# 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 stated often 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.
  - Does increased trade in the "globalization era" change this?

## 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, however, 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, 2010).
- 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.

# Motivation, Continued

- 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 firms and endogenous producer 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).
- By combining these ingredients, we answer Krugman's (1995) "call for research."

# Results

- 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).
    - The positive relation between trade and comovement is not captured by standard New Keynesian models that proxy trade integration with reduction in home bias.

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

# Results, Continued

**Three Key Results on Monetary Policy**

- First, when trade linkages are weak, the optimal, cooperative policy is inward-looking but 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.

- Second, as trade integration reallocates market share toward more productive firms, the need of positive inflation to correct long-run distortions is reduced.
  - Reallocation of market shares results in an endogenous increase in average firm productivity.
  - This makes job matches more valuable and pushes employment toward the efficient level, reducing the need for inflation to accomplish that by eroding markups.

# Results, Continued

- Third, 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.

# Results, Continued

**Comovement and Exchange Rate Pegs**

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

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

**Cooperation versus Historical Behavior**

- Gains from cooperation are sizable relative to historical Federal Reserve behavior.

- The constrained efficient allocation generated by optimal cooperative policy can still be achieved by appropriately 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.

# 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).

- Optimal policy with endogenous producer entry:
  - Bergin and Corsetti (2008, 2013), Bilbiie, Fujiwara, and Ghironi (2014), Cacciatore, Fiori, and Ghironi (2013), Chugh and Ghironi (2011), Faia (2010), and Lewis (2010).
    - Most related to Bilbiie, Fujiwara, and Ghironi (2014) and Cacciatore, Fiori, and Ghironi (2011).

- 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).

# The Model

- Two countries: Home and Foreign; each populated by a unit mass of atomistic households.

- Each household is an extended family with a continuum of members on 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).

- Cashless economy as in Woodford (2003).

# 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

- Unit mass of intermediate producers.

- Production function: $y_t^I = Z_t l_t h_t$, where $Z_t$ is exogenous aggregate productivity.
  - $Z_t$ and $Z_t^*$ follow bivariate $AR(1)$ in logs.

**DMP Labor Market Frictions**

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

- Matching technology generates aggregate matches:

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

$U_t \equiv$ aggregate unemployment, $V_t \equiv$ aggregate vacancies.

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

- Time-to-train (Krause and Lubik, 2007) and exogenous separation at rate $\lambda \in (0, 1) \Rightarrow$

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

# Intermediate Goods Production, Continued

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

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

  - $\varphi_t \equiv$ price of intermediate good in units of consumption; $w_t \equiv$ nominal wage; $\vartheta\pi^2_{w,t}/2 \equiv$ cost of wage adjustment; $\pi_{w,t} \equiv$ wage inflation.
  - 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 $1-\lambda$) $+$ 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, dividing match surplus between worker and firm.
  - Due to nominal rigidity, bargaining occurs over nominal rather than real wage (Arseneau and Chugh, 2008; Gertler, Trigari, and Sala, 2008; Thomas, 2008).
- Firm surplus, $J_t$:

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

  - $J_t =$ 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.
- Worker surplus, $H_t \equiv$ value of employment, $W_t$, $-$ value of unemployment, $U_{u,t}$:
  - $W_t =$ real wage bill $+$ expected future value:

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

  - $U_{u,t} =$ utility gain from leisure, $v(h_t)/u_{C,t}$, $+$ unemployment benefit, $b$,$+$ expected future value; $\iota_t \equiv M_t/U_t =$probability of becoming employed:

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

# Intermediate Goods Production, Continued

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

- F.o.c.$\Rightarrow$ sharing rule:

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

  - Bargaining shares are time-varying due to wage adjustment costs (Gertler and Trigari, 2009).
  - Sharing rule $\Rightarrow$ bargained wage.

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

- $\Rightarrow v_{h,t}/u_{C,t} = \varphi_t Z_t$.

# 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 $\omega$ and defined over a continuum $\Omega$:

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

  - 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:

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

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

# 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.

- Plants produce with different technologies indexed by relative productivity $z$.
  - Identify a product with the corresponding plant productivity $z$, omitting $\omega$.

- Upon product creation, the productivity level of the new plant $z$ is drawn from a common distribution $G(z)$ with support on $[z_{\min}, \infty)$.

- $z$ 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.

- $\Rightarrow$ 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:

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

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

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

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

# Productivity Averages and Cost Minimization, Continued

- Cost minimization implies optimality condition for product creation and cutoff productivity above for product export.

- 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).

# Productivity Averages and Cost Minimization, Continued

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

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

  - 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.

# 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, $P^h_{x,t}$, letting price in foreign market be $P_{x,t} = \tau_t P^h_{x,t}/S_t$, where $S_t \equiv$ NER.

- Nominal costs of adjusting domestic and export price:

$$\Gamma_{d,t} \equiv \nu \pi^2_{d,t} P_{d,t} Y_{d,t}/2, \quad \text{and} \quad \Gamma^h_{x,t} \equiv \nu \pi^{h^2}_{x,t} P^h_{x,t} Y_{x,t}/2, \quad \nu \geq 0,$$

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

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

**Note**

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

- Therefore, producers choose different prices for Home and Foreign markets even under PCP.
  - Plant heterogeneity and fixed export costs imply that LOP does not hold.

# 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 $Q_t \equiv SP^*_t/P_t$ 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 Intertemporal Optimization

- 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.

- Standard Euler equations for bond holdings follow.

# Aggregate Accounting

- 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:

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

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 monetary policy (maximization of weighted average of Home and Foreign welfare) 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.
  - 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.

TABLE 3: DISTORTIONS

| | |
|---|---|
| $\Upsilon_{\mu_{d,t}} \equiv \frac{\mu_{d,t}}{\mu_{d,t-1}} - 1$ | time varying domestic markups, product creation |
| $\Upsilon_{\mu_{x,t}} \equiv \frac{\mu_{x,t}}{\mu_{d,t}} - 1$ | time varying export markups, product creation |
| $\Upsilon_{\varphi,t} \equiv \frac{1}{\mu_{d,t}} - 1$ | monopoly power, job creation and labor supply |
| $\Upsilon_{\eta,t} \equiv \eta_t - \varepsilon$ | 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 |
| $\Upsilon_{\pi_{x,t}} \equiv \frac{\nu}{2}\pi^2_{x,t}$ | export price adjustment costs |

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

TABLE 4: CALIBRATION

| | Parameter | Source/Target |
|---|---|---|
| Risk Aversion | $\gamma_C = 1$ | Literature |
| Frisch elasticity | $1/\gamma_h = 0.4$ | Literature |
| Discount Factor | $\beta = 0.99$ | $r = 4\%$ |
| Elasticity Matching Function | $\varepsilon = 0.4$ | Literature |
| Firm Bargaining Power | $\eta = 0.4$ | Literature |
| Home Production | $b = 0.54$ | Literature |
| Exogenous separation | $\lambda = 0.10$ | Literature |
| Vacancy Cost | $\kappa = 0.16$ | $s = 60\%$ |
| Matching Efficiency | $\chi = 0.68$ | $q = 70\%$ |
| Elasticity of Substitution | $\theta = 3.8$ | Literature |
| Plant Exit | $\delta = 0.026$ | $\frac{JD^{EXIT}}{JD} = 40\%$ |
| Pareto Shape | $k = 3.4$ | Literature |
| Pareto Support | $z_{\min} = 1$ | Literature |
| Sunk Entry Cost | $f_e = 0.69$ | Literature |
| Fixed Export Costs | $f_x = 0.005$ | $(N_x/N) = 21\%$ |
| Iceberg Trade Costs | $\tau = 1.75$ | $(I + X)/Y = 10\%$ |
| Rotemberg Wage Adj. Cost | $\vartheta = 60$ | $\frac{\sigma_l}{\sigma_{Y_R}} = 0.56$ |
| Rotemberg Price Adj. Cost | $\nu = 80$ | Literature |
| Taylor - Interest Rate Smoothing | $\varrho_i = 0.71$ | Literature |
| Taylor - Inflation Parameter | $\varrho_\pi = 1.62$ | Literature |
| Taylor - Output Gap Parameter | $\varrho_Y = 0.34$ | Literature |
| Bond Adjustment Cost | $\psi = 0.0025$ | Literature |

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.

# Optimal Monetary Policy with Weak Trade Linkages

**Long Run**

- Long-run inflation is always symmetric across countries.

- This follows from steady-state Euler equations of households, which imply:

$$1 + \pi_C = \beta(1 + i) = 1 + \pi_C^*.$$

- Moreover, $\pi_C = \pi_d = \pi_x = \pi_w$.

- To understand the incentives that shape optimal policy in the long run, notice that a symmetric long-run equilibrium with constant endogenous variables eliminates some distortions:

  – Constant, synchronized markups remove markup variation and misalignment distortions from product creation margin ($\Upsilon_{\mu_d} = \Upsilon_{\mu_x} = 0$).

  – Symmetry across countries removes the risk-sharing distortion of incomplete markets ($\Upsilon_Q = 0$), and constant, zero net foreign assets eliminate the effect of asset adjustment costs ($\Upsilon_a = 0$).

# Optimal Monetary Policy with Weak Trade Linkages, Continued

**Long Run, Continued**

- The optimal long-run target for net inflation with low trade is $1.4$ percent.

- **Intuition:** All remaining steady-state distortions but costs of wage and price adjustment require lower markups.
  - Firms' monopoly power in downstream sector and positive unemployment benefits imply suboptimally low job-creation.
  - Since $\pi_C = \pi_w$, positive inflation raises firms' bargaining power $\bar{\eta}$, favoring vacancy posting by firms.

- Ramsey authority trades beneficial effects of reducing these distortions against the costs of non-zero inflation implied by allocating resources to wage and price changes and by departure from Hosios condition (since $\bar{\eta} > \varepsilon$).

- Compared to zero-inflation outcome, Ramsey authority reduces inefficiency wedge in job creation.

- Welfare gains amount to $0.34$ percent of annualized steady-state consumption.

# Optimal Monetary Policy with Weak Trade Linkages, Continued

**Business Cycle**

- Relative to historical rule (a policy of near producer price stability, defined as zero deviation of average domestic producer price inflation from its long-run level), the Ramsey authority generates a much smaller increase in wage inflation and a larger departure from price stability (disinflation).

- As in steady state, there is a tension between beneficial effects of manipulating inflation and its costs.

- Moreover, there is a tradeoff between stabilizing inflation in goods prices (which stabilizes domestic markups) and wage inflation (which stabilizes unemployment).

- Finally, there is a tension between stabilizing domestic markups, $\mu_{d,t}$, and export markups, $\mu_{x,t}$.

# Optimal Monetary Policy with Weak Trade Linkages, Continued

**Business Cycle, Continued**

- Price stability is suboptimal because wage inflation is too volatile, and markup stabilization correspondingly too strong, under this policy.

- Historical Fed behavior result in positive employment comovement across countries.

- In contrast, Ramsey policy pushes unemployment rates in opposite directions by engineering wage disinflation rather than inflation in Foreign.

- This results in higher unemployment in the relatively less productive economy.

- Welfare cost of business cycles falls by approximately $20$ percent:
  - Optimal departures from price stability lower the cost of business cycles from $1.02$ percent of steady-state consumption under the historical policy to $0.82$ percent.

- Welfare loss implied by optimal interest rules relative to Ramsey policy is less than $0.008$ percent of steady-state consumption.
  - When trade linkages are weak, Ramsey-optimal policy is well approximated by optimized inward-looking interest rate rule.

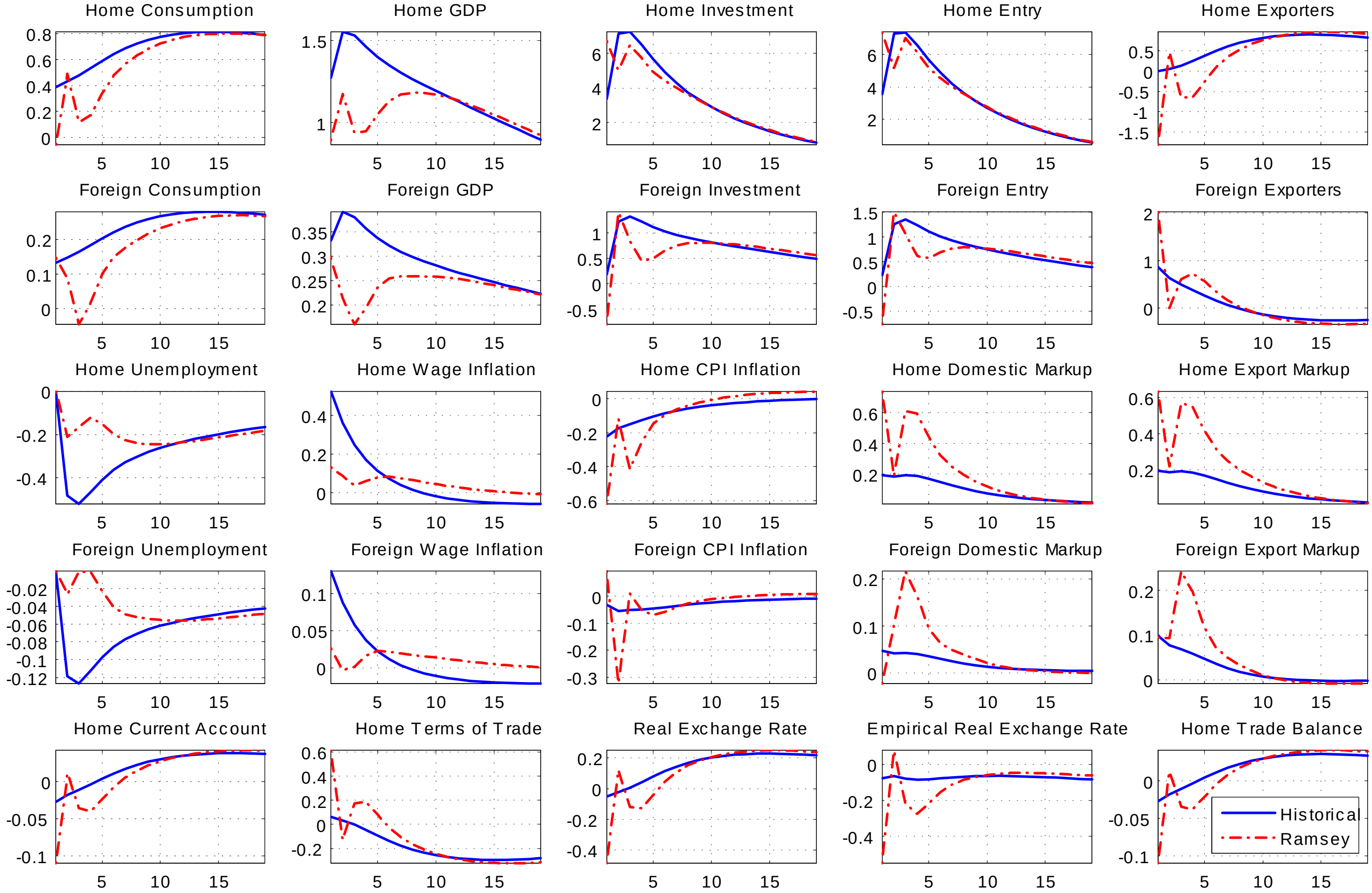


Figure 1: Home Productivity Shock, no trade linkages and producer currency pricing.

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

# Optimal Monetary Policy and Trade Integration

**Long Run**

- Following reduction of trade barriers, products of relatively more productive non-exporting plants are added to 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, gain in market share of existing and new exporting plants is strong enough to guarantee that $\tilde{z}$ increases.

- This has implications for monetary policy.

# Optimal Monetary Policy and Trade Integration, Continued

**Long Run, Continued**

- Focus on the consequences of trade integration for steady-state inefficiency wedges under long-run zero net inflation, $\pi_C = 0 = \Upsilon_{\pi_d} = \Upsilon_{\pi_x} = \Upsilon_{\pi_w}$.

- First, markups are constant and equal to one in steady state; $\Rightarrow \Upsilon_{\mu_d} = \Upsilon_{\mu_x} = 0$.

- Moreover, Hosios condition implied by our calibration $\Rightarrow \bar{\eta} = \varepsilon$ and $\Upsilon_{\eta} = \Upsilon_{\pi_w} = 0$.

- Finally, full symmetry across countries $\Rightarrow \Upsilon_Q = 0$.

- Two distortions remain: monopoly power distortion on job creation, $\Upsilon_{\varphi} = (1/\mu_d) - 1$, and non-zero unemployment benefits, $\Upsilon_b$.

# Optimal Monetary Policy and Trade Integration, Continued

**Long Run, Continued**

- The effect of trade integration on welfare operates by indirectly reducing welfare losses induced by $\Upsilon_{\varphi}$ and $\Upsilon_{b}$.

- More precisely, trade integration raises average productivity and dampens negative consequences of monopoly power and distortionary unemployment benefits.
  - The increase in $\tilde{z}$ increases the average marginal revenue of a match and pushes employment toward its efficient level (Cacciatore, 2014, and Felbermayr, Prat, and Schmerer, 2011).

- Consistent with this, stronger trade lowers steady-state optimal inflation.
  - Less need to use inflation to correct steady-state distortions.

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 and Trade Integration, Continued

**Business Cycle**

- Benigno and Benigno (2003): No gain from coordinating policies (flexible ERs and domestic price stability are optimal) if shocks are perfectly correlated across countries.

- Increased trade integration results in stronger business cycle comovement in our model.

- Fluctuations triggered by country-specific shocks become more global, resulting in an "endogenous" Benigno-Benigno result:
  - Appropriately designed, inward-looking interest rate rules can still replicate the constrained efficient allocation and need of cooperation remains muted.
  - However, historical (Fed) policy behavior implies inefficient fluctuations in cross-country demand, inducing larger welfare costs when trade linkages are strong.

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 |

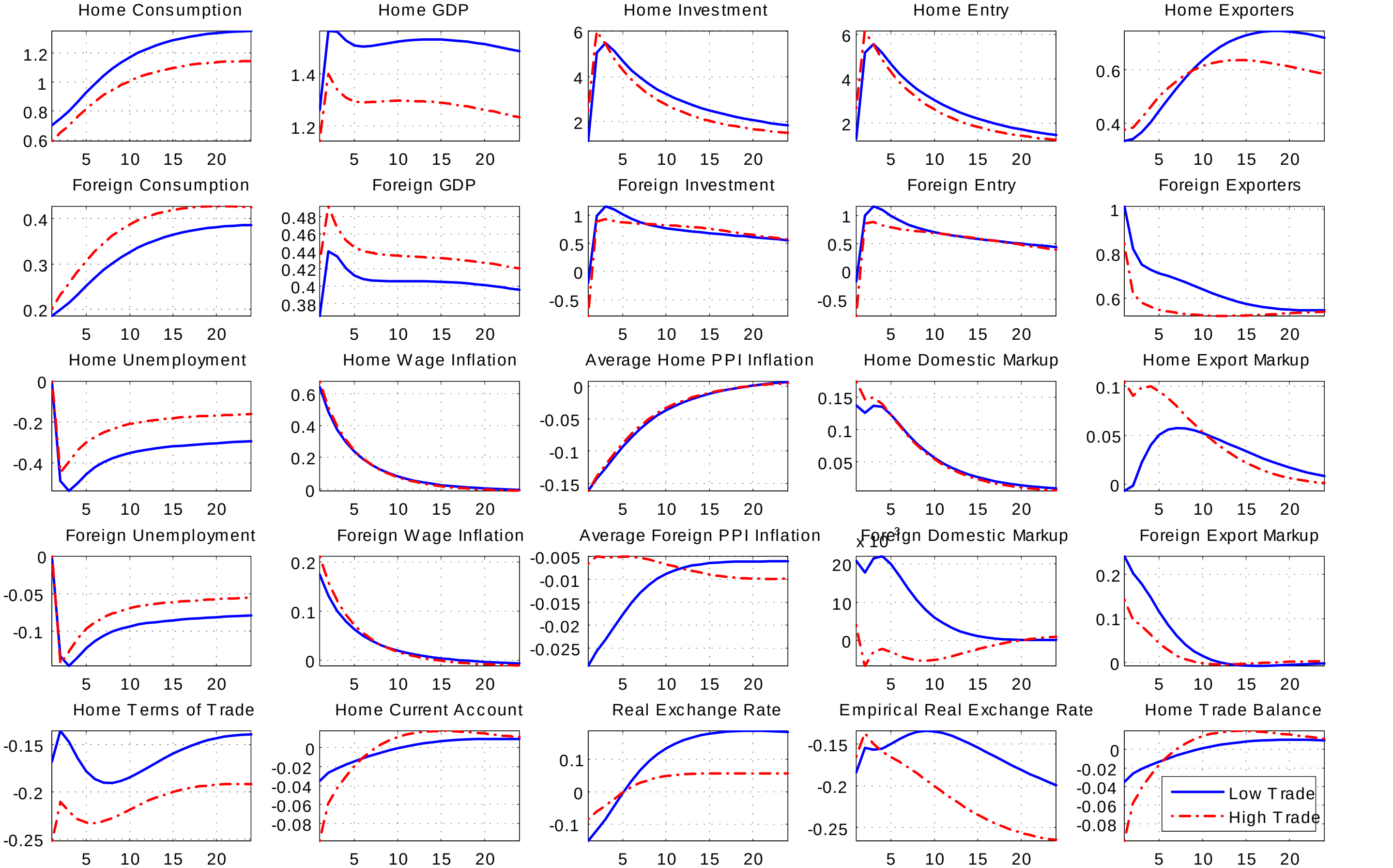


Figure 2: Home Productivity Shock, trade integration and producer currency pricing.

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

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).

# Additional Exercises

- Peg:
  - Increased comovement per se makes an ER peg more desirable for the pegger.
  - If center country follows historical Fed behavior, this generates inefficient spillovers with strong trade linkages, offsetting the gain from increased comovement.
- LCP: Results are similar to PCP.
- Unrestricted, optimal non-cooperative policy:
  - Each central bank chooses policy to maximize welfare of its representative household.
  - Following Benigno and Benigno (2006), each policymaker's strategy specified in terms of consumer price inflation rate, $\pi_{C,t}$, as a function of shocks, taking other country's consumer price inflation rate as given (two-country, open-loop Nash equilibrium).
  - Domestic policymakers have an incentive to manipulate TOT, resulting in inefficient ER volatility relative to constrained efficient, cooperative benchmark.

# Additional Exercises, Continued

- – When trade linkages are weak, welfare loss of non-cooperative policy is very small, regardless of PCP vs. LCP.
    - · Intuitively, weak trade linkages imply that each policymaker has little incentive to manipulate TOT.
  - – Stronger trade linkages do not significantly change this conclusion.
    - · Intuitively, increased synchronization reduces incentives to manipulate TOT since fluctuations become endogenously more global.

# 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 cooperative outcome.
  - Increase in business cycle synchronization across countries generated by trade integration is key reason why gains from cooperation are small relative to optimal non-cooperative behavior.

## Conclusions

- Much remains to be done:
  - We did not analyze optimal trade policy nor its potentially 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 as important, promising areas where to take this research next.