\mu_z) + \rho_z \ln(Z_{t-1}) + \epsilon_{z,t} \tag{28}$$

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. With the assumption that Home tradable-good-producing firms have absolute advantage over their Foreign counterparts ($\mu_z > \mu_z^*$), Home has a higher wage than Foreign does ($W_t > W_t^* \mathcal{E}_t$).

For the Home tradable-good-producing firm j, each task k t(j,k) can either be implemented by domestic labor or by offshoring. The offshored production carries Home idiosyncratic labor augmenting technology $z_t(j)$. 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 given by

$$P(\zeta_t(k) \leq \bar{\zeta}) = F(\bar{\zeta}, \lambda) = 1 - \exp(-\lambda\bar{\zeta}) \tag{29}$$

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 tradable-good-producing firm j will choose to offshore when offshoring cost is below $W_t/W_t^*\mathcal{E}_t$, and the lowest possible offshoring cost is 1. Given the distribution of the idiosyncratic offshoring cost $\zeta_t(k)$, the nominal unit input cost of the tradable-good-producing firm j is given by

$$C_t(\mathbf{W_t}) = W_t^*\mathcal{E}_t F(1, \lambda) + \int_{W_t^*\mathcal{E}_t}^{W_t} x dF(x, \frac{\lambda}{W_t^*\mathcal{E}_t}) + W_t[1 - F(W_t, \frac{\lambda}{W_t^*\mathcal{E}_t})] \tag{30}$$

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 tradable-good-producing firms are able to produce all the variety of tradable goods ex-ante, and Home made and Foreign made tradable goods j are perfect substitutes in producing the final goods, the tradable goods are sold in perfectly competitive international market. For Home final good producers, the available nominal prices of tradable 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 presence of the trade friction, Purchasing Power Parity doesn't hold in this model.

As the representative Home final good producer always purchases the tradable good j from the cheaper source, the nominal price of the tradable 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 $t = 0, 1, 2...$ Based on Eaton and Kortum (2002)'s probabilistic approach, I can get the nominal price index of tradable goods' bundle $P_{m,t}$, which is given by

$$P_{m,t} = [Z_t C_t(\mathbf{W_t})^{-\theta} + Z_t^*(W_t^* \tau \mathcal{E}_t)^{-\theta}]^{-\frac{1}{\theta}}[\Gamma(\frac{1-\mu+\theta}{\theta})]^{\frac{1}{1-\mu}} \tag{31}$$

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 cost, offshoring cost or labor wage in either country leads to a lower nominal marginal cost in Home. As the trade cost or offshoring cost declines, the Foreign factors has a greater effect on Home final-good producers' marginal cost, and on Home CPI inflation as well.

Since tradable-good-producing firms $j \in [0, 1]$ are ex-ante symmetric, by Law of Large Numbers, the fraction of the tradable goods that the Home final good producers purchase from domestic firms $S_{h,t}$ is the same as the probability that a representative Home tradable-good-producing firm j serves Home market, which is equivalent to the probability that firm j provides a lower price in Home market than its Foreign competitor does. Home tradable-good-producing firms' market share in Home market $S_{h,t}$ is given by

$$S_{h,t} = \frac{Z_t C_t(\mathbf{W_t})^{-\theta}}{Z_t C_t(\mathbf{W_t})^{-\theta} + Z_t^*(W_t^*{}_t \tau \mathcal{E}_t)^{-\theta}} \tag{32}$$

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

$$S_{f,t} = \frac{Z_t[C_t(\mathbf{W_t})\tau/\mathcal{E}_t]^{-\theta}}{Z_t[C_t(\mathbf{W_t})\tau/\mathcal{E}_t]^{-\theta} + Z_t^* W_t^{*-\theta}} \tag{33}$$

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 of tradable tradable inputs towards Foreign produced ones. 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 tradable 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 tradable-good-producing firms to zero, determining Home tradable goods' market clear condition:

$$P_{m,t}S_{h,t}Y_t + P^*_{m,t}S_{f,t}Y^*_t\mathcal{E}_t = C_t(\mathbf{W_t})\frac{h_t}{1-F(W_t, \frac{\lambda}{W^*_t\mathcal{E}_t})} \tag{34}$$

which implies that the revenue of Home tradable good producers equals the sum of the payment to domestic labor and offshoring.

Foreign tradable goods' market clear condition is given by

$$P_{m,t}(1-S_{h,t})Y_t + P^*_{m,t}\mathcal{E}_t(1-S_{f,t})Y^*_t = W^*_t h^*_t\mathcal{E}_t + W_t h_t - C_t(\mathbf{W_t})\frac{h_t}{1-F(W_t, \frac{\lambda}{W^*_t\mathcal{E}_t})} \tag{35}$$

which implies that Foreign tradable-good-producing firms' revenue is equal to the earnings of Foreign labor net offshoring.

3.5 Central Bank

In each country, the central bank conducts monetary policy following standard Taylor rule proposed by Taylor (1993), augmented by the lagged nominal interest rate.[14]

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

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 that Home central bank adjusts the short term nominal interest rate according to the last period's 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 the magnitude of interest rates' responses to inflation, measured by Φ_π, the magnitude of interest rates' responses to output, measured by Φ_Y. $\frac{\Phi_\pi}{1-\rho_r} > 1$ is a sufficient condition to ensure existence of a unique nonexplosive rational expectation equilibrium.

3.6 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 $t = 0, 1, 2...$; all the tradable-good-producing

[14]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

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 $w_t = W_t/P_t$, real input cost of Home tradable-good-producing firms $c_t(\mathbf{w}) = C_t(\mathbf{W})/P_t$, real marginal cost of final-good producers $p_{m,t} = P_{m,t}/P_t$, real domestic bond holdings $b_t = B_t/P_t$ and real international bond holding $b_{I,t} = B_{I,t}/P_t$. The aggregate resource constraint can be written as

$$C_t + \frac{b_{I,t}}{i_t} = w_t h_t + b_{I,t-1} + Y_t - p_{m,t}Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}} - 1)^2 Y_t \tag{36}$$

and the consumption goods' market clear condition is given by

$$C_t = Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}} - 1)^2 Y_t \tag{37}$$

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

$$ca_t = \frac{b_{I,t}}{i_t} - \frac{b_{I,t-1}}{i_t} = (1 - \frac{1}{i_t})b_{I,t-1} + w_t h_t - p_{m,t}Y_t \tag{38}$$

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

$$\frac{b_{I,t}}{i_t} - b_{I,t-1} = \frac{w_t h_t - w^*_t h^*_t Q_t - p_{m,t}Y_t + p^*_{m,t}Y^*_t Q_t}{2} \tag{39}$$

3.7 Financial Autarky

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

$$C_t + \frac{b_t}{r_t} \leq w_t h_t + b_{t-1} + D_t \tag{40}$$

The inter-temporal optimality condition is the standard closed economy Euler equation, which is given by

$$\beta E[(\frac{C_{t+1}}{C_t})^{-\sigma} r_t \frac{P_t}{P_{t+1}}] = 1 \tag{41}$$

Under Financial autarky, the inability to trade inter-temporally imposes that the trade balance condition holds every period. That is the value of the imports must equal to the value of exports evaluated using the same currency:

$$p_{m,t}^{*} Q_t S_{f,t} Y_t^{*} = p_{m,t}(1 - S_{h,t}) Y_t + c_t(\mathbf{w_t}) \frac{h_t}{1 - F(w_t, \frac{\lambda}{w_t^{*} Q_t})} - w_t h_t \tag{42}$$

in which the left-hand side term is Foreign imports, the first term on the right-hand side is Home imports of tradable goods, and the last two terms on the right-hand side measure offshoring. 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 the Online Appendix.

4 Calibration and Macro Dynamics

This section presents the impulse responses of the key macro variables in the model to an unexpected transitory technology shock and to an 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 details are given as follows.

4.1 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 is set at $\sigma = 1$, 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 intermediation friction parameter is set at $\psi = 0.01$, in order to ensure the model stationarity and a small enough effect of asset adjustment on the model dynamics. 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 γ and the elasticity of tradable goods μ are set using the estimated value from Bernard, Eaton, Jensen, and Kortum (2003), $\gamma = \mu = 3.8$.[15] The adjustment cost parameter is set at $\phi = 33$ to match the price adjustment

[15] As in Eaton and Kortum (2002), the model contains two parameters related to the elasticity of substitution between the tradable goods from two sources. μ governs substitutability of 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

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). The persistency of nominal interest rate is set at $\rho_i = 0.76$, and the persistency of the technology shock is set at $\rho_z = 0.83$, according to the estimated values in Lubik and Schorfheide (2006). The trade cost τ and offshoring cost λ are set to match steady state import to GDP ratio at 17% and the ratio of offshoring to import at 30% in Home country.[16] 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.[17]

4.2 Real GDP in the Model

Before proceeding to analyzing the impulse responses of the model to technology and monetary policy shocks, let's take a detour to define the real GDP. 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-stage 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 tradable inputs. The expression of real GDP is given by

$$Y_{\mathsf{GDP,t}} = (1 - p_{m,t})Y_t - \frac{\phi}{2}(\frac{\Pi_t}{\tilde{\Pi}} - 1)^2 Y_t + w_t h_t \tag{43}$$

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 tradable-good-producing 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.

4.3 Macro Dynamics

4.3.1 Positive Technology Shock

The blue lines in Figure 1 are the impulse responses of baseline model to an unexpected positive technology shock (positive one percent deviation) in Home tradable-good-producing sector, which

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.

[16] 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.

[17] It is 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.

reflects the increase in the average realization of the idiosyncratic technology shocks of Home tradable-good-producing firms. The positive technology shock moves prices and quantities in opposite directions: real GDP rises while CPI inflation falls in Home. The Home monetary authority reacts to the technology progress 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. The puzzling initial decline in Home real wage is due to the presence of nominal rigidity. The technology progress is more than enough to meet the increased consumption demand, and the insufficient labor demand drives down the nominal wage. Since the prices are sticky in the short run, the real wage falls correspondingly. Lastly, the positive technology shock has a negative spillover effect on Foreign in terms of output and export, since strengthened absolute advantage of Home tradable-good-producing firms shifts global demand towards Home tradable goods and away from Foreign ones.

To illustrate the role of offshoring, it is helpful to compare the impulse responses of the baseline model with those of the model without offshoring (symmetric Home and Foreign countries). Offshoring weakens the international business cycle synchronization, while magnifies the effect of technology shock on domestic output and export. Due to the nominal rigidity, the positive technology reduces Home tradable good producers' demand of inputs.[18] As a part of the inputs, offshoring declines on impact of the shock, which reduces Foreign output. As positive technology shock raises global demand of Home produced tradable goods relative to Foreign produced ones, it raises Home and Foreign real wages' differential ($\hat{w}_t - \hat{w}_t^* - Q_t$). As this wage gap persists and the effect of the positive technology shock diminishes, the Home producers expand offshoring moderately, which in turn lowers their production cost, and the induced productivity effect enhances their competitiveness in global market, raising Home export and output.[19]

4.3.2 Expansionary Monetary Policy Shock

In the baseline model, the expansionary monetary policy shock (negative one percent deviation in nominal interest rate) in Home (blue lines in Figure 2) raises Home output and inflation, and leads real exchange rate to depreciate, which boosts Home export. As monetary expansion raises Home and Foreign wages' differential, Home increases import as well as offshoring to take advantage of cheaper Foreign labor. As a consequence, Foreign experiences a positive demand

[18] This is consistent with the empirical findings that are documented in Kimball et al. (2006) and Galí (1999), which shows that the positive technology shock has contractionary effect on labor input.

[19] In contrast, Zlate (2016) and Burstein et al. (2008) find that offshoring amplies the international business cycle synchronization given a technology shock. Both models don't have nominal rigidity. Zlate (2016) doesn't feature multiple stages' production, and the positive technology shock in the advance economy raises the Home and Foreign wages' differential, which drives up offshoring on impact of the shock. Burstein et al. (2008) has vertical production linkage, and highlights the important role of the low trade elasticity between offshoring and the locally produced intermediate inputs in generating strenghthened international business cycle synchronization.

spillover effect: output and inflation 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 the relatively low labor supply elasticity of the model calibration choice.

Comparing the impulse responses of the baseline model and those of the model without offshoring (red dashed lines in Figure 2) indicates that, offshoring strengthens the international business cycle synchronization, and magnifies the effect of technology shock on domestic output and export. As offshoring incresaes in response to the expansionary monetary policy shock, it magnifies the spillover of the positive demand shock's effect on Foreign output. Moveover, the offshoring induced productivity effect boosts Home export as well output.

5 Globalization, Offshoring and Effectiveness of Monetary Policy

This section explores the mechanisms through which increasing import penetration, expanding offshoring, and liberalizing international financial market influence the monetary transmission mechanism. The model is simulated to conduct the counterfactual analysis and to quantify the effect of different channels. The end of this section presents sensitivity analysis.

5.1 The Mechanism

5.1.1 Log-linearized Real GDP and New Keynesian Philips Curve

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 24). The percentage deviation of a variable from its steady state value is denoted by the variable with hat. For simplicity, technology shocks are shut off. The expression of the NKPC is given by

$$\hat{\Pi}_t = \beta E[\hat{\Pi}_{t+1}] + \frac{\gamma - 1}{\phi}[\Lambda_1 S_h \hat{w}_t + (1 - \Lambda_1 S_h)(\hat{w}^*_t + \hat{Q}_t)] \tag{44}$$

where S_h is the steady state value of the Home tradable-good-producing firms' market share in Home market, and $\Lambda_1 = we^{-\frac{\lambda w}{w^* Q}}/c(\mathbf{w})$ is the elasticity of Home tradable-good-producing firms' unit input cost $c_t(\mathbf{w_t})$ with respect to Home labor cost w_t.

NKPC implies that current CPI inflation depends on the expected next period's CPI inflation $E[\hat{\Pi}_{t+1}]$, and the weighted sum of the domestic labor wage w_t and foreign labor wage evaluated using Home currency $w_t^* Q_t$. It differs from the standard closed economy NKPC, since Foreign labor cost affects Home CPI inflation. Given $\partial(\Lambda_1 S_h)/\partial\tau > 0$ and $\partial(\Lambda_1 S_h)/\partial\lambda < 0$, increasing openness to regular trade or offshoring weakens the effect of Home labor cost on Home CPI inflation, while strengthens the effect of Foreign labor cost on Home CPI inflation.[20]

The log-linearized expression of Home real GDP is given by

$$\hat{Y}_{GDP,t} = p_m[\hat{h}_t + (1 - S_h\Lambda_1)(\hat{w}_t - \hat{w}_t^* - Q_t)] + (1 - p_m)\hat{C}_t \tag{45}$$

where p_m is the steady state value of Home final-good-producing firms' unit input cost. Home real GDP is driven by Home hours worked, Home and Foreign wages' differential and Home consumption demand. As the economy increases its exposure to regular imports or to offshoring, the effect of Home and Foreign wages' differential on real GDP increases. The dependence of the real GDP on Home and Foreign wages' differential reflects the trade induced efficiency gain effect, since facing a postive wage gap, trade makes it possible for Home final good producers or tradable good producers to lower the production cost via regular trade or offshoring. However, under trade autarky, Home can't take advantage of regular trade or offshoring when there is a positive wage gap, and real GDP depends solely on domestic variables, which boils down to the closed economy case.

5.1.2 Trade Openness and Labor Market Dynamics

The log-linearized NKPC and real GDP equations reveal the important role of Home and Foreign labor markets in determining inflation and output dynamics. The analysis proceeds with a focus on labor market. As trade openness has no effect on labor supply conditions, this section examines how trade openness leads to structural changes in the labor demand conditions.

The log-linearized Home (Foreign) tradable goods' market clear condition yields the Home (Foreign) labor demand condition. The derivation is given in the online appendix. Home and Foreign hours worked depend on domestic and foreign real wages, real exchange rate and global consumption demand. Figure 3 shows that 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 wages, and strengthens the global demand spillover. The effects of trade integration on labor demand elasticities are asymmetric between Home and Foreign: The less developed country is more severely affected.

Falling trade cost or offshoring cost leads to greater demand spillover effect, since both

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

changes strengthen the linkage of domestic demand and foreign production. Falling trade cost or offshoring cost can raise labor demand elasticities, since a trade cost decline promotes product market competition, and an offshoring cost decline provides a greater ease for tradable good producers to substitute domestic labor with offshoring. However, offshoring can enhance 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 offshoring induced productivity effect can reduce labor demand elasticity and dampen the demand spillover effect.

Figure 4 presents the quantitative implications of offshoring-induced productivity effect. The first row compares the effects of two trade liberalization scenarios on the labor demand elasticities: 1) trade growth driven by the simultaneous decline 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 4 compare the effects of offshoring on the labor demand elasticities under low and high trade openness regimes. It implies that when the trade openness is low, the offshoring cost decline raises labor demand elasticity, while when trade openness is high, the offshoring cost decline reduces labor demand elasticity. The reason is that the lower trade cost promotes the tradable goods' market competition, which magnifies the productivity effect associated with offshoring.

5.1.3 Trade Openness and Effectiveness of Monetary Policy

How do the trade openness induced changes in labor demand conditions influence the responsiveness of labor market to monetary disturbances? When trade openness raises demand spillover, a given increase in consumption demand has a weaker stimulative effect on domestic hours worked. With a higher labor demand elasticity, a given increase in labor demand boosts domestic labor wage by less. The combined effect is that, under greater trade openness, hours worked and labor wage exhibit weaker responses to domestic expansionary monetary policy changes, and the monetary expansion raises foreign hours worked and labor wage by more (the black dotted line and red dashed lines in Figure 5). Moreover, due to the spillover effect, trade openness stabilizes the responses of Home and Foreign wages' differential to monetary changes.

The NKPC equation 44 reveals a tradeoff associated with trade openness: it weakens the CPI inflation's dependence on domestic labor wage, which exhibits subdued responses to domestic monetary changes, while strengthens the CPI inflation's dependence on foreign labor wage, which exhibits magnified responses to domestic monetary changes. In Figure 5, trade openness leads to weaker responses of CPI inflation to monetary changes, which indicates that Home labor wage plays a dominating role in determining how trade openness influences the responsiveness of CPI inflation to monetary changes. Similarly, since hours worked play a dominating role in determining real GDP dynamics, trade openness dampens the effect of monetary changes on domestic output.

5.1.4 Financial Openness and the Effectiveness of Monetary Policy

International financial market integration weakens the responsiveness of real exchange rate to monetary policy shock, thereby reducing the responses of 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 (the blue line and the black dotted line in Figure 5).

5.2 Quantitative Results

Table 3 quantifies the effect of trade openness, offshoring and financial liberalization on responses of output and inflation to expansionary monetary changes. It reports the percentage changes of the peaks of impulse responses of real GDP and CPI inflation from low trade openness regime to high trade openness regime under four trade or financial liberalization scenarios.

5.2.1 Baseline Calibration

The upper left section of the table reports the baseline results. In case 1, where the economy moves from almost trade autarky (import to real GDP ratio at 1%) to post 2005 trade regime (import to real GDP ratio at 17% and offshoring to import ratio at 30%) and international financial market moves from autarky to incomplete market, the effect of monetary policy changes on output and inflation is dampened by 22%. Case 2 implies that under an incomplete international financial market, the trade liberalization that is given in case 1 reduces the effect of monetary policy shock on output and inflation by 15%. In case 3, the growth of trade is driven by the decline in trade cost alone. Comparing the results from case 2 and those from case 3 reveals that due to the induced productivity effect, offshoring can weaken the effect of trade openness on the output elasticity with respect to monetary policy shock. Yet, under baseline calibration, the offsetting effect is quantitatively small. Case 4 shows that under financial autarky, the effect of trade openness on the output elasticity or the inflation elasticity with respect to monetary policy shock is negligible.

5.2.2 Robustness: Alternative Calibration Choices

Table 3 reports the quantitative results of the aforementioned four scenarios 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 monetary policy 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 $\theta = 1$ since the international macro literature tends to choose a low trade elasticity.

The model's qualitative implications on the connection of trade or financial 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 a lower volatility of the economy in response to demand shocks, hence the differences of the impulse responses of the models under different trade and financial openness regimes are smaller. With the changed risk aversion and labor supply elasticity, the decline in offshoring cost still weakens the effect of trade openness on output elasticity with respect to monetary policy shocks, since according to the first two rows of Figure 6, trade openness that involves offshoring leads labor demand elasticity to increase by less and a weaker international demand spillover.

The implications of offshoring on how trade openness influences monetary policy effectiveness 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 the responses of both output and inflation to monetary changes 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 changes, thereby limiting the offshoring cost reduction induced efficiency gain effect on output. The third row of Figure 6 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.

6 Conclusion

This paper establishes a new fact that greater trade openness weakens the effect of the monetary policy changes on the industry-level output. The empirical analysis also suggests that offshoring doesn't necessarily strengthen the impact of trade openness on the the effect of monetary policy changes. Based on this evidence, this paper provides an open economy New Keynesian model, which features heterogeneous tradable-good-producing firms and one-way offshoring from the advanced economy to the less developed one. The model implies that trade openness weakens the effect of monetary policy changes through dampening the responses of domestic labor market to monetary policy shocks, since a simultaneous decline in trade cost and offshoring raises international demand spillover and labor demand elasticity. In addition, offshoring induces a productivity effect, which can offset the dampening effect of trade openness on output elasticity with respect to domestic monetary policy shock. The calibrated model shows that trade openness or financial openness weakens the effectiveness of monetary policy, and the general equilibrium effect of the offshoring induced productivity effect is small.

Acknowledgement

This paper is based on the first and second chapters of my dissertation. I would like to thank Peter N. Ireland for his guidance and advice. For helpful comments, I thank Susanto Basu, Ben Li, Jaromir Nosal, Fabio Schiantarelli, John Seater and Zhijie Xiao. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The usual disclaimer applies.

References

Acemoglu, Daron, David Autor, David Dorn, Gordon H. Hanson, and Brendan Price (2016), "Import competition and the great us employment sag of the 2000s." *Journal of Labor Economics*, 34, S141 – S198.

Amiti, Mary and Jozef Konings (2007), "Trade liberalization, intermediate inputs, and productivity: Evidence from indonesia." *The American Economic Review*, 97, pp. 1611–1638.

Arkolakis, Costas and Ananth Ramanarayanan (2009), "Vertical specialization and international business cycle synchronization." *Scandinavian Journal of Economics*, 111, 655–680.

Ball, Laurence (2006), "Has globalization changed inflation?" NBER Working Papers 12687, National Bureau of Economic Research, Inc.

Benigno, PIERPAOLO (2009), "Price stability with imperfect financial integration." *Journal of Money, Credit and Banking*, 41, 121–149.

Benigno, Pierpaolo and Ester Faia (2010), "Globalization, Pass-Through and Inflation Dynamic." NBER Working Papers 15842, National Bureau of Economic Research, Inc.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum (2003), "Plants and productivity in international trade." *American Economic Review*, 93, 1268–1290.

Bernard, Andrew B., J. Bradford Jensen, and Peter K. Schott (2006), "Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants." *Journal of International Economics*, 68, 219–237.

Bianchi, Francesco and Andrea Civelli (2014), "Globalization and Inflation: Evidence from a Time Varying VAR." *Review of Economic Dynamics*.

Boivin, Jean and Marc P. Giannoni (2006), "Has Monetary Policy Become More Effective?" *The Review of Economics and Statistics*, 88, 445–462.

Boivin, Jean, Michael T. Kiley, and Frederic S. Mishkin (2010), "How Has the Monetary Transmission Mechanism Evolved Over Time?" In *Handbook of Monetary Economics* (Benjamin M. Friedman and Michael Woodford, eds.), volume 3 of *Handbook of Monetary Economics*, chapter 8, 369–422, Elsevier.

Burstein, Ariel, Christopher Kurz, and Linda Tesar (2008), "Trade, production sharing, and the international transmission of business cycles." *Journal of Monetary Economics*, 55, 775–795.

Cacciatore, Matteo and Fabio Ghironi (2013), "Trade, Unemployment, and Monetary Policy." Technical Report 724.

Caliendo, Lorenzo and Fernando Parro (2015), "Estimates of the Trade and Welfare Effects of NAFTA." *Review of Economic Studies*, 82, 1–44.

Chetty, Raj, Adam Guren, Day Manoli, and Andrea Weber (2011), "Are micro and macro labor supply elasticities consistent? a review of evidence on the intensive and extensive margins." *American Economic Review*, 101, 471–75.

Clarida, Richard, Jordi Galí, and Mark Gertler (2000), "Monetary policy rules and macroeconomic stability: Evidence and some theory." *The Quarterly Journal of Economics*, 115, 147–180.

Clarida, Richard, Jordi Galí, and Mark Gertler (2002), "A simple framework for international monetary policy analysis." *Journal of Monetary Economics*, 49, 879 – 904.

Cravino, Javier and Andrei A. Levchenko (2015), "Multinational Firms and International Business Cycle Transmission." Working Papers 643, Research Seminar in International Economics, University of Michigan.

Cwik, Tobias, Gernot J. Mller, and Maik H. Wolters (2011), "Does trade integration alter monetary policy transmission?" *Journal of Economic Dynamics and Control*, 35, 545 – 564.

Davis, Steven J. and John Haltiwanger (2001), "Sectoral job creation and destruction responses to oil price changes." *Journal of Monetary Economics*, 48, 465–512.

Dedola, Luca and Francesco Lippi (2005), "The monetary transmission mechanism: Evidence from the industries of five OECD countries." *European Economic Review*, 49, 1543–1569.

Eaton, Jonathan and Samuel Kortum (2002), "Technology, geography, and trade." *Econometrica*, 70, 1741–1779.

Eaton, Jonathan, Samuel Kortum, Brent Neiman, and John Romalis (2011), "Trade and the global recession." Working Paper 16666, National Bureau of Economic Research.

Feenstra, Robert C and Gordon H Hanson (1996), "Globalization, Outsourcing, and Wage Inequality." *American Economic Review*, 86, 240–45.

Feenstra, Robert C. and Gordon H. Hanson (1999), "The impact of outsourcing and high-technology capital on wages: Estimates for the united states, 19791990." *The Quarterly Journal of Economics*, 114, 907–940.

Galí, Jordi (1999), "Technology, employment, and the business cycle: Do technology shocks explain aggregate fluctuations?" *American Economic Review*, 89, 249–271.

Galí, Jordi and Tommaso Monacelli (2005), "Monetary policy and exchange rate volatility in a small open economy." *The Review of Economic Studies*, 72, 707–734.

Ghironi, Fabio and Marc J. Melitz (2005), "International Trade and Macroeconomic Dynamics with Heterogeneous Firms." *The Quarterly Journal of Economics*, 120, 865–915.

Grossman, Gene M. and Esteban Rossi-Hansberg (2008), "Trading Tasks: A Simple Theory of Offshoring." *American Economic Review*, 98, 1978–97.

Guerrieri, Luca, Christopher Gust, and J. David Lpez-Salido (2010), "International Competition and Inflation: A New Keynesian Perspective." *American Economic Journal: Macroeconomics*, 2, 247–80.

Gust, Christopher, Sylvain Leduc, and Robert Vigfusson (2010), "Trade integration, competition, and the decline in exchange-rate pass-through." *Journal of Monetary Economics*, 57, 309 – 324.

Hummels, David, Jakob R. Munch, and Chong Xiang (2016), "Offshoring and labor markets." Working Paper 22041, National Bureau of Economic Research.

Ireland, Peter N. (2004), "Technology Shocks in the New Keynesian Model." *The Review of Economics and Statistics*, 86, 923–936.

Kimball, Miles S., John G. Fernald, and Susanto Basu (2006), "Are Technology Improvements Contractionary?" *American Economic Review*, 96, 1418–1448.

Kleinert, Jrn, Julien Martin, and Farid Toubal (2015), "The few leading the many: Foreign affiliates and business cycle comovement." *American Economic Journal: Macroeconomics*, 7, 134–59.

Lubik, Thomas and Frank Schorfheide (2006), "A Bayesian Look at the New Open Economy Macroeconomics." In *NBER Macroeconomics Annual 2005, Volume 20*, NBER Chapters, 313–382, National Bureau of Economic Research, Inc.

Milani, Fabio (2012), "Has globalization transformed u.s. macroeconomic dynamics?" *Macroeconomic Dynamics*, 16, 204–229.

Monacelli, Tommaso and Luca Sala (2009), "The International Dimension of Inflation: Evidence from Disaggregated Consumer Price Data." *Journal of Money, Credit and Banking*, 41, 101–120.

Peersman, Gert and Frank Smets (2005), "The Industry Effects of Monetary Policy in the Euro Area." *Economic Journal*, 115, 319–342.

Razin, Assaf and Prakash Loungani (2005), "Globalization and Equilibrium Inflation-Output Tradeoffs." In *NBER International Seminar on Macroeconomics 2005*, NBER Chapters, 171–192, National Bureau of Economic Research, Inc.

Rodrguez-Clare, Andrs (2010), "Offshoring in a ricardian world." *American Economic Journal: Macroeconomics*, 2, 227–58.

Rogoff, Kenneth S. (2003), "Globalization and global disinflation." *Proceedings - Economic Policy Symposium - Jackson Hole*, 77–112.

Rotemberg, Julio J (1984), "A Monetary Equilibrium Model with Transactions Costs." *Journal of Political Economy*, 92, 40–58.

Sbordone, Argia M. (2008), "Globalization and inflation dynamics: the impact of increased competition." Technical report.

Schmitt-Grohe, Stephanie and Martin Uribe (2004), "Solving dynamic general equilibrium models using a second-order approximation to the policy function." *Journal of Economic Dynamics and Control*, 28, 755–775.

Schmitt-Grohé, Stephanie and Martn Uribe (2003), "Closing small open economy models." *Journal of International Economics*, 61, 163–185.

Schott, Peter K. (2004), "Across-product versus within-product specialization in international trade." *The Quarterly Journal of Economics*, 119, 647–678.

Senses, Mine Zeynep (2010), "The effects of offshoring on the elasticity of labor demand." *Journal of International Economics*, 81, 89–98.

Simonovska, Ina and Michael E. Waugh (2014), "The elasticity of trade: Estimates and evidence." *Journal of International Economics*, 92, 34–50.

Sims, Christopher A (1980), "Macroeconomics and Reality." *Econometrica*, 48, 1–48.

Taylor, John B. (1993), "Discretion versus policy rules in practice." *Carnegie-Rochester Conference Series on Public Policy*, 39, 195–214.

Woodford, Michael (2007), *Globalization and Monetary Control*, 13–77. University of Chicago Press.

Zlate, Andrei (2016), "Offshore production and business cycle dynamics with heterogeneous firms." *Journal of International Economics*, 100, 34 – 49.

Table 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
# of Observations		417		

Table 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
Observations	417	417	417	417	417	417	417	417	417	417	417	417
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

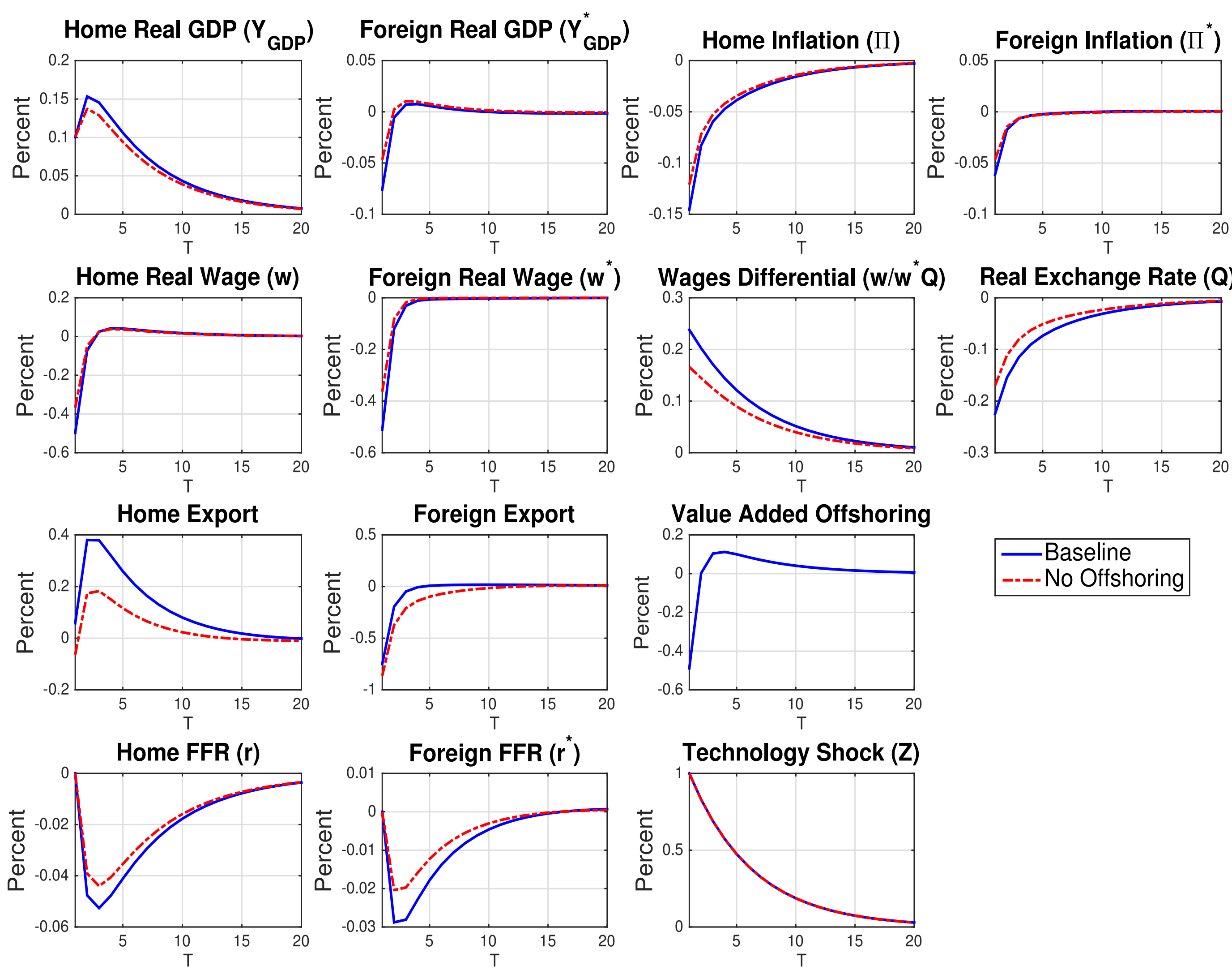
Note: This table reports the heteroscedasticity robust regression results of regressing the industry-level output elasticities on the openness measures. Import Penetration Ratio is measured as the sum of imports over the sample period / the sum of domestic absorption over the sample period. $\hat{Y}_M$ stands for the maximum elasticity. $\hat{Y}_A$ stands for the average of impulse response of first three years. Standard deviation in parentheses. Offshoring is measured as the sum of intermediate imports over sample period / the sum of material cost over sample period. The Offshoring Dummy is 1 if the industry participates in offshoring. * p<0.10, ** p<0.05, *** p<0.01

Table 3: 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
	$\eta = 2.33$				$\theta = 1$			
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

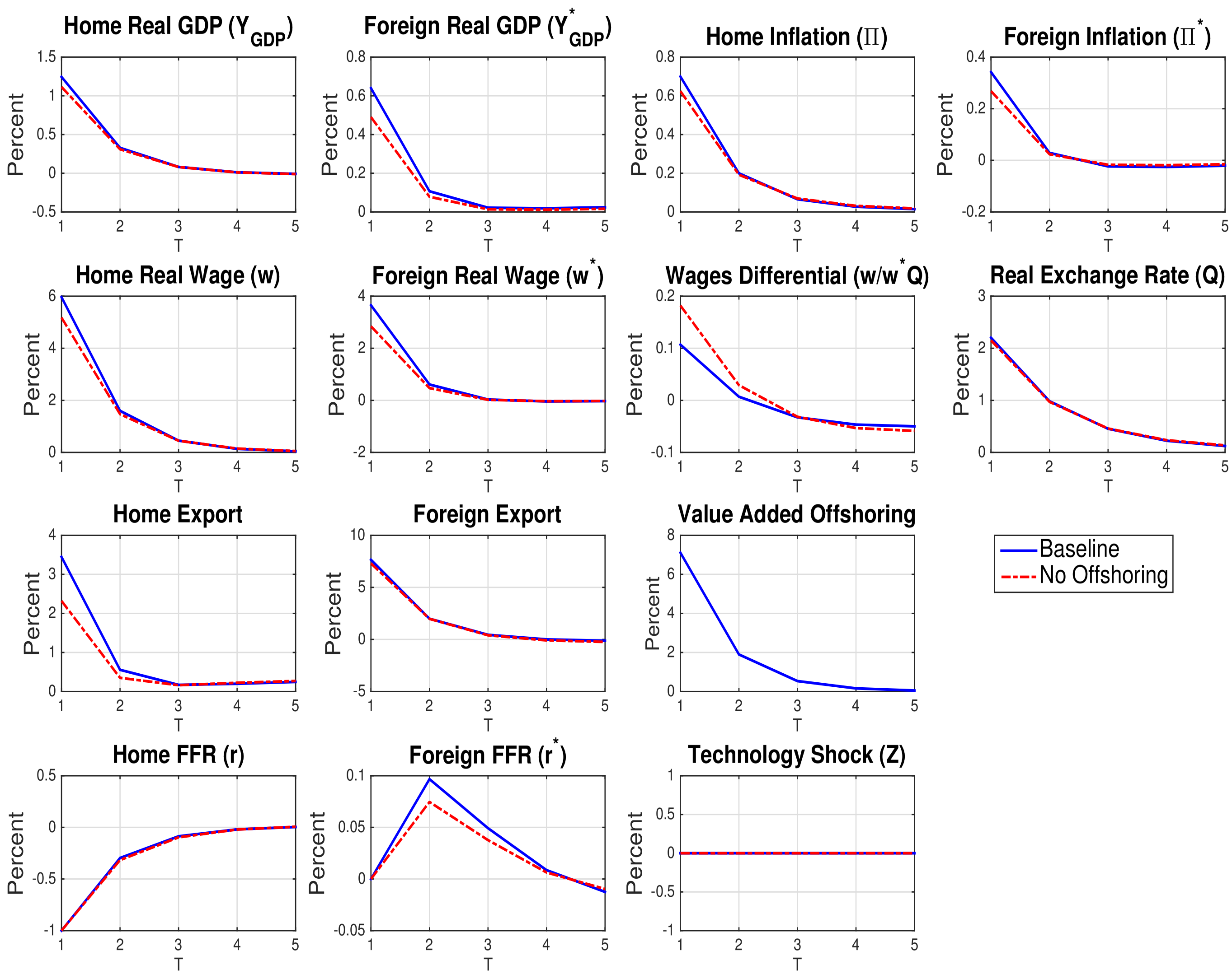
Note: This table reports the percentage changes of the listed variables' peak impulse responses from low trade openness regime to high trade openness regime. The exercise is conducted using four different sets of calibrations: the baseline calibration and changing the calibrated values of risk aversion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

Figure 1: Model Impulse Responses To Unexpected Positive Technology Shock.



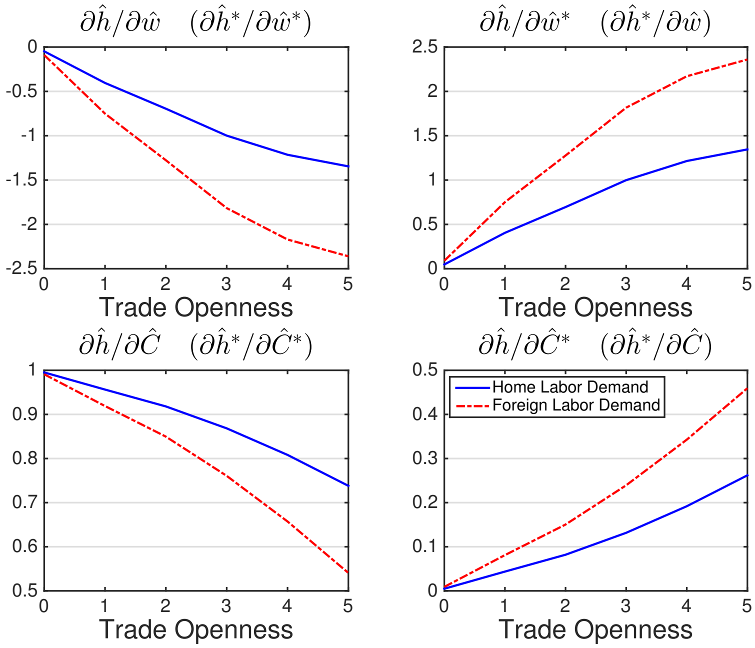
The blue lines are the impulse responses of the baseline model, in which import to real GDP ratio is 17% and offshoring to import ratio is 30%. The red dashed lines are impulse responses of the model, in which Home and Foreign are symmetric, and import to real GDP ratio is 17% without offshoring.

Figure 2: Model Impulse Responses To Unexpected Expansionary Monetary Policy Shock.



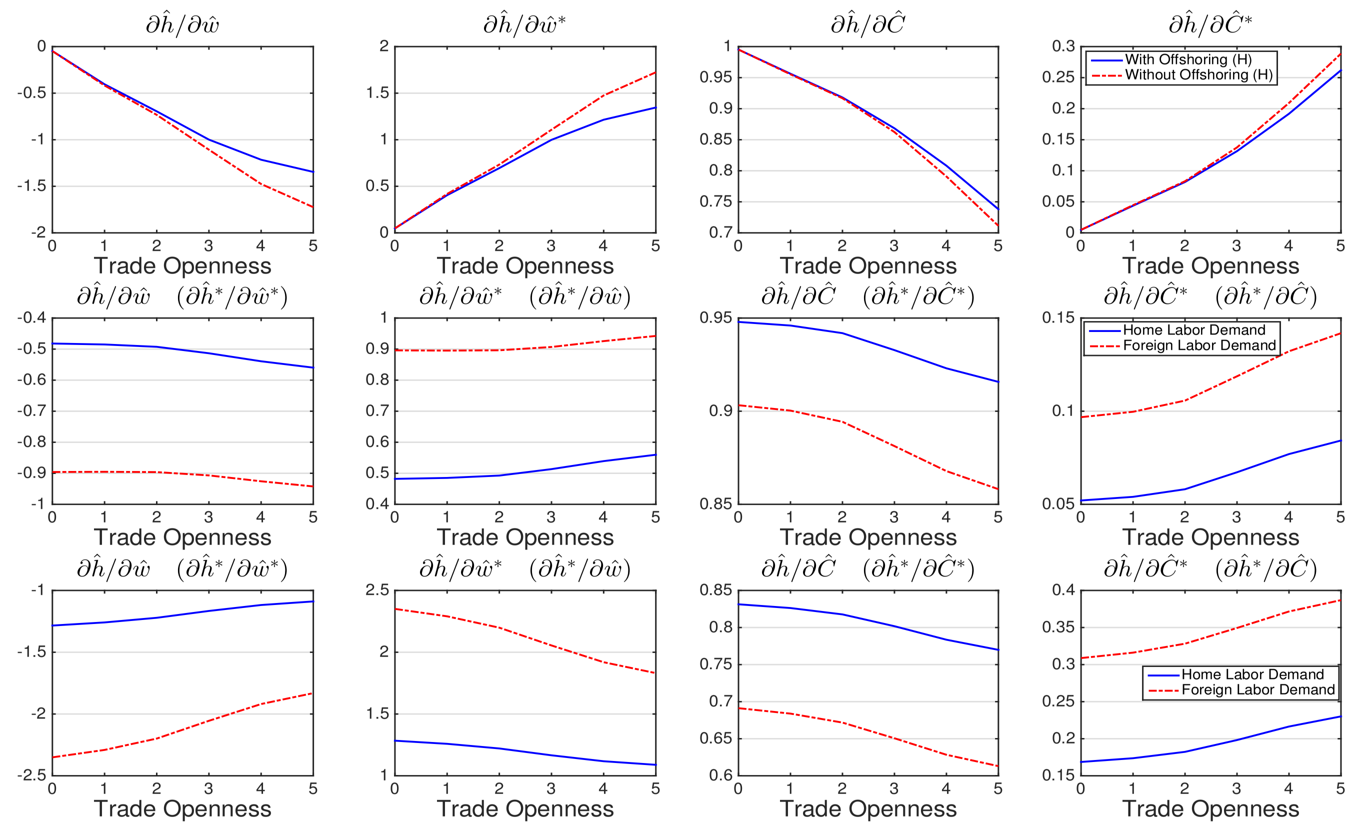
The blue lines are the impulse responses of the baseline model, in which import to real GDP ratio is 17% and offshoring to import ratio is 30%. The red dashed lines are impulse responses of the model, in which Home and Foreign are symmetric and import to real GDP ratio is 17% without offshoring.

Figure 3: Labor Demand Elasticity



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 offshoring to total imports ratio, [(0.5%,0.5%), (3%, 3%), (6%, 12%), (10%, 17%), (15%, 28%), (21%, 37%)].

Figure 4: Labor Demand Elasticities: Counterfactuals



This figure shows the relationship between labor demand elasticities and trade cost as well as offshoring cost. The four panels in the first row compares the case 1, in which growth of trade is driven by the decline in trade cost alone, and the case 2 in which growth of trade is driven by the decline in both 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 offshoring 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 the decline in offshoring cost alone, and the case 4, in which, given a low trade cost, the growth of trade is driven by the 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 offshoring 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 5: Comparing Impulse Responses of Models to Monetary Policy Shocks

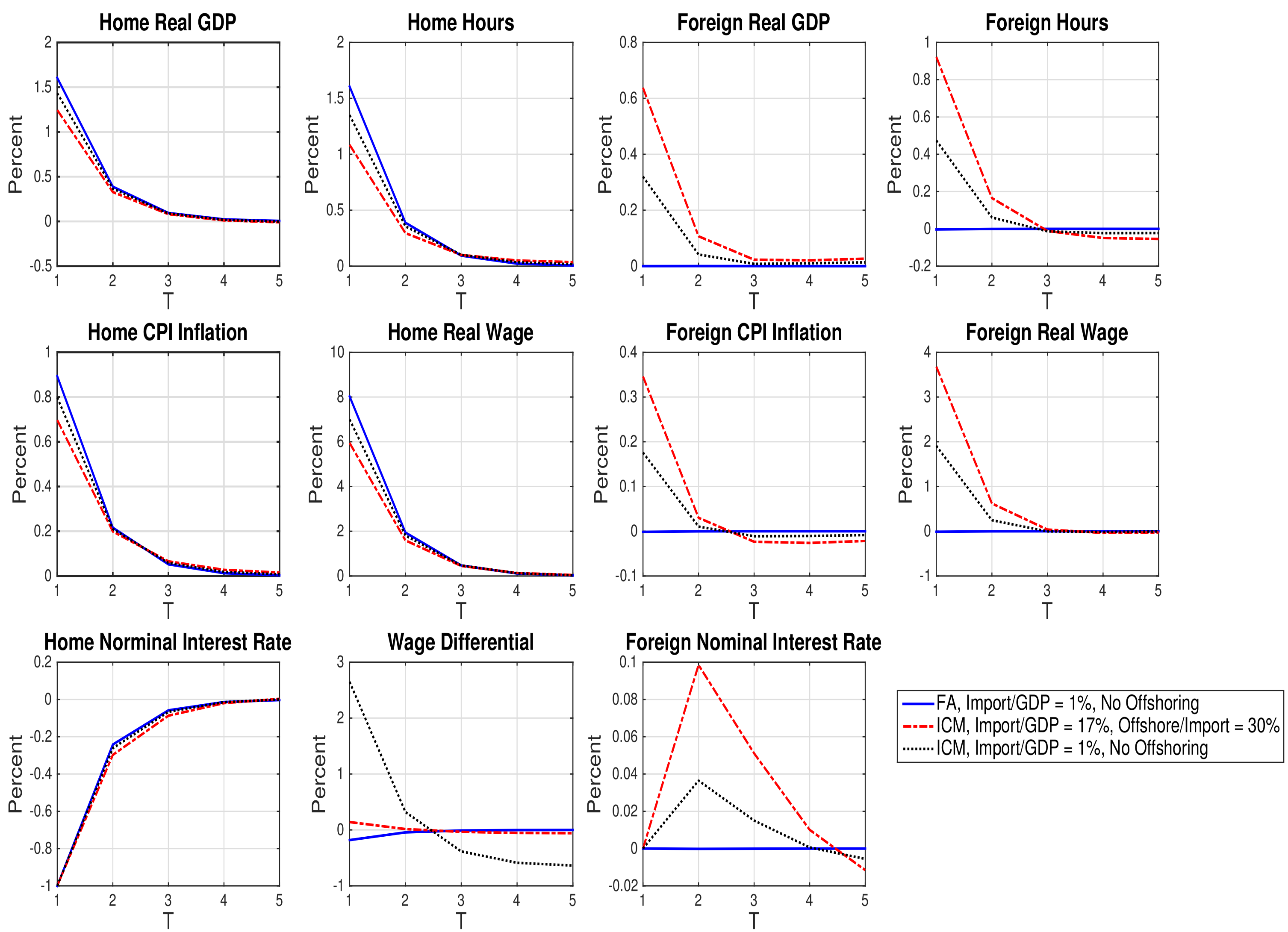
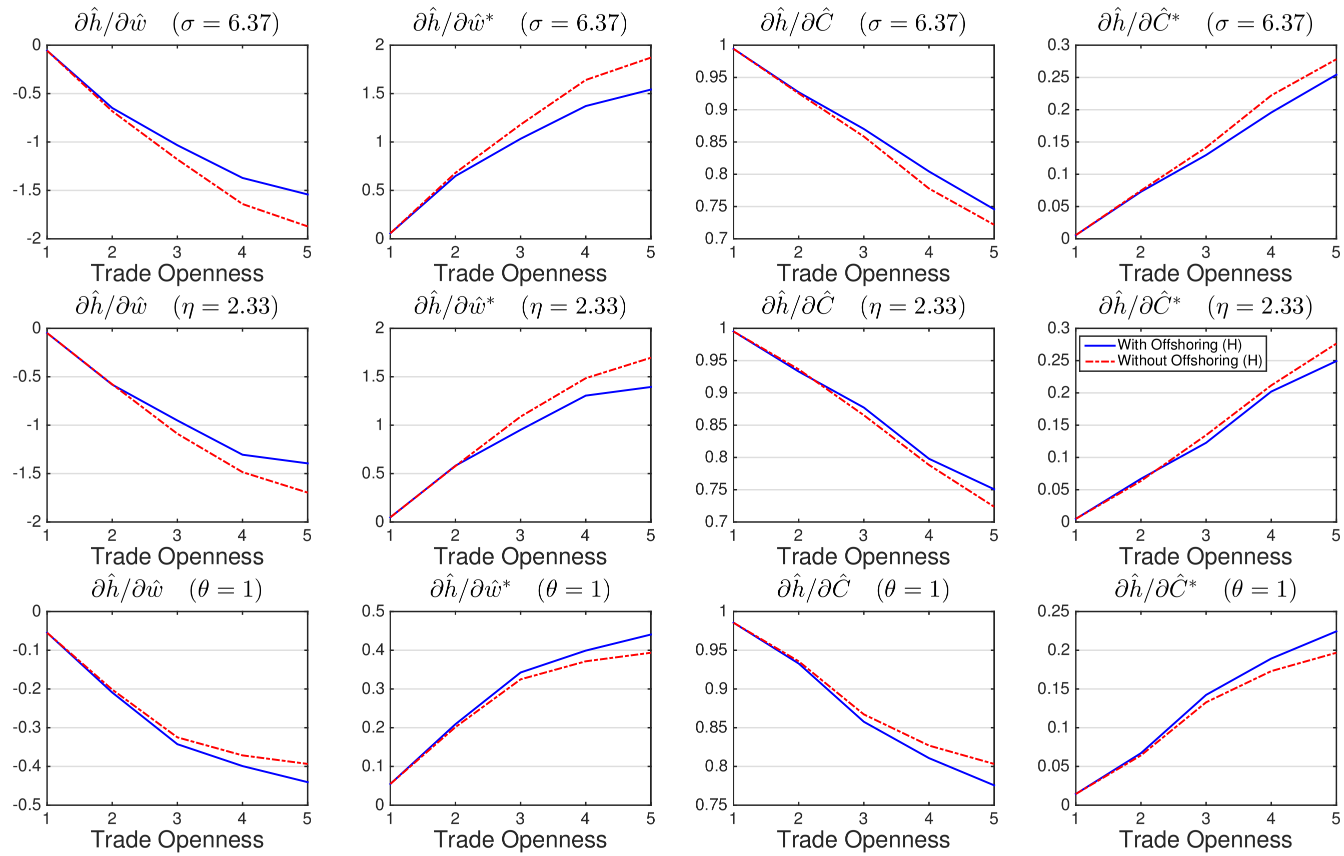


Figure 6: Labor Demand Elasticities: Robustness



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 the model, in which the decline of trade cost drives the growth of trade, and the Home labor demand elasticities computed from the model, in which the decline of both trade cost and offshoring cost drives 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 offshoring 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 offshoring to total imports, [(0%, 0%), (5%, 7%), (10%, 14%), (15%, 21%), (20%, 28%)].