Trade, Unemployment, and Monetary Policy

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Motivation

"I would like to know how the macroeconomic model that I more or less believe can be reconciled with the trade models that I also more or less believe. [...] What we need to know is how to evaluate the microeconomics of international monetary systems. Until we can do that, we are making policy advice by the seat of our pants."

Paul R. Krugman (1995), "What Do We Need to Know about the International Monetary System?" in Peter B. Kenen, ed., *Understanding Interdependence*, Princeton U Press.

Motivation, Continued

- The optimal conduct of monetary policy is a traditional subject of research.
- In the open economy context, both policy and academic discussions have often tied the analysis to the degree of trade integration of the countries involved.
- In the policy arena, implementation of the European Single Market after 1985 was viewed as a crucial step toward the euro.
  - The connection between increased trade integration and tighter monetary cooperation is often stated in official EU documents.
- At the other end of the spectrum, limited weight of international trade in U.S. GDP was invoked in the past to motivate small Fed incentives to engage in international coordination.
- More recently, the consequences of openness and international interdependence have featured prominently in decision-making by U.S. policymakers.
- The Trans-Pacific Partnership (TPP) agreement—a major trade deal involving the U.S. and eleven other Pacific Rim countries—includes a joint declaration by the participants stating their agreement to refrain from exchange rate manipulation and to engage in increased macroeconomic policy cooperation.

Motivation, Continued

- In the academic literature, Frankel and Rose (1998) and Clark and van Wincoop (2001) provided backing for the argument that trade affects monetary policy incentives by finding evidence that trade integration results in stronger business cycle comovement.
  - Countries may endogenously satisfy one of Mundell's (1961) optimum currency area criteria.
- The New Keynesian literature made an effort to incorporate trade integration among the determinants of policy incentives.
- This literature characterizes trade integration in terms of home bias in preferences and/or the weight of imported inputs in production (Coenen et al., 2007, Faia and Monacelli, 2008, Pappa, 2004, Lombardo and Ravenna, 2014).
- Results are very valuable, but proxying a policy outcome (the extent of trade integration) with parameters of preferences and technology may confound the consequences of a policy change (lowering trade barriers) with determinants of agents' behavior that should be invariant to policy.

What We Do

- We re-examine the classic question of trade integration and optimal monetary policy in a two-country model that incorporates the standard ingredients of the current workhorse frameworks in international trade and macro:
  - heterogeneous producers and endogenous entry in domestic and export markets (Melitz, 2003);
  - nominal rigidity; and dynamic, stochastic, general equilibrium.
- Reflecting the attention of policymakers to labor market dynamics and unemployment, we introduce search-and-matching frictions in labor markets (Diamond, 1982a,b, Mortensen and Pissarides, 1994—DMP below).
- By combining these ingredients, we answer Krugman's (1995) "call for research"—and more recent calls for integration of micro-level dynamics in macro policy analysis (Lagarde, 2015, Mann, 2016).

Related Literature

- Endogenous entry, product variety, and business cycles in closed and open economies:
  - Bilbiie, Ghironi, and Melitz (2012) and references therein, Auray and Eyquem (2011), Cacciatore (2014), Cavallari (2011), Contessi (2010), Corsetti, Martin, and Pesenti (2007, 2013), Dekle, Jeong, and Kiyotaki (2010), Ghironi and Melitz (2005), Rodríguez-López (2011), and Zlate (2010).
    - Most related to Cacciatore (2014) and Ghironi and Melitz (2005).
- Optimal policy with endogenous producer entry:
  - Bergin and Corsetti (2008, 2013), Bilbiie, Fujiwara, and Ghironi (2014), Cacciatore, Fiori, and Ghironi (2015, 2016), Chugh and Ghironi (2015), Faia (2012), and Lewis (2013).
    - Most related to Bergin and Corsetti (2013), Bilbiie, Fujiwara, and Ghironi (2014), Cacciatore, Fiori, and Ghironi (2015, 2016).
- Optimal monetary policy in New Keynesian models: Corsetti, Dedola, and Leduc (2010), Galí (2008), Schmitt-Grohé and Uribe (2010), Walsh (2010), Woodford (2003).
  - Labor market frictions: Arseneau and Chugh (2008), Blanchard and Galí (2010), Faia (2009), Thomas (2008).
  - Price stability in open economies: Benigno and Benigno (2003, 2006), Catão and Chang (2012), Galí and Monacelli (2005), Dmitriev and Hoddenbagh (2012).

Model Summary

- Households consist of employed and unemployed members; perfect risk-sharing within each household $\Rightarrow$ no ex post heterogeneity.
- Household utility depends on consumption of a basket and the disutility of efforts by employed members.
- Households trade nominal bonds across countries; incomplete international asset market.

Model Summary, Continued

- Two vertically integrated production sectors in each country.

- Upstream sector: Perfectly competitive firms use labor subject to DMP frictions and exogenous sector-wide, country-specific productivity shocks to produce a non-tradable intermediate good.

  – Nominal wages are subject to adjustment costs.

Model Summary, Continued

- Downstream sector: Monopolistically competitive, multi-product firms produce sectoral bundles of varieties (or product features) using the intermediate good with heterogeneous variety-specific productivity.
  - Creation of new varieties is subject to sunk costs, and there are both fixed and iceberg trade costs.
  - Only varieties (or product features) produced with sufficiently high productivity are included in the export bundle.
  - Price setting happens at the level of the bundles for domestic and export sale; prices are subject to adjustment costs; producer currency pricing as benchmark.
    - Bundle-level price setting preserves Melitz's (2003) aggregation.
- Monetary policy: Worldwide Ramsey-optimal cooperative policy, country-level non-cooperative Ramsey, optimized interest rate rules, "historical" policy (calibrated Taylor-type rules), exchange rate peg.

Some Key Model Properties: Trade and the Business Cycle

- Under historical Fed policy, the model reproduces empirical regularities for the U.S. and international business cycle, including increased comovement following trade integration (captured by a reduction in iceberg trade costs, including tariffs).
  - Endogenous producer entry and labor market frictions are central to this result—a traditional challenge for international business cycle models (Kose and Yi, 2001, 2006).
  - Costly producer entry and frictions in labor markets dampen “resource shifting,” and the demand-side effects of easier trade prevail in affecting comovement.
    - The positive relation between trade and comovement is often not captured by standard New Keynesian models that proxy trade integration with reduction in home bias.

TABLE 5: BUSINESS CYCLE STATISTICS

Variable	$\sigma_{X_R^U}$		$\sigma_{X_R^U}/\sigma_{Y_R^U}$		1st Autocorr		$corr(X_{R,t}^U, Y_{R,t}^U)$	
Y_R	**1.71**	1.50	**1**	1	**0.83**	0.79	**1**	1
C_R	**1.11**	0.94	**0.64**	0.63	**0.70**	0.73	**0.67**	0.87
I_R	**5.48**	5.50	**3.20**	3.68	**0.89**	0.80	**0.87**	0.86
l	**0.97**	0.82	**0.56**	0.56	**0.88**	0.72	**0.79**	0.81
w_R	**0.91**	0.79	**0.52**	0.53	**0.91**	0.92	**0.56**	0.76
X_R	**5.46**	2.40	**3.18**	1.66	**0.67**	0.70	**0.18**	0.17
I_R	**4.35**	2.08	**2.54**	1.39	**0.32**	0.69	**0.70**	0.77
TB_R/Y_R	**0.25**	0.39	**0.14**	0.26	**0.43**	0.71	**-0.47**	-0.48
$corr(C_{R,t}, C_{R,t}^*)$	**0.44**	0.16						
$corr(Y_{R,t}, Y_{R,t}^*)$	**0.51**	0.26						

Bold fonts denote data moments, normal fonts denote model generated moments.

TABLE 7: TRADE INTEGRATION AND GDP COMOVEMENT

	$\Delta corr(Y_{R,t}, Y^*_{R,t})$—Producer Currency Price		
	$\frac{Trade}{GDP} = 0.1$	$\frac{Trade}{GDP} = 0.2$	$\frac{Trade}{GDP} = 0.35$
Historical Rule	0.36	0.45	0.49
Peg	0.05	0.19	0.27
Ramsey	0.07	0.29	0.43
Nash	0.28	0.35	0.48
	$corr(Y_{R,t}, Y^*_{R,t})$—Local Currency Price		
	$\frac{Trade}{GDP} = 0.1$	$\frac{Trade}{GDP} = 0.2$	$\frac{Trade}{GDP} = 0.35$
Historical Rule	0.33	0.42	0.47
Peg	0.05	0.20	0.27
Ramsey	0.36	0.53	0.62
Nash	0.28	0.36	0.42

Some Key Model Properties: Trade and Productivity

- In the long run, trade integration results in reallocation of market shares toward the relatively more efficient producers, consistent with the evidence.

- In turn, this generates an endogenous increase in average firm productivity.

Optimal Monetary Policy: Result 1

- When trade linkages are weak, the optimal, cooperative policy requires significant departures from price stability both in the long run and over the business cycle.
  - Optimal policy uses inflation to narrow inefficiency wedges relative to the efficient allocation.
  - Optimal policy can be approximated by (cooperatively) optimized, inward-looking interest rate rules.

TABLE 3: MARGINS AND DISTORTIONS

$\Upsilon_{\mu_{d,t}} \equiv \frac{\mu_{d,t}}{\mu_{d,t-1}} - 1$	time varying domestic markup, product creation
$\Upsilon_{\mu_{x,t}} \equiv \frac{\mu_{x,t}}{\mu_{d,t}} - 1$	time varying export markup, product creation
$\Upsilon_{\tau_t} \equiv \tau_t^P$	non-optimized trade policy, product creation and trade
$\Upsilon_{\varphi,t} \equiv \frac{1}{\mu_{d,t}} - 1$	monopoly power, job creation and labor supply
$\Upsilon_{\eta,t} \equiv \eta_{w,t} - \varepsilon$	failure of the Hosios condition*, job creation
$\Upsilon_{b,t} \equiv b$	unemployment benefits, job creation
$\Upsilon_{Q,t} \equiv \frac{u^*_{c,t}}{u_{c,t}} - Q_t$	incomplete markets, risk sharing
$\Upsilon_{a,t} \equiv \psi a_{t+1} + \psi a_{*,t+1}$	cost of adjusting bond holdings, risk sharing
$\Upsilon_{\pi_w,t} \equiv \frac{\vartheta}{2}\pi^2_{w,t}$	wage adjustment costs, resource constraint and job creation
$\Upsilon_{\pi_{d,t}} \equiv \frac{\nu}{2}\pi^2_{d,t}$	domestic price adjustment costs, resource constraint
$\Upsilon_{\pi_{x,t}} \equiv \frac{\nu}{2}\pi^2_{x,t}$	export price adjustment costs, resource constraint

* From sticky wages and/or $\eta \neq \varepsilon$.

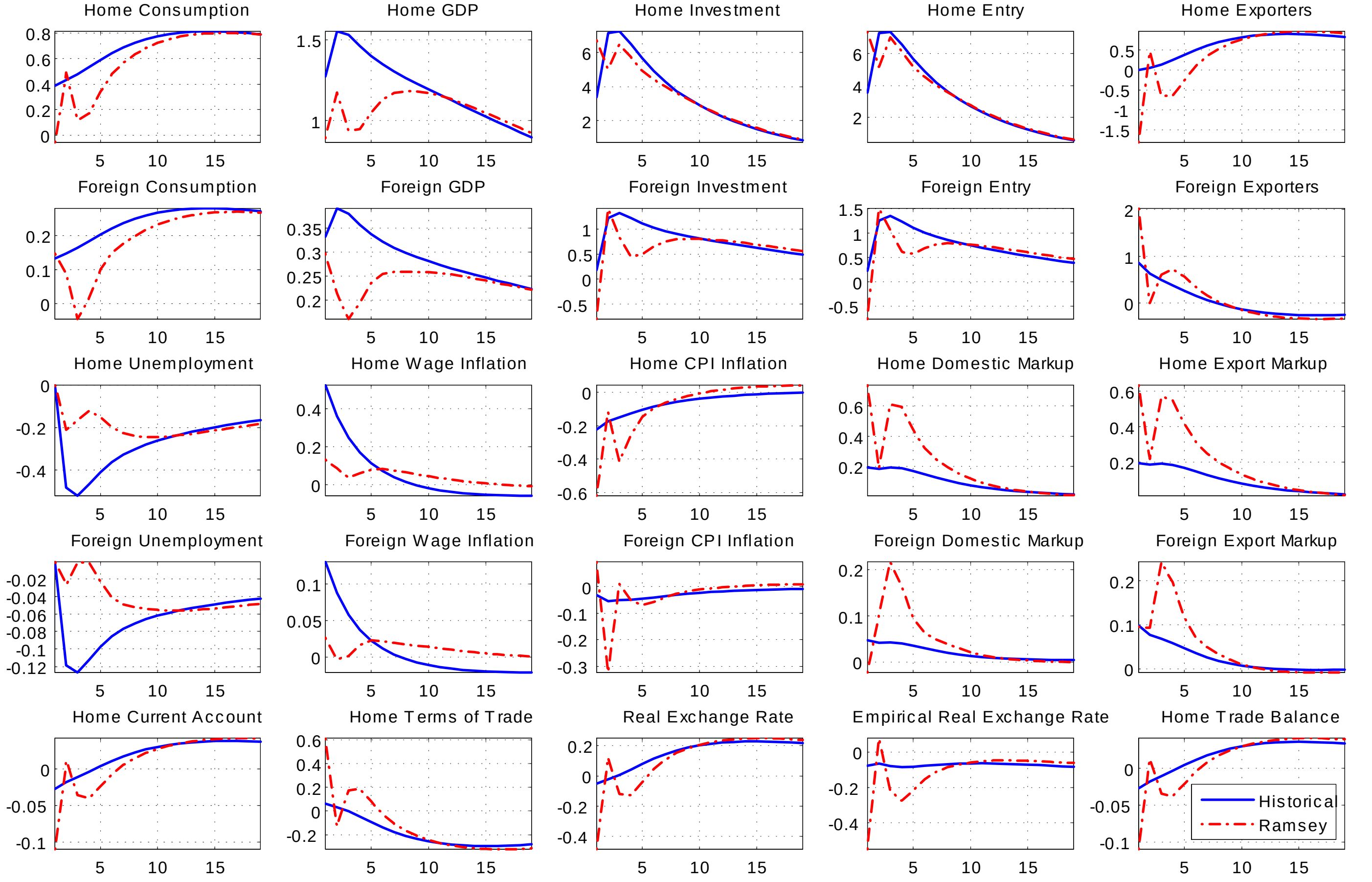


Figure 1: Home Productivity Shock, low trade linkages and producer currency pricing.

Variables are in percentage deviations from the steady state. Unemployment and inflation are in deviations from the steady state.

Optimal Monetary Policy: Result 2

- As trade integration reallocates market share toward more productive firms, the need of positive inflation to correct long-run distortions is reduced.
- Following reduction of trade barriers, products of relatively more productive non-exporting plants are added to the export bundle, and market share of domestic products shrinks due to increased foreign competition.
- Define weighted productivity average $\tilde{z}$ that reflects the combined market shares of all Home firms, accounting for costly trade:

$$\tilde{z} \equiv \left\{ \left[\tilde{z}_d^{\theta-1} + \left(\frac{\tilde{z}_x}{\tau} \right)^{\theta-1} \frac{N_x}{N_d} \right] \right\}^{\frac{1}{\theta-1}} .$$

- Even if average productivity of exporting plants, $\tilde{z}_x$, falls after trade integration, the gain in market share of existing and new exporting plants is strong enough to guarantee that $\tilde{z}$ increases.
- $\Rightarrow$ Reallocation of market shares results in an endogenous increase in average firm productivity.
- This makes job matches more valuable to upstream firms and pushes employment toward the efficient level, reducing the need for inflation to accomplish that by eroding markups and shifting bargaining power.

TABLE 6: TRADE INTEGRATION – NON STOCHASTIC STEADY STATE

	Ramsey Gain	Ramsey Inflation
$\frac{Trade}{GDP} = 0.1$	0.34%	1.40%
$\frac{Trade}{GDP} = 0.2$	0.22%	1.20%
$\frac{Trade}{GDP} = 0.35$	0.16%	1.05%

Optimal Monetary Policy: Result 2b

- Bergin and Corsetti (2013) focus on cross-sectoral relocation of production across a differentiated, monopolistically competitive sector and a perfectly competitive sector that produces a homogeneous good.

- They emphasize the role of optimal monetary policy in generating a pro-competitive effect for the differentiated sector.

- In our model, monetary policy affects the composition of trade along a within-sector extensive margin.

- Relative to price stability, the Ramsey-optimal policy results in a larger number of exported products—N_x is approximately 4 percent higher.
  - The reason is that the employment gains induced by positive inflation raise aggregate demand in both countries, stimulating producer entry into the domestic and export markets.

- However, the productivity cutoff for exporting, z_x, is independent of steady-state inflation.
  - A given change in π induces an equal change in the marginal revenue product of exporting an additional variety and the fixed cost of doing that, φf_x, leaving z_x unaffected.

Optimal Monetary Policy: Result 3

- Increased business cycle synchronization implies that country-specific shocks have more global consequences, and welfare gains from cooperation are small relative to *optimal* non-cooperative policy.
  - This echoes Benigno and Benigno's (2003) finding that there are no gains from cooperation when shocks (and, therefore, business cycles) are perfectly correlated across countries.
  - Our model provides a structural microfoundation for their finding, by making increased business cycle correlation an endogenous consequence of trade integration.
- Important: Gains from cooperation are sizable relative to *historical* Fed behavior.
  - Sims (2007).
- The constrained-efficient allocation generated by optimal cooperative policy can still be achieved by appropriately (cooperatively) designed inward-looking policy rules, but sub-optimal (historical) policy implies inefficient fluctuations in cross-country demand that result in large welfare costs when trade linkages are strong.

TABLE 8: TRADE INTEGRATION – NON STOCHASTIC STEADY STATE

	*Relative Gain from Coordination** —*PCP*				
	Optimal Rule*	Historical Rule	Peg		Nash
			Leader	Follower	
$\frac{Trade}{GDP} = 0.1$	0.88%	18.62%	18.81%	43.45%	0.0001%
$\frac{Trade}{GDP} = 0.2$	3.13%	25.36%	26.90%	45.40%	0.001%
$\frac{Trade}{GDP} = 0.35$	3.15%	29.69%	32.31%	48.39%	0.09%
	*Relative Gain from Coordination** —*LCP*				
	Optimal Rule**	Historical Rule	Peg		Nash
			Leader	Follower	
$\frac{Trade}{GDP} = 0.1$	2.17%	20.91%	20.89%	44.90%	0.10%
$\frac{Trade}{GDP} = 0.2$	2.66%	29.09%	29.49%	47.34%	0.90%
$\frac{Trade}{GDP} = 0.35$	3.16%	36.16%	37.00%	51.97%	2.42%

*Gains are the ratio of welfare costs of business cycle under the Ramsey-optimal policy and the alternative;

**The optimal rule is derived under weak trade linkages (10%) and producer currency pricing (PCP); the rule is kept constant across trade regimes and under local currency pricing (LCP).

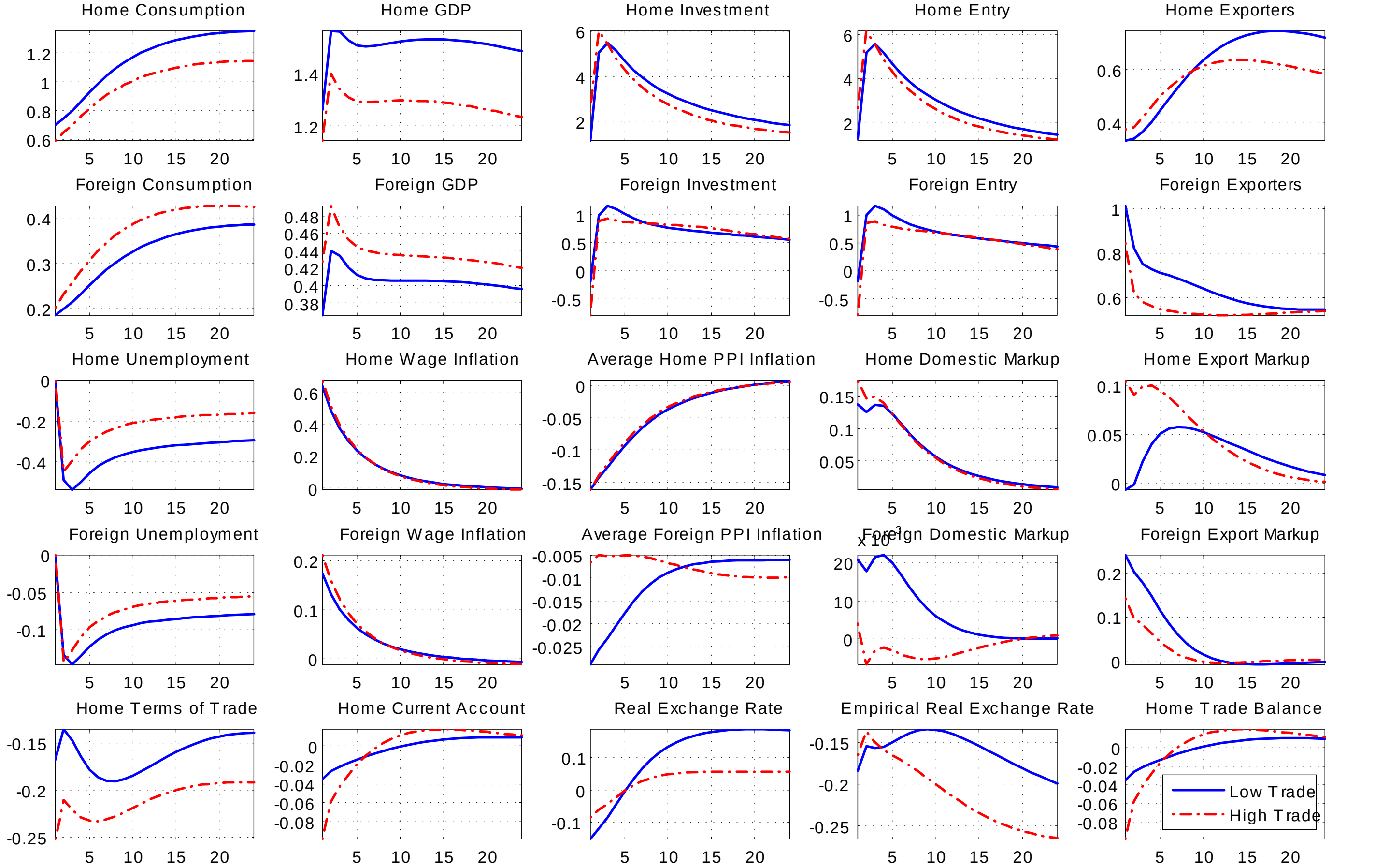


Figure 2: Home Productivity Shock, trade integration and producer currency pricing.

Variables are in percentage deviations from the steady state. Unemployment and inflation are in deviations from the steady state.

Some Other Results

Comovement and Exchange Rate Pegs

- Increased comovement makes an exchange rate peg more desirable for the pegger.

- However, if the center country follows historical Fed behavior, this generates inefficient spillovers with strong trade linkages, offsetting the gain from increased comovement.

Local Currency Pricing

- Results are similar to the benchmark case of producer currency pricing.

The Model

- Two countries: Home and Foreign.
- Cashless economy as in Woodford (2003).
- Each country populated by a unit mass of atomistic households.
- Each household is an extended family with a continuum of members along the unit interval.
- In equilibrium, some family members are unemployed, while some others are employed.
- Perfect insurance within the household $\Rightarrow$ no *ex post* heterogeneity across individual members (Andolfatto, 1996; Merz, 1995).

Household Preferences

- Representative home household maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(C_t) - l_t v(h_t)], \quad \beta \in (0,1).$$

  – $C_t =$ consumption basket, $l_t =$ number of employed workers, $h_t =$ hours worked by each employed worker.

- C_t aggregates consumption of imperfectly substitutable Home and Foreign "sectoral" consumption outputs (or bundles of product features) in Dixit-Stiglitz form:

$$C_t = \left[\int_0^1 C_t(i)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}}, \quad \phi > 1.$$

- Consumption-based price index:

$$P_t = \left[\int_0^1 P_t(i)^{1-\phi} di \right]^{\frac{1}{1-\phi}},$$

where $P_t(i)$ is the price index for sector i.

Production

- Two vertically integrated production sectors in each country.
- Upstream sector: Perfectly competitive firms use labor to produce a non-tradable intermediate input.
- Downstream sector: Each sector i is populated by a representative monopolistically competitive, multi-product firm that purchases intermediate input and produces differentiated sectoral consumption bundle $C_t(i)$.
  - $C_t(i)$ aggregates products (or product features) produced by firm i.
  - In equilibrium, some of these products are exported while the others are sold only domestically.
- This structure greatly simplifies introduction of labor market frictions and sticky prices.

Intermediate Goods Production

Labor Market Frictions

- Unit mass of intermediate producers.

- Each of them employs a continuum of workers.

- Labor markets are characterized by DMP search and matching frictions.

- To hire new workers, firms need to post vacancies, incurring a cost of κ units of consumption per vacancy posted.

- Let $U_t \equiv$ aggregate unemployment and $V_t \equiv$ aggregate vacancies $\Rightarrow$ matching technology generates aggregate matches

$$M_t = \chi U_t^{1-\varepsilon} V_t^{\varepsilon}, \quad \chi > 0, 0 < \varepsilon < 1.$$

- Each firm meets unemployed workers at rate $q_t \equiv M_t / V_t$.

Intermediate Goods Production, Continued

- Newly created matches become productive only in the next period (Krause and Lubik, 2007).

- For an individual firm, the inflow of new hires in $t+1$ is therefore $q_t \upsilon_t$, where υ_t is the number of vacancies posted by the firm in period t.

- Firms and workers can separate exogenously with probability $\lambda \in (0,1)$.

- $\Rightarrow$ law of motion of employment, l_t (those working at time t), in a given firm:

$$l_t = (1-\lambda)l_{t-1} + q_{t-1}\upsilon_{t-1}.$$

Intermediate Goods Production, Continued

- The representative intermediate firm produces $y_t^I = Z_t l_t h_t$, where Z_t is exogenous aggregate productivity:

$$\begin{bmatrix} \log Z_t \\ \log Z_t^* \end{bmatrix} = \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix} \begin{bmatrix} \log Z_{t-1} \\ \log Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}.$$

- Firms faces a quadratic cost of adjusting the hourly nominal wage rate, w_t (Arsenau and Chugh, 2008).

- For each worker, the cost of changing the nominal wage between period $t-1$ and t (in units of consumption) is $\vartheta \pi_{w,t}^2/2$, $\vartheta \geq 0$, where $\pi_{w,t} \equiv (w_t/w_{t-1}) - 1$.

Intermediate Goods Production, Continued

- Intermediate producers sell to final producers at price φ_t in units of consumption.

- They choose the number of vacancies, υ_t, and employment, l_t, to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{u_{C,t}}{u_{C,0}} \left(\varphi_t Z_t l_t h_t - \frac{w_t}{P_t} l_t h_t - \kappa \upsilon_t - \frac{\vartheta}{2} \pi_{w,t}^2 l_t \right).$$

  – Firms assumed to be owned domestically.

- F.o.c.'s for vacancies and employment $\Rightarrow$ job creation equation:

$$\frac{\kappa}{q_t} = E_t \left\{ \beta_{t,t+1} \left[(1-\lambda) \frac{\kappa}{q_{t+1}} + \varphi_{t+1} Z_{t+1} h_{t+1} - \frac{w_{t+1}}{P_{t+1}} h_{t+1} - \frac{\vartheta}{2} \pi_{w,t+1}^2 \right] \right\}, \quad \beta_{t,t+1} \equiv \beta u_{C,t+1} / u_{C,t}.$$

  – At optimum, vacancy creation cost per current match $=$ expected discounted value of vacancy creation cost per future match (further discounted by probability of current match survival $1-\lambda$), plus profits from time-t match.

  – Profits from match $=$ future marginal revenue product from match and its wage cost, including wage adjustment costs.

Intermediate Goods Production, Continued

Wage Determination

- w_t solves individual Nash bargaining process, dividing match surplus between workers and firms.
  - Due to nominal rigidity, we assume that bargaining occurs over nominal rather than real wage (Arseneau and Chugh, 2008; Gertler, Trigari, and Sala, 2008; Thomas, 2008).

Intermediate Goods Production, Continued

- $J_t \equiv$ real value of existing, productive match for a producer:

$$J_t = \varphi_t Z_t h_t - \frac{w_t}{P_t} h_t - \frac{\vartheta}{2} \pi_{w,t}^2 + E_t \beta_{t,t+1} (1-\lambda) J_{t+1}.$$

  – $J_t =$ per period marginal value product of match, $\varphi_t Z_t h_t$, net of wage bill and costs to adjust wages, plus expected discounted continuation value.

Intermediate Goods Production, Continued

- $W_t \equiv$ value of being matched for a worker:

$$W_t = \frac{w_t}{P_t} h_t + E_t \left\{ \beta_{t,t+1} \left[(1-\lambda) W_{t+1} + \lambda U_{u,t+1} \right] \right\}.$$

  - $W_t =$ real wage bill plus expected future value of being matched.

- $U_{u,t} \equiv$ value of being unemployed:

$$U_{u,t} = \frac{v(h_t)}{u_{C,t}} + b + E_t \left\{ \beta_{t,t+1} [(\iota_t W_{t+1} + (1-\iota_t) U_{u,t+1}] \right\}.$$

  - $v(h_t)/u_{C,t} =$ utility gain from leisure in terms of consumption, $b \equiv$ unemployment benefit from the government (financed with lump sum taxes), $\iota_t \equiv M_t/U_t =$ probability of becoming employed at time t.

Intermediate Goods Production, Continued

- $\Rightarrow$ worker's surplus $H_t \equiv W_t - U_{u,t}$:

$$H_t = \frac{w_t}{P_t} h_t - \left(\frac{v(h_t)}{u_{C,t}} + b \right) + (1 - \lambda - \iota_t) E_t \left(\beta_{t,t+1} H_{t+1} \right).$$

- Nash bargaining maximizes weighted surplus average $J_t^{\eta} H_t^{1-\eta}$ w.r.t. w_t, where $\eta \in (0,1)$ is firm bargaining power.

- F.o.c. implies sharing rule:

$$\eta_t H_t = (1 - \eta_t) J_t, \quad \text{where} \quad \eta_t \equiv \frac{\eta}{\eta - (1-\eta) \left(\frac{\partial H_t}{\partial w_t} / \frac{\partial J_t}{\partial w_t} \right)}.$$

  - Bargaining shares are time-varying due to wage adjustment costs (Gertler and Trigari, 2009).

- Sharing rule $\Rightarrow$ bargained wage.

Intermediate Goods Production, Continued

- Hours per worker determined to maximize joint surplus $J_t + H_t$.

- $\Rightarrow v_{h,t}/u_{C,t} = \varphi_t Z_t$.
  - Hours are independent of wage because they are chosen to maximize joint surplus.

Final Goods Production

- In each consumption sector i, the representative, monopolistically competitive producer i produces output bundles (or bundles of product features) for domestic sale or export.

- Producer i is a multi-product firm that produces a set of differentiated products (or product features), indexed by ω and defined over a continuum Ω:

$$Y_t(i) = \left(\int_{\omega \in \Omega} y_t(\omega, i)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}}, \quad \theta > 1.$$

  - Note 1: Sectors (and sector-representative firms) are small relative to the overall size of the economy.

  - Note 2: Each product variety $y_t(\omega, i)$ is created by producer i.

- Drop the index i to simplify notation (symmetry).

- The cost of the product bundle Y_t, denoted with P_t^y, is:

$$P_t^y = \left(\int_{\omega \in \Omega}^{\infty} p_t^y(\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}},$$

  where $p_t^y(\omega)$ is the nominal marginal cost of producing variety ω.

Final Goods Production, Continued

- The number of products (or product features) created and commercialized by each final producer is endogenous.

- At each point in time, only a subset of products $\Omega_t \subset \Omega$ is actually available to consumers.

- To create a new product, the final producer needs to undertake a sunk investment, $f_{e,t}$, in units of intermediate input.
  - Producers need to set up "production lines" (or "plants") to produce new products.

Final Goods Production, Continued

- Plants produce with different technologies indexed by relative productivity z.
- To save notation, identify a product with the corresponding plant productivity z, omitting ω.
- Upon product creation, the productivity level of the new plant z is drawn from a common distribution $G(z)$ with support on $[z_{\min}, \infty)$.
  - Foreign plants draw productivity levels from an identical distribution.
- This relative productivity level remains fixed thereafter.
- Each plant uses intermediate input to produce its differentiated product variety, with real marginal cost:

$$\varphi_t(z) \equiv \frac{p_t^y(z)}{P_t} = \frac{\varphi_t}{z}.$$

Final Goods Production, Continued

- At time t, each final Home producer commercializes $N_{d,t}$ products and creates $N_{e,t}$ new products that will be available for sale at time $t+1$.

- New and incumbent plants can be hit by a "death" shock with probability $\delta \in (0,1)$ at the end of each period.

- $\Rightarrow$ law of motion for stock of producing plants:

$$N_{d,t+1} = (1-\delta)(N_{d,t} + N_{e,t}).$$

The Export Decision

- When serving the Foreign market, producer i faces per-unit iceberg costs, $\tau_t > 1$, and fixed export costs, $f_{x,t}$.
  - Fixed export costs in units of intermediate input; paid for each exported product.
- Total fixed cost: $\overline{f}_{x,t} \equiv N_{x,t} f_{x,t}$, where $N_{x,t} \equiv$ number of products exported to Foreign.
- Absent fixed export costs, each producer would sell all its products in Home and Foreign.
- Fixed export costs imply that only products produced by plants with sufficiently high productivity (above cutoff $z_{x,t}$) are exported.
- $z_{x,t} =$ lowest level of plant productivity such that profit from exporting product is positive (determined below)

Productivity Averages and Cost Minimization

- Define average productivity for all producing plants $\tilde{z}_d$ and average for all plants that export $\tilde{z}_{x,t}$:

$$\tilde{z}_d = \left[\int_{z_{\min}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{\theta-1}}, \qquad \tilde{z}_{x,t} = \left[\frac{1}{1-G(z_{x,t})}\right]\left[\int_{z_{x,t}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{\theta-1}}.$$

- Assume that $G(\cdot)$ is Pareto with shape parameter $k > \theta - 1 \Rightarrow$

$$\tilde{z}_d = \alpha^{\frac{1}{\theta-1}} z_{\min} \quad \text{and} \quad \tilde{z}_{x,t} = \alpha^{\frac{1}{\theta-1}} z_{x,t}, \quad \text{where} \quad \alpha = k/\left[k - (\theta - 1)\right].$$

- Share of exporting plants:

$$N_{x,t} \equiv \left[1 - G(z_{x,t})\right] N_{d,t} = \left(\frac{z_{\min}}{\tilde{z}_{x,t}}\right)^{-k} \alpha^{\frac{k}{\theta-1}} N_{d,t}.$$

Productivity Averages and Cost Minimization, Continued

- Output bundles for domestic and export sale and associated unit costs:

$$Y_{d,t} = \left[\int_{z_{\min}}^{\infty} y_{d,t}(z)^{\frac{\theta-1}{\theta}} dG(z)\right]^{\frac{\theta}{\theta-1}}, \qquad Y_{x,t} = \left[\int_{z_{x,t}}^{\infty} y_{x,t}(z)^{\frac{\theta-1}{\theta}} dG(z)\right]^{\frac{\theta}{\theta-1}},$$

$$P^y_{d,t} = \left[\int_{z_{\min}}^{\infty} p^y_t(z)^{1-\theta} dG(z)\right]^{\frac{1}{1-\theta}}, \qquad P^y_{x,t} = \left[\int_{z_{x,t}}^{\infty} p^y_t(z)^{\frac{\theta-1}{\theta}} dG(z)\right]^{\frac{1}{1-\theta}}.$$

- Real costs of producing bundles $Y_{d,t}$ and $Y_{x,t}$ can be written as:

$$\frac{P^y_{d,t}}{P_t} = N_{d,t}^{\frac{1}{1-\theta}} \frac{\varphi_t}{\tilde{z}_d}, \qquad \frac{P^y_{x,t}}{P_t} = N_{x,t}^{\frac{1}{1-\theta}} \frac{\varphi_t}{\tilde{z}_{x,t}}.$$

Productivity Averages and Cost Minimization, Continued

- Total EPD cost of final producer:

$$E_t \left\{ \sum_{s=t}^{\infty} \beta_{t,t+s} \left[\frac{P^y_{d,s}}{P_s} Y_{d,s} + \tau_s \frac{P^y_{x,s}}{P_s} Y_{x,s} + \left(\frac{N_{s+1}}{1-\delta} - N_s \right) f_{e,s} \varphi_s + N_{x,s} f_{x,s} \varphi_s \right] \right\},$$

$$\beta_{t,t+s} \equiv \beta^{s-t} (u_{C,t+s}/u_{C,t}).$$

- Producer determines $N_{d,t+1}$ and productivity cutoff $z_{x,t}$ to minimize this subject to

$$N_{x,t} = \left(\frac{z_{\min}}{\tilde{z}_{x,t}} \right)^{-k} \alpha^{\frac{k}{\theta-1}} N_{d,t},$$

$$\frac{P^y_{d,t}}{P_t} = N_{d,t}^{\frac{1}{1-\theta}} \frac{\varphi_t}{\tilde{z}_d}, \qquad \frac{P^y_{x,t}}{P_t} = N_{x,t}^{\frac{1}{1-\theta}} \frac{\varphi_t}{\tilde{z}_{x,t}},$$

and $\tilde{z}_{x,t} = \alpha^{\frac{1}{\theta-1}} z_{x,t}$.

Export Cutoff Determination

- F.o.c. w.r.t. $z_{x,t}$ yields:

$$\frac{P_{x,t}^{y}}{P_t} Y_{x,t} \tau_t = \frac{(\theta - 1)k}{[k - (\theta - 1)]} f_{x,t} N_{x,t} \varphi_t.$$

  - Marginal revenue from adding product with productivity $z_{x,t}$ to export bundle $=$ fixed cost.
  - Products by plants with productivity below $z_{x,t}$ sold only domestically.
  - Composition of traded bundle is endogenous and fluctuates over time with changes in export profitability.

Product Creation

- F.o.c. w.r.t. $N_{d,t+1}$ determines product creation:

$$\varphi_t f_{e,t} = E_t \left\{ (1-\delta)\,\beta_{t,t+1} \left[\begin{array}{c} \varphi_{t+1}\left(f_{e,t+1} - \frac{N_{x,t+1}}{N_{d,t+1}} f_{x,t+1} \right) \\ + \frac{1}{\theta-1}\left(\frac{P^y_{d,t+1} Y_{d,t+1}}{P_{t+1} N_{t+1}} + \frac{P^y_{x,t+1} Y_{x,t+1}}{P_{t+1} N_{t+1}} \tau_{t+1} \right) \end{array} \right] \right\}.$$

  - At optimum, cost of producing additional product $=$ expected benefit.
  - Expected benefit $=$ expected saving on future sunk investment costs plus marginal revenue from sale (net of fixed export costs, if exported).

Price Setting

- Let $P_{d,t} \equiv$ price of bundle $Y_{d,t}$ in Home currency, $P_{x,t} \equiv$ price of exported bundle $Y_{x,t}$ in Foreign currency.

- Each final producer faces demand for its product bundles:

$$Y_{d,t} = \left(\frac{P_{d,t}}{P_t}\right)^{-\phi} Y_t^C, \qquad Y_{x,t} = \left(\frac{P_{x,t}}{P_t^*}\right)^{-\phi} Y_t^{C*},$$

  where Y_t^C and Y_t^{C*} are aggregate demands of the consumption basket in Home and Foreign.

  – Aggregate demand in each country includes sources other than consumption, but takes same form as consumption basket, with same elasticity of substitution $\phi > 1$ across sectoral bundles.

  – $\Rightarrow$ price index for consumption aggregator is also price index for aggregate demand of the basket.

Price Setting, Continued

- Prices are sticky: Final producers must pay quadratic price adjustment costs when changing domestic and export prices (Rotemberg, 1982).

- Benchmark: producer currency pricing (PCP):
  - Each final producer sets $P_{d,t}$ and domestic currency price of export bundle, $P_{x,t}^h$, letting price in foreign market be $P_{x,t} = \tau_t P_{x,t}^h / S_t$, where $S_t \equiv$ NER.

- Nominal costs of adjusting domestic and export price:

$$\Gamma_{d,t} \equiv \nu \pi_{d,t}^2 P_{d,t} Y_{d,t}/2, \quad \text{and} \quad \Gamma_{x,t}^h \equiv \nu \pi_{x,t}^{h^2} P_{x,t}^h Y_{x,t}/2, \quad \nu \geq 0,$$

  where $\pi_{d,t} \equiv (P_{d,t}/P_{d,t-1}) - 1$ and $\pi_{x,t}^h \equiv (P_{x,t}^h / P_{x,t-1}^h) - 1$.

- Price rigidity at bundle level is necessary to preserve Melitz aggregation.

Price Setting, Continued

- Absent fixed export costs, the producer would set $P_{d,t}$ and LOP (adjusted for iceberg costs) would determine export price as $P_{x,t} = \tau_t P_{d,t}/S_t$.

- With fixed export costs, however, composition of domestic and export bundles is different, and marginal costs of producing them are not equal.

- Therefore, final producers choose different prices for Home and Foreign markets even under PCP.

  – Plant heterogeneity and fixed export costs imply that LOP does not hold for exported bundles.

Price Setting, Continued

- Optimal price setting yields:

$$\frac{P_{d,t}}{P_t} = \frac{\phi}{(\phi - 1)\,\Xi_{d,t}} \left(\frac{P^y_{d,t}}{P_t} \right),$$

where:

$$\Xi_{d,t} \equiv \left(1 - \frac{\nu}{2}\pi^2_{d,t}\right) \nu \left(\pi_{d,t} + 1\right) \pi_{d,t} - \frac{\nu}{(\phi - 1)} E_t \left[\beta_{t,t+1} \left(\pi_{d,t+1} + 1\right) \pi_{d,t+1} \frac{Y_{d,t+1}}{Y_{d,t}} \right],$$

and:

$$\frac{P_{x,t}}{P^*_t} = \frac{\phi}{(\phi - 1)\,\Xi^h_{x,t}} \left(\frac{\tau_t P^y_{x,t}}{Q_t P_t} \right),$$

where $Q_t \equiv S P^*_t / P_t$ is the consumption-based real exchange rate, and:

$$\Xi^h_{x,t} \equiv \left(1 - \frac{\nu}{2}\pi^{h^2}_{x,t}\right) \nu \left(\pi^h_{x,t} + 1\right) \pi^h_{x,t} - \frac{\nu}{(\phi - 1)} E_t \left[\beta_{t,t+1} \left(\pi^h_{x,t+1} + 1\right) \pi^h_{x,t+1} \frac{Y_{x,t+1}}{Y_{x,t}} \right].$$

  – Absent fixed export costs $z_{x,t} = z_{\min}$ and $\Xi_{x,t} = \Xi^h_{d,t}$.

Household Budget Constraint

- Representative household can invest in non-contingent bonds traded domestically and internationally.
- International assets markets are incomplete.
- Home bonds, issued by Home households, are denominated in Home currency; Foreign bonds, issued by Foreign households, are denominated in Foreign currency.
- Costs of adjusting bond holdings pin down steady-state net foreign assets and ensure stationarity (Turnovsky, 1985).
- Home household's period budget constraint:

$$\begin{aligned} & A_{t+1} + S_t A_{*,t+1} + \frac{\psi}{2} P_t \left(\frac{A_{t+1}}{P_t} \right)^2 + \frac{\psi}{2} S_t P_t^* \left(\frac{A_{*,t+1}}{P_t^*} \right)^2 + P_t C_t + T_t^G \\ = & \ (1 + i_t) A_t + (1 + i_t^*) A_{*,t} S_t + w_t L_t + P_t b(1 - l_t) + T_t^A + T_t^I + T_t^F . \end{aligned}$$

  - $T_t^G \equiv$ lump-sum tax that finances unemployment benefits, $T_t^A \equiv$ lump-sum rebate of costs of adjusting bond holdings, and $T_t^I \equiv$ lump-sum rebate of profits from intermediate producers, $T_t^F \equiv$ lump-sum rebate of profits from final producers.

Household Intertemporal Decisions

- Let $a_{t+1} \equiv A_{t+1}/P_t$ and $a_{*,t+1} \equiv A_{*,t+1}/P_t^*$.
- $\Rightarrow$ Euler equations for bond holdings:

$$1 + \psi a_{t+1} = (1 + i_{t+1}) E_t \left(\frac{\beta_{t,t+1}}{1 + \pi_{C,t+1}} \right),$$

$$1 + \psi a_{*t+1} = (1 + i_{t+1}^*) E_t \left[\beta_{t,t+1} \frac{Q_{t+1}}{Q_t \left(1 + \pi_{C,t+1}^* \right)} \right],$$

where $\pi_{C,t} \equiv (P_t/P_{t-1}) - 1$ and $\pi_{C,t}^* \equiv \left(P_t^*/P_{t-1}^* \right) - 1$.

Net Foreign Assets

- Bonds are in zero net supply: $a_{t+1} + a^*_{t+1} = 0$ and $a^*_{*,t+1} + a_{*,t+1} = 0$ in all periods.

- Home NFA:

$$a_{t+1} + Q_t a_{*,t+1} = \frac{1+i_t}{1+\pi_{C,t}} a_t + Q_t \frac{1+i^*_t}{1+\pi^*_{C,t}} a_{*,t} + Q_t N_{x,t} \tilde{\rho}_{x,t} \tilde{y}_{x,t} - N^*_{x,t} \tilde{\rho}^*_{x,t} \tilde{y}^*_{x,t}.$$

- Defining $1 + r_t \equiv (1+i_t) / (1+\pi_{C,t})$ and similarly for $1 + r^*_t$, change in NFA between t and $t+1$ is determined by the current account:

$$(a_{t+1} - a_t) + Q_t (a_{*,t+1} - a_{*,t}) = CA_t \equiv r_t a_t + Q_t r^*_t a_{*,t} + TB_t,$$

where $TB_t \equiv$ trade balance:

$$TB_t \equiv Q_t N_{x,t} \tilde{\rho}_{x,t} \tilde{y}_{x,t} - N^*_{x,t} \tilde{\rho}^*_{x,t} \tilde{y}^*_{x,t},$$

where we defined average real export price and quantity:

$$\tilde{\rho}_{x,t} \equiv N_{x,t}^{\frac{1}{\theta-1}} (P_{x,t}/P^*_t), \quad \tilde{y}_{x,t} = \tilde{\rho}_{x,t}^{-\phi} N_{x,t}^{\frac{\theta-\phi}{1-\theta}} Y_t^{C*},$$

and similarly for $\tilde{\rho}^*_{x,t}$ and $\tilde{y}^*_{x,t}$.

Monetary Policy

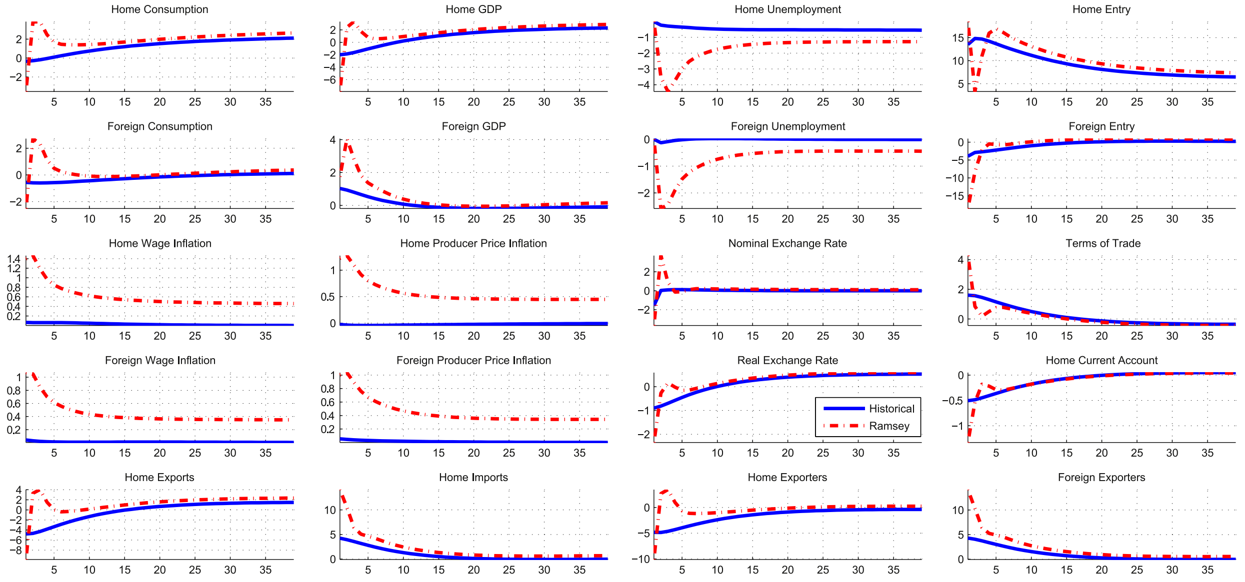
- We compare Ramsey-optimal, cooperative conduct of monetary policy to:
  - Historical central bank behavior under flexible ER, captured by standard rule for interest rate setting in the spirit of Taylor (1993) for both central banks:

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left[(1 + i) \left(1 + \tilde{\pi}_{C,t}\right)^{\varrho_\pi} \left(Y^g_{R,t} \right)^{\varrho_Y} \right]^{1-\varrho_i}.$$

    where $\tilde{\pi}_{C,t}$ is data-consistent CPI inflation and $Y^g_{R,t}$ is data-consistent output gap (data-consistent = removing pure variety effects not captured by data).
  - Cooperatively optimized, inward-looking interest rate rules under flexible ER.
  - ER peg, in which a country sets its interest rate and the other pegs ER.
  - Non-cooperative, “unrestricted” optimal policy.

Results and More...

- Results 1, 2, and 3 emerge.
- But the framework can be used to address a variety of questions of importance for current policy debates.
- Trade integration is a structural reform that can involve more than changes in iceberg costs.
- Agreements such as TPP include provisions on market regulation—harmonization of regulatory standards that, for instance, impinge on entry barriers in production across countries.
- The consequences of such policy actions and their interdependence with macro policy can naturally be studied in our framework, which also makes it possible to address the issue of whether or not this type of reforms have deflationary effects.
  - This is argued by Eggertsson, Ferrero, and Raffo (2014) and subsequent literature using a reduced-form model of reforms that treats them as exogenous markup cuts in off-the-shelf New Keynesian models.
- The next figure provides an example: Harmonization of entry regulation at U.S. levels by a previously highly regulated country is not deflationary, does not depreciate the terms of trade, and results in deficit for significant part of the transition. Optimal policy in response to deregulation is expansionary (Draghi, 2015). (New optimal inflation target is lower.)



Home product market deregulation, flexible regulation in foreign. Historical policy (solid) versus optimal policy (dashes).

Conclusions

- We re-examined classic questions on trade integration and international monetary policy in a DSGE model with micro-level trade dynamics and labor market frictions.

- With low trade integration, departures from price stability are optimal in the long run and over the business cycle, but trade-induced productivity gains reduce the need of positive inflation to correct long-run distortions.

- Over the business cycle, trade integration results in larger benefits from cooperation relative to historical policy, but optimized inward-looking policy rules can still approximate the cooperative outcome.
  - Stronger business cycle synchronization across countries generated by trade integration is the key reason why gains from cooperation are small relative to optimal non-cooperative behavior.
  - It is also the key reason why the costs of pegging the currency and giving up monetary independence are lower if the center country is optimizing its policy.

- The framework makes it possible to study several issues of relevance to ongoing debates—which we have been doing in other papers.

Conclusions, Continued

- Much remains to be done:
  - We did not analyze optimal trade policy nor its strategic interdependence with monetary policymaking (Basevi, Delbono, and Denicolo', 1990).
  - We did not introduce financial frictions, a role for trade finance (Amity and Weinstein, 2011; Manova, 2013), and their impact on policy.
- We view these (and others) as important, promising areas where to take this research next.