The Macroeconomic Stabilization of Tariff Shocks: What is the Optimal Monetary Response?

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Motivation

• Both the U.S.-China trade war and Brexit show a break in a trend of freer trade and globalization.

• Recent research has noted these large trade shocks have macroeconomic implications, creating or worsening recessions.

• Central banks have been looking for guidance on appropriate monetary policy responses to tariff shocks like Brexit and U.S. trade war.

• Here is some background context....

Trade-weighted average tariffs computed from product-level (6 digit) tariff and trade data, weighted by exporting country’s exports to the word in 2017. source: https://www.piie.com/research/piie-charts/us-china-trade-war-tariffs-date-chart
Tariffs currently cover 66.4% of Chinese exports to the U.S.

source: https://www.piie.com/research/piie-charts/us-china-trade-war-tariffs-date-chart
Brexit uncertainty

• During the first 4.5 years following Brexit referendum in 2016, absence of a new EU trade deal created uncertainty about trade relations.

• Some research suggests uncertainty over trade relations lowered investment in UK, and led to economic slowdown.

• Despite trade deal implemented in Dec. 2020, there are additional regulatory costs for exports, and uncertainty about possible future tariffs.
Motivation

• This paper aims to provide guidance to central banks on appropriate monetary policy to deal with macroeconomic implications of tariff shocks.

• So it studies the monetary dimension of tariffs:

• price stickiness alters the effect of tariffs on international relative prices, and hence the impact on aggregate exports and production,

• and it means monetary policy affects the real exchange rate, which also affects relative prices, and could be used to help offset a tariff.
Related literature

- Most of macro literature on tariffs focuses on real models; not consider monetary policy role.
- The papers with monetary models tend to assume standard Taylor rule, not optimal policy. (Barrattieri et al. (2017), Erceg et al. (2018), Caldara et al. (2018), Linde and Pescatori (2019))
- Auray, et al (2020) consider strategic interaction of optimal exchange rate and tariff policies; we study optimal response to an exog. tariff shock,
- and we include several key features from trade models…
Preview of Results

• We use a calibrated monetary DSGE (dynamic stochastic general equilibrium) model with trade features to compute optimal monetary policy.

• Monetary expansion to induce exchange rate depreciation can blunt effects of a tariff shock on a country’s exports.

• Even in case of a symmetric trade war, where exchange rate cannot help, coordinated monetary expansion can blunt fall in global output.

• Ramsey optimal policy is opposite of standard Taylor policy rule prescription in the latter case.
Outline of Model

Two countries: Home and Foreign

Two tradable sectors:

1) Differentiated manufacturing sector (D):
   - monopolistic competition
   - firm entry
   - sticky prices
   - Iceberg trade cost
   - (no firm heterogeneity in productivity)

2) Non-differentiated sector (N), perfectly competitive, flexible prices, frictionless trade.

Ad valorem tariffs – here focus on diff. sector.
Outline of Model, cont’d

• **Production** requires labor and intermediates;

• Endogenous labor supply (leisure affects utility).

• Trade in bonds permits **non-zero trade balance**.

• **Shocks**: ad-valorem tariff subject to AR shocks, calibrated to Trump trade war.

• Solve for second-order approximation around deterministic steady state.

• Compute conditional welfare including transition.

• **Monetary policy**: study standard rules as well as computing Ramsey optimal (cooperative) policy.
Goods market structure

Home consumption index, $C$, includes

- $n$ varieties $h$ of the differentiated good ($D$) produced in Home country,
- $n^*$ varieties $f$ produced in Foreign,
- home-country-specific (non-differentiated) good ($H$)
- A foreign-country-specific good ($F$).

$$C_t \equiv C_{D,t}^{\theta} C_{N,t}^{1-\theta}$$

where

$$C_{D,t} \equiv \left( \int_0^{n_i} c_t(h)^{\phi-1} dh + \int_0^{n^*_i} c_t(f)^{\phi-1} df \right)^{\phi\over\phi-1}$$

$$C_{N,t} \equiv \left( \frac{\eta-1}{\eta} C_{H,t}^\eta + \left(1 - \nu\right)^{1-\eta} C_{F,t}^\eta \right)^{\eta\over\eta-1}$$
Corresponding price indexes and demands:

\[ P_t \equiv \frac{P_{D,t}^\theta P_{N,t}^{1-\theta}}{\theta^\theta (1-\theta)^{1-\theta}} \]

\[ P_{D,t} = \left( n_t p_t (h)^{1-\phi} + n_t^* (p_t (f) T_{D,t})^{1-\phi} \right)^{\frac{1}{1-\phi}} \]

\[ P_{N,t} = \left( \nu P_{H,t}^{1-\eta} + (1-\nu) (P_{F,t} T_{N,t})^{1-\eta} \right)^{\frac{1}{1-\eta}} \]

\[ C_{D,t} = \theta \left( P_{D,t} / P_t \right)^{-\xi} C_t \]

\[ C_{N,t} = C_{D,t} = (1-\theta) \left( P_{N,t} / P_t \right)^{-\xi} C_t \]

\[ c_t(h) = \left( p_t (h) / P_{Dt} \right)^{-\phi} C_{Dt} \]

\[ C_{H,t} = \nu (P_{Ht} / P_{Nt})^{-\eta} C_{Nt} \]

\[ C_{H,t} = \nu (P_{H,t} / P_{N,t})^{-\eta} C_{N,t} \]

\[ C_{F,t} = (1-\nu) (P_{Ft} / P_{Nt})^{-\eta} C_{N,t} \]
Differentiated (Manufacturing) Goods

• Production of $y_t(h)$ uses labor $l_t(h)$ and composite of other differentiated goods $G_t(h)$, with sector productivity shock, $\alpha_{Dt}$

$$y_t(h) = \alpha_{Dt} [G_t(h)]^\xi [l_t(h)]^{-\xi}$$

• Manufacturing firms
  • prepay a one-time sunk entry cost, $K_t$, in units of combined labor and differentiated goods index.
  • set prices subject to Rotemberg adjustment cost in domestic currency units (producer currency pricing); output demand determined.
  • Face trade cost $\tau_D$ in selling in foreign market.
Firm Problem

• Managers maximize firms’ value, sum of discounted profits:

\[ v_t(h) = E_t \left\{ \sum_{s=0}^{\infty} \left( \beta (1 - \delta) \right)^s \frac{\mu_{t+s}}{\mu_t} \pi_{t+s}(h) \right\} \]

Subject to exit shock, \( \delta \), where \( \mu_t = PC^\sigma_t \) and profits are:

\[ \pi_t(h) = p_t(h)d_t(h) + e_t p_t^*(h)d_t^*(h) - mc_{t,y_t}(h) - P_{t,AC_{p,t}}(h) \]

\[ mc_t = \zeta^{-\zeta} (1 - \zeta)^{\zeta-1} P_{D,t}^\zeta W_t^{1-\zeta} / \alpha_{D,t} \] is marginal cost.

• Optimal choice of inputs:

\[ \frac{P_{D,t}G_t(h)}{W_t l_t(h)} = \frac{\zeta}{1 - \zeta} \]
Price setting

• Price changes subject to Rotemberg adjustment cost:

$$AC_t(h) = \frac{\psi_P}{2} \left( \frac{p_t(h)}{p_{t-1}(h)} - 1 \right)^2 p_t(h) y_t(h)$$

• Optimal price setting:

$$p_t(h) = \frac{\phi}{\phi - 1} mc_t + \frac{\psi_P}{2} \left( \frac{p_t(h)}{p_{t-1}(h)} - 1 \right)^2 p_t(h) - \psi_P \frac{1}{\phi - 1} \left( \frac{p_t(h)}{p_{t-1}(h)} - 1 \right) \frac{p_t(h)}{p_{t-1}(h)}$$

$$+ \frac{\psi_P}{\phi - 1} E_t \left[ \beta \frac{\Omega_{t+1}}{\Omega_t} \left( \frac{p_{t+1}(h)}{p_t(h)} - 1 \right) \frac{p_{t+1}(h)}{p_t(h)} \right]$$

Where

$$\Omega_t = \left[ \left( \frac{p_t(h)}{p_{D,t}} \right)^{-\phi} \left( C_{D,t} + G_t + n e_t (1 - \theta_K) K_t + AC_{P,D,t} + AC_{B,D,t} \right) \right]$$

$$+ \left( \frac{(1 + \tau_D) p_t(h)}{e_t P^*_D,t} \right)^{-\phi} \left( 1 + \tau_D \right) \left( C^*_{D,t} + G^*_t + n e_t^* (1 - \theta_K) K^*_t + AC^*_{P,D,t} + AC^*_{B,D,t} \right) / \mu_t.$$
Firm Entry

• Firms enter until the point that firm value equals the entry cost:

\[ v_t(h) = P_{Dt} K_t \]

• Sunk cost subject to congestion externality:

\[ K_t = \bar{K} \left( \frac{ne_t}{ne_{t-1}} \right)^\chi \]

function of number of new firm entrants \((ne)\).

\[ n_{t+1} = (1 - \delta)(n_t + ne_t) \]
Non-differentiated Good Production

• Production linear in labor, subject to own shocks:

\[ y_{H,t} = \alpha_{N,t} l_{H,t} \]

• Firms perfectly competitive, price takers:

\[ p_{H,t} = \frac{W_t}{\alpha_H} \]

• Trade subject to iceberg trade cost:

\[ p_{H,t}^* = p_{H,t}^* \left(1 + \tau_N \right) / e_t \]
Tariffs

• Ad-valorem tariff imposed by importing country on price of imported differentiated goods.

• Can affect either sector, but we focus on differentiated goods tariffs.

• Tariff revenue rebated to households.

• Distorts the relative price between domestic and imported goods faced by consumers

\[ c_t(f) = \left( p_t(f) T_{D,t} / P_{D,t} \right)^{-\phi} C_{D,t} \]
Households Problem

\[
\max \ E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{1-\sigma} C_t^{1-\sigma} + \chi \ln \frac{M_t}{P_t} - \frac{1}{1+\psi} l_t^{1+\psi} \right]
\]

\[P_t C_t = W_t l_t + \int_0^{n_t} \pi_t(h) dh - W_t q + M_t - M_{t-1} + B_t - (1 + i_{t-1}) B_{t-1} - T_t\]

- Utility from consumption, real money balances \((M/P)\); disutility from labor \((l)\).
- Income from labor earnings at wage rate \(W\), interest \((i)\) on domestic bonds \((B)\), profits from ownership of firms \((\pi)\). Pay lump sum tax \((T)\).
- Implies standard Household FOCs for Consumption Euler, labor supply, money demand
Household Problem Implies

Defining $\mu_t = P_tC_t^\sigma$,

Consumption Euler: $\frac{1}{\mu_t} = \beta(1 + i_t) E_t \left[ \frac{1}{\mu_{t+1}} \right]

Labor supply: $W_t = l_t^\psi \mu_t$

Money demand: $M_t = \mu_t \left( \frac{1 + i_t}{i_t} \right)$

Interest rate parity:

$$E_t \left[ \frac{\mu_t}{\mu_{t+1}} \frac{e_{t+1}}{e_t} (1+i_t^*) \left(1 + \psi_B \left( \frac{e_t B_{ft}}{p_{H_t} y_{H_t}} \right) \right) \right] = E_t \left[ \frac{\mu_t}{\mu_{t+1}} (1 + i_t) \right]$$
Market clearing

- **Labor:**
  \[ \int_0^n l_t(h)dh + l_{H,t} = l_t \]

- **Bonds:**
  \[ B_{H,t} + B_{H,t}^* = 0 \]
  \[ B_{F,t} + B_{F,t}^* = 0. \]

- **Balance of Payments:**
  \[ \int_0^n p_t^*(h)(d_t^*(h))dh - \int_0^n p_t(f)(d_t(f))df + P_{H,t}^* \left( C_{H,t}^* + AC_{P,H,t}^* + AC_{B,H,t}^* \right) \]
  \[ -P_{F,t} \left( C_{F,t} + AC_{P,F,t} + AC_{B,F,t} \right) - i_{t-1}B_{H,t-1}^* + e_i\epsilon_{t-1}B_{F,t-1} = \left( B_{H,t}^* - B_{H,t-1}^* \right) + e_t \left( B_{F,t} - B_{F,t-1} \right) \]

- **Government budget constraint:**
  \[ M_t - M_{t-1} + T_t = 0 \]
Monetary Policy rules

1. No policy (constant money growth)

\[ \frac{M_t}{M_{t-1}} = \nu \]

2. Ramsey optimal policy maximizes:

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{1}{2} \left( \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{1}{1+\psi} I_t^{1+\psi} \right) + \frac{1}{2} \left( \frac{1}{1-\sigma} C_t^{\gamma-\sigma} - \frac{1}{1+\psi} I_t^{\gamma+\psi} \right) \right)
\]

3. Taylor rule:

\[
1 + i_t = (1 + i_{t-1})^{\gamma_i} \left[ (1 + \bar{\delta}) \left( \frac{p_t(h)}{p_{t-1}(h)} \right)^{\gamma_p} \left( \frac{Y_t}{\bar{Y}} \right)^{\gamma_Y} \right]^{1-\gamma_i}
\]

Includes output deviation.

\[
Y_t = \left( \int_0^{n_i} p_t(h) y_t(h) \, dh + p_{Ht} y_{Ht} \right) / P_t
\]
shocks

• Tariff shocks:

\[
\begin{bmatrix}
\log T_{D,t} - \log \bar{T}_D \\
\log T^*_D - \log \bar{T}^*_D \\
\log T_{N,t} - \log \bar{T}_N \\
\log T^*_N - \log \bar{T}^*_N
\end{bmatrix}
= \rho_T
\begin{bmatrix}
\log T_{D,t-1} - \log \bar{T}_D \\
\log T^*_D - \log \bar{T}^*_D \\
\log T_{N,t-1} - \log \bar{T}_N \\
\log T^*_N - \log \bar{T}^*_N
\end{bmatrix}
+ \varepsilon_{Tt}
\]

• Productivity shocks (when included):

\[
\begin{bmatrix}
\log \alpha_{D,t} - \log \bar{\alpha}_D \\
\log \alpha_{N,t} - \log \bar{\alpha}_N
\end{bmatrix}
= \rho_A
\begin{bmatrix}
\log \alpha_{D,t-1} - \log \bar{\alpha}_D \\
\log \alpha_{N,t-1} - \log \bar{\alpha}_N
\end{bmatrix}
+ \varepsilon_{At}
\]
Welfare

• computed in terms of consumption units that households would be willing to forgo to continue under the Ramsey policy regime:

\[
\sum_{t=0}^{\infty} \beta^t \left( u\left( C_{t, \text{alt. policy}}, L_{t, \text{alt. policy}} \right) \right) = \frac{u \left[ \left( 1 + \frac{\Delta}{100} \right) \left( C_{t, \text{Ramsey}}^\text{Ramsey}, L_{t, \text{Ramsey}}^\text{Ramsey} \right) \right]}{1 - \beta}
\]

• Impose identical initial conditions across different monetary policy regimes, using Ramsey allocation,

• we include transition dynamics in the computation to avoid spurious welfare reversals:
Numerical Simulations:
Calibrating differentiated sector

• Share of differentiated goods: Rauch (1999).
• Elasticities of Substitution: Broda and Weinstein (2006) 5.2 for differentiated goods (as defined by Rauch 1999); 15.3 for non-differentiated.
• Intermediates share from outside lit. $\zeta = 1/3$.
• Calibrate trade cost to match exports as share of GDP: $\tau_D = 0.33$
• Shocks: sectoral data from Groningen Growth and Development Centre, calibrate to U.S. data
## Parameter Values

### Preferences
- **Risk aversion** \( \sigma = 2 \)
- **Time preference** \( \beta = 0.96 \)
- **Labor supply elasticity** \( 1/\psi = 1.9 \)
- **Differentiated goods share** \( \theta = 0.61 \)
- **Non-differentiated goods home bias** \( \nu = 0.5 \)
- **Differentiated goods elasticity** \( \phi = 5.2 \)
- **Non-differentiated goods elasticity** \( \eta = 15.3 \)

### Technology
- **Firm death rate** \( \delta = 0.1 \)
- **Price stickiness** \( \psi_p = 8.7 \)
- **Intermediate input share** \( \zeta = 0.33 \)
- **Differentiated goods trade cost** \( \tau_D = 0.33 \)
- **Non-differentiated goods trade cost** \( \tau_N = 0 \)
- **Mean sunk entry cost** \( \bar{K} = 1 \)
- **Firm entry adjustment cost** \( \lambda = 0.10 \)
- **Bond holding cost** \( \psi_B = 0.001 \)
Parameter values continued

Monetary Policy (for the historical policy rule):

- Interest rate smoothing \( \gamma_i = 0.7 \)
- Inflation response \( \gamma_p = 1.7 \)
- GDP response \( \gamma_y = 0.1 \)

Shocks:

**Tariff shocks:**
- Mean 1.02
- Standard deviation 0.06
- Autoregressive 0.56

**Productivity shocks (when included):**
- Standard deviation 0.01
- International corr. 0.25
- Autoregressive, own 0.90
- Autoregressive, int’l 0.09
Experiments

Two types of tariff shocks on D sector:
1. Unilateral Tariff imposed on one country.
2. Symmetric Tariff (full retaliation).

Objects of study for each shock:
• Dynamics: impulse responses of single shock
• unconditional means: effect of uncertainty in full stochastic simulation
• Conditional welfare

Three alternative money policy responses:
• No policy (constant money growth)
• Standard Taylor policy stabilizing inflation
• Ramsey cooperative optimal policy
Background for context

Consider a standard case studied in the literature: shock lowering productivity of home good.

**Effect under flexible prices:**
- Output falls
- Price rises to reflect marginal cost (inflation)

**Effect under price stickiness:**
- Price cannot not rise as much in short run.
- So demand does not fall; so output not fall.
- Implies inefficiently too much production.
Background for context, cont.

Optimal monetary policy in standard case:

• Under certain standard conditions, will replicate the flexible price allocation.
• Monetary contraction makes output fall more.
• Often can be executed by rule targeting zero inflation in price of goods with sluggish prices.
• So adjust the rest of the economy, so sticky prices do not need to change.
• This policy is consistent with a standard “Taylor rule” with high weight on stabilizing inflation relative to output.
Case 1: Unilateral tariff shock
Flexible price benchmark:
Foreign tariff lowers home GDP and trade balance.
Figure 1. Unilateral foreign tariff on home exports

Flexible price benchmark:
Shifts home production from diff. to nondiff. goods.
Sticky prices:
Amplify effects of tariff on relative prices and quantities.
Because firms cannot lower prices to offset tariff or reflect lower wage costs.
Standard Taylor rule stabilizes inflation.
Moves sticky price equilibrium closer to flexible price equilibrium.
Figure 1. Unilateral foreign tariff on home exports

**Optimal (Ramsey) policy uses monetary expansion: interest rate cut and currency depreciation**
Figure 1. Unilateral foreign tariff on home exports

Does not replicate flexible price equilibrium to eliminate the sticky price distortion;

Instead uses sticky prices to affect real exchange rate to help offset tariff effect on rel. prices and production.
Effect of tariff shock uncertainty

• Stochastic simulation with stochastic shocks to tariffs in both countries.

• Solve with second order perturbation methods

• for unconditional means of variables, and

• for effect of suboptimal policy on conditional welfare (discounted stream of utility from a common starting point), in consumption units.

• Report results under standard Taylor rule relative to optimal Ramsey policy.
Table 1: means and welfare under unilateral tariff shocks

<table>
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<th>Unconditional means (% change from Ramsey case)</th>
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<th>substitutes</th>
</tr>
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<tr>
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<td>-15.662</td>
</tr>
<tr>
<td>Welfare (% change from Ramsey case, C units)</td>
<td>-0.155</td>
<td>-0.293</td>
</tr>
</tbody>
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For benchmark calibration, suboptimal Taylor rule in presence of tariff shocks:
- reduces consumption and leisure (raising employment and GDP), which lowers welfare,
- and lowers investment in firm creation.
Table 1: means and welfare under unilateral tariff shocks

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| Welfare                | (% change from Ramsey case, C units): |
|                        | -0.155    | -0.293      |

For higher substitutability between sectors (elast 1.4):
All effects amplified, including on welfare.
Case 2: Symmetric tariff shock (full retaliation case)
Figure 2. Symmetric tariff shock

Symmetric tariff: leads to fall in global GDP and diff. goods production.
Figure 2. Symmetric tariff shock

Also leads to higher inflation…

which induces Taylor rule to raise interest rate (monetary contraction)
Optimal policy: no role for exchange rate depreciation...

But still role for monetary expansion to cut interest rate and moderate global fall in output.

(Opposite response to Standard Taylor rule)
Table 2: means and welfare under symmetric tariff

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<td>GDP</td>
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<tr>
<td>Employment</td>
<td>0.014</td>
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<tr>
<td>Consumption</td>
<td>-0.010</td>
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<tr>
<td>Firm entry</td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>-0.086</td>
</tr>
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Welfare (% change from Ramsey case, C units):

-0.053

For tariff war shocks, smaller welfare loss from suboptimal monetary policy than unilateral tariff shocks.
Other results

- Alternative version of price stickiness, in local currency units (LCP)
  - Tariff transmission same as before LCP not matter for transmission of tariff shock.
  - But exchange rate depreciation not matter for relative prices; optimal policy looks more like standard Taylor rule policy.

- Single sector (macro) model: Similar results as above, since tariffs still have effect via changes in trade balance even if not trade composition.
LCP does not affect transmission of tariff shock rel to PCP. (LCP no policy case similar to Figure 1 earlier)
Figure 3. LCP: Unilateral tariff shock

But Optimal monetary policy less useful under LCP: not able use exchange rate to offset effect of Tariff shock; similar to Taylor policy.
Conclusions

• There is a role for monetary policy to ease the costs of tariff shocks.

• Monetary expansion to induce greater exchange rate depreciations can help blunt the effects of a unilateral tariff.

• Even in the case of a symmetric trade war where exchange rates cannot help, monetary expansion can blunt fall in global output.

• Optimal policy in the latter case is the opposite of the standard Taylor rule used as benchmark by central banks.