The Business Cycle Volatility Puzzle
emerging vs developed economies

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Motivation

- Emerging economies are characterized by higher business cycle volatility than developed ones
- Potential channels:
    1. Aggregate shocks
    2. International prices shocks
    3. Structural composition of the economy
        - sector-level
        - firm-level

Research question

How much each channel **contributes** to the differences in GDP volatility between emerging and developed economies?

What We Do

- Build multi-sector small open economy model with heterogeneous firms and production linkages.
- Decompose GDP volatility in four channels that depend on *sufficient statistics*:
  1. Macro: sum of total sales shares (*Domar weights*) and aggregate TFP volatility
  2. International prices: sectoral trade imbalances and volatility of international prices
  3. Sectoral: distribution of sectors' *Domar weights* and sector-level TFP volatility
  4. Granular: distribution of large firms' *Domar weights* and firm-level TFP volatility
- Conduct an accounting exercise using national accounts, input-output, international trade, and firm-level data for 10 emerging and 19 developed economies.

What We Find

- GDP volatility in emerging economies is 2.2 times the volatility in developed

How much each channel contributes to the **difference** in GDP volatility?

Channel		Contribution	
		benchmark	correlated shocks
Macro		12%	51%
International Prices		0%	1%
Micro	Sectoral	83%	43%
	Granular	5%	5%
Int. Prices and Sectoral interaction		-	0.3%

Related Literature

1. Macro
   - *Neumeyer Perri 2005; Uribe Yue 2006; Chang Fernandez 2013; Calvo Izquierdo Talvi 2006; Vegh Vulletin 2014; Mobarak 2005*
2. International prices
   - *Kehoe Ruhl 2008; Leibovici Kohn Tretvoll 2019*
3. Sectoral channel
   - *Carvalho Gabaix 2013; Koren Tenreyro 2007; Da Rocha Restuccia 2006*
4. Granular channel
   - *Gabaix 2011; di Giovanni Levchenko 2012*

Our Contribution

The paper's main contributions are:

- single framework which features the 4 channels and their interactions
  - derive SOE Hulten thm (tradable and non-tradable sectors, heterogeneous firms)
- *sufficient statistics* approach
  - to quantify differences in GDP volatility between EM and DEV
  - using data from a large set of economies
- granular channel for differences in GDP volatility between EM and DEV

Outline

- Accounting Framework
- Baseline Application
- Other Exercises

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- **Accounting Framework**
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Environment

- Sectors $\mathcal{S} = \left\{ \underbrace{1, ..., S_{NT}}_{\mathcal{S}^{NT}}, \underbrace{S_{NT} + 1, ..., S_T + S_{NT}}_{\mathcal{S}^{T}} \right\}$
- Denote $\mathcal{I}_s$ as the set of heterogeneous firms i within sector s
- Tradable prices p_s with $s \in \mathcal{S}^T$ are exogenous (SOE assumption)
- Production function for firm i in sector s is $\mathcal{A}_i F_s (L_i, \mathbf{X}_i)$
  - $\mathbf{X}_i = \begin{bmatrix} X_{i,1} & \cdots & X_{i,s} & \cdots & X_{i,N} \end{bmatrix}$ intermediate inputs
  - $\ln \mathcal{A}_i = a + a_s + a_i$ exogenous productivity shifter
  - $F_s(.)$ decreasing returns to scale technology

Household Problem

A representative household solves the following static problem

$$\max_{\mathbf{C}} U(\mathbf{C})$$

subject to

$$\mathbf{p}\mathbf{C}' + B^* \leq w + \sum_{i \in \mathcal{I}} \pi_i, \tag{1}$$

- $\mathbf{C} = \begin{bmatrix} C_1 & \cdots & C_s & \cdots & C_N \end{bmatrix}$
- Utility function $U(\mathbf{C})$ homogeneous degree one
- B^* are exogenous *net* transfers to the rest of the world
- HH provide one unit of labor inelastically

Firms Problem

Each firm i in sector s produces an homogenous good s, and choose inputs to max profits taking prices as given:

$$\pi_i = \max_{L_i, \mathbf{X}_i} p_s y_i - wL_i - \mathbf{p}\mathbf{X}_i^{'}, \tag{2}$$

- $y_i = \mathcal{A}_i F_s(L_i, \mathbf{X}_i)$
- $\mathbf{X}_i = \begin{bmatrix} X_{i,1} & \cdots & X_{i,s} & \cdots & X_{i,N} \end{bmatrix}$; $\mathbf{p} = \begin{bmatrix} p_1 & \cdots & p_s & \cdots & p_N \end{bmatrix}$
- $\ln \mathcal{A}_i = a + a_s + a_i$ exogenous
- F_s has decreasing returns to scale

Market clearing & Aggregation

- Labor market clearing

$$\sum_{i \in \mathcal{I}} L_i = 1. \tag{3}$$

- Non-tradable sectors market clearing. For $s \in \mathcal{S}^{NT}$

$$\sum_{i \in \mathcal{I}_s} y_i = C_s + \sum_{i \in \mathcal{I}} X_{i,s} \qquad \text{if } s \in \mathcal{S}^{NT}. \tag{4}$$

- Aggregate tradable resource constraint

$$\sum_{s \in \mathcal{S}^T} p_s \left(\sum_{i \in \mathcal{I}_s} y_i - C_s - \sum_{i \in \mathcal{I}} X_{i,s} \right) = B^*, \tag{5}$$

firm in NT sector

firm in T sector

Competitive Equilibrium

Definition

A competitive equilibrium is an allocation $\{\{\mathbf{X}_i\}_{i\in\mathcal{I}}, \mathbf{C}, \{L_i\}_{i\in\mathcal{I}}\}$ with exogenous productivity shifter $\mathcal{A}_i = A\tilde{A}_s A_i$, tradable prices $\mathbf{p}^T$, aggregate net exports B^*, and prices $\{\mathbf{p}, w\}$ such that

- given prices $\mathbf{p}$ and w, firms maximize their profits,
- given $\mathbf{p}$, w and B^*, the representative household maximizes her utility,
- the non-tradable goods and labor markets clear.

Domar Weigths & Trade Imbalances

- $\mathrm{GDP} = U(\mathbf{C}) + B^* = \sum_{s\in\mathcal{S}} p_s \left(\sum_{i\in\mathcal{I}_s} y_i - \sum_{i\in\mathcal{I}} X_{i,s}\right).$

- Define the sales share in GDP or *Domar weight* of firm $i \in \mathcal{I}_s$ as

$$\lambda_i \equiv \frac{p_s y_i}{Y}.$$

  - $Y = \mathrm{GDP}$
  - property: $\sum_{i\in\mathcal{I}_s} \lambda_i \geq 1$

- Define sector $s \in \mathcal{S}_T$ trade imbalance as

$$b_s \equiv \frac{p_s \left(\sum_{i\in\mathcal{I}_s} y_i - C_s - \sum_{i\in\mathcal{I}} X_{i,s}\right)}{Y}.$$

Business Cycle Volatility Accounting 1/3

Proposition (Augmented Hulten Theorem)

The first order response of output $Y(.)$ *to changes in* $A, \tilde{\mathbf{A}}_s, \mathbf{A}_i, B^*, \mathbf{p}^T$ *is*

$$d\log Y\left(B^*, \mathbf{p}^T, A, \tilde{\mathbf{A}}_s, \mathbf{A}_i\right) = \Lambda da + \sum_{s\in\mathcal{S}} \Lambda_s d\tilde{a}_s + \sum_{i\in\mathcal{I}} \lambda_i da_i + \sum_{s\in\mathcal{S}_T} b_s d\log p_s. \tag{6}$$

Assuming that the exogenous shocks are uncorrelated then it follows that the variance of GDP growth (in log differences) is

$$Var\left(d\log Y\right) = \underbrace{\Lambda^2\sigma_A^2}_{macro} + \underbrace{\sum_{s\in\mathcal{S}} \Lambda_s^2\sigma_{\tilde{A}_s}^2}_{sector} + \underbrace{\sum_{i\in\mathcal{I}} \lambda_i^2\sigma_{A_i}^2}_{granular} + \underbrace{\sum_{s\in\mathcal{S}_T} b_s^2\sigma_{p_s}^2}_{int.\ prices}, \tag{7}$$

where $\log A_i \equiv a_i$, $\log\tilde{A}_s \equiv \tilde{a}_s$, $\log A \equiv a$.

Business Cycle Volatility Accounting 2/3

We can express equation (7) in terms of BC volatility differences between EM and DEV economies:

$$
\begin{aligned}
Var\left(d\log Y_{EM}\right) - Var\left(d\log Y_{DEV}\right) = &\underbrace{\Lambda^2_{EM}\sigma^2_{A,EM} - \Lambda^2_{DEV}\sigma^2_{A,DEV}}_{\text{macro}} \\
&+ \underbrace{\sum_{s\in\mathcal{S}}\Lambda^2_{s,EM}\sigma^2_{\tilde{A}_s,EM} - \sum_{s\in\mathcal{S}}\Lambda^2_{s,DEV}\sigma^2_{\tilde{A}_s,DEV}}_{\text{sectoral}} \\
&+ \underbrace{\sum_{i\in\mathcal{I}^{EM}}\lambda^2_{i,EM}\sigma^2_{A_i,EM} - \sum_{i\in\mathcal{I}^{DEV}}\lambda^2_{i,DEV}\sigma^2_{A_i,DEV}}_{\text{granular}} \\
&+ \underbrace{\sum_{s\in\mathcal{S}_T}\left(b^2_{s,EM} - b^2_{s,DEV}\right)\sigma^2_{p_s}}_{\text{international prices}}.
\end{aligned}
\qquad (8)
$$

sectoral and granular

Business Cycle Volatility Accounting 3/3

Corollary (Proposition 1 with Correlated Shocks)

When allowing for correlation across sectors, firms and prices, and, additionally, between prices and sectoral TFP, equation (7) becomes:

$$Var\left(d\log Y\right) = \underbrace{\mathbf{\Lambda}'\Omega_{\tilde{A}}\mathbf{\Lambda}}_{sectoral} + \underbrace{\mathbf{b}'\Omega_{p^{\top}}\mathbf{b}}_{international\ prices} + \underbrace{\mathbf{b}'D\left(\Omega_{(p^{\top},\tilde{A})}\right)\mathbf{\Lambda}}_{international\ prices\ and\ sectors} + \underbrace{\lambda'\Omega_{A}\lambda}_{granular} + \underbrace{\Lambda^2\sigma_A^2}_{aggregate}, \qquad (9)$$

where

- $\mathbf{\Lambda}$ *vector of sectoral Domar weights and* $\Omega_{\tilde{A}}$ *cov matrix for sectoral TFP (log) change,*
- $\mathbf{b}$ *vector of trade balances and* $\Omega_{p^{\top}}$ *cov matrix for (log) changes of international prices,*
- $D\left(\Omega_{(p^{\top},\tilde{A})}\right)$ *diagonal of cov matrix btw changes in sectoral TFP and changes in int. prices*
- λ *vector of firm-level Domar weights and* Ω_{A} *cov matrix for firm-level TFP (log) change.*

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- Accounting Framework
- **Baseline Application**
- Other Exercises

Business Cycle Volatility

$$\frac{Var\left(d\log Y_{EM}\right)}{Var\left(d\log Y_{DEV}\right)} = 2.2$$

- Country classification:
  - developed: members of OECD with avg. PPP adjusted GDP per cap $>$ \$25,000
  - emerging: avg. PPP adjusted GDP per cap $<$ \$25,000
- Data source: World Development Indicators (WDI)
  - estimate cyclical component of GDP and compute variance
  - 1990-2016 sample

cross-country detail

Channels' Data Sources

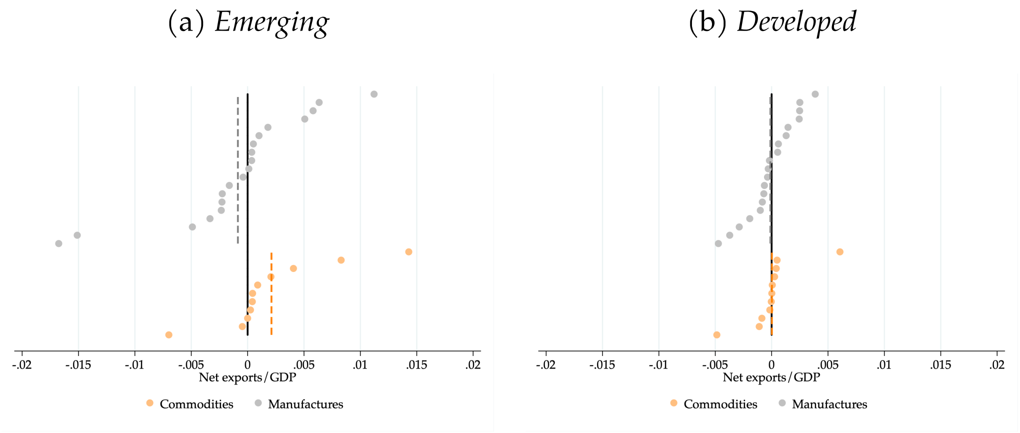
	International Prices		Sectoral	Macro	Granular
Sufficient statistic	$\mathbf{b}_c$		$\boldsymbol{\Lambda}_c$	Λ_c	λ_c
Data sources	COMTRADE		OECD		Worldscope
Volatility	Ω_{p^T}	$\text{diag}\left(\Omega_{(p^T,\tilde{A}_T)}\right)$	$\Omega_{\tilde{A}}$	$\sigma^2_{A_c}$	$\sigma^2_{A_i}$
Data source		Jorgenson et al. (2005)		Residual	Gabaix(2011)

Additional assumptions for baseline exercise

- sector- and firm-level cov matrix the same across EM and DEV (relaxed in alt exercise)
- no cov across a_i (Gabaix 2011)

International Prices Channel

Sectoral trade imbalances (as % of GDP)



Sectoral & Granular Channels

	Emerging	Developed
Sum of Domar weigths of most volatile sectors	0.62 (0.46,0.68)	0.38 (0.32,0.40)
Sum of Domar weigths of least volatile sectors	0.70 (0.62,0.78)	0.89 (0.77,0.93)
Sum of Domar weigths of top 70 largest firms	0.48 (0.24,0.55)	0.36 (0.29,0.49)

Note: in parentheses we report the values corresponding to the 25th and 75th pct.

sectoral detail granular detail

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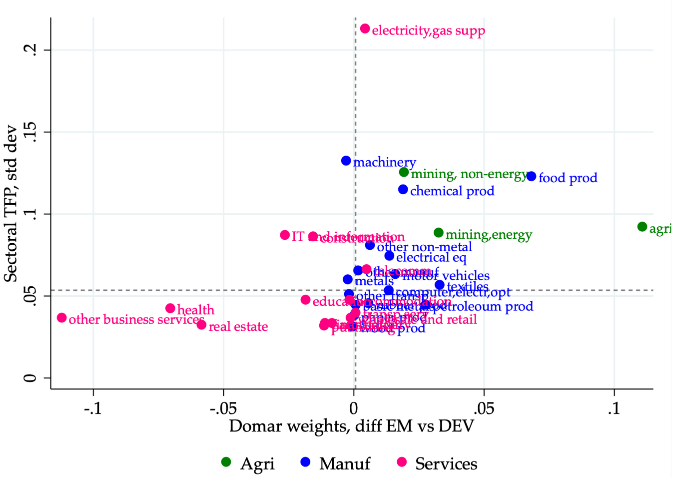
Further Exercises

1. **Sectoral channel and structural transformation**
2. Time-series
3. Intrinsic volatility differences details
4. International prices and exchange rate shocks details

Which Sectors Explain the Volatility Differences? (1/2)



Which Sectors Explain the Volatility Differences? (2/2)

	Domar W EM	Domar W DEV	Volatility (std)	Contribution to differences
Agriculture	0.21	0.05	0.10	46%
Manufacturing	0.62	0.42	0.08	53%
Services	1.00	1.32	0.06	-46%
Total				57%

* net of cross-sector correlations

Further Exercises

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2. **Time-series**
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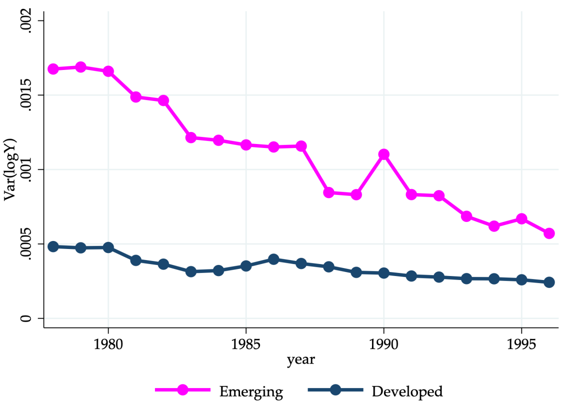
Volatility Differences Across Time

Output volatility



notes: volatility for 15-year window with reference year = median of window

Changes in Economic Structure

- Using WIOD historical input-output data

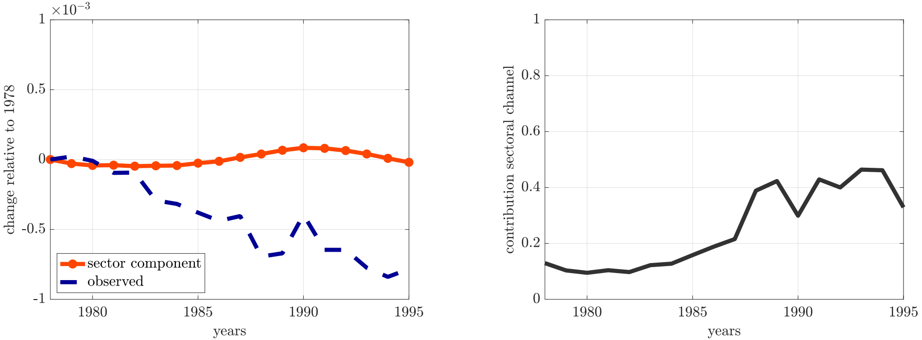
Sectoral Domar weights

	Emerging			Developed		
	1978	1995	Δ	1978	1995	Δ
Agriculture	0.21	0.12	-0.09	0.13	0.07	-0.06
Manufacturing	0.70	0.65	-0.05	0.73	0.55	-0.18
Services	0.87	1.12	0.25	1.10	1.26	0.16

Can Changes in Economic Structure Explain the Trend?

(a) Volatility and Sectoral Channel

(b) Contribution to $(\sigma^2_{EM,t} - \sigma^2_{DEV,t})$



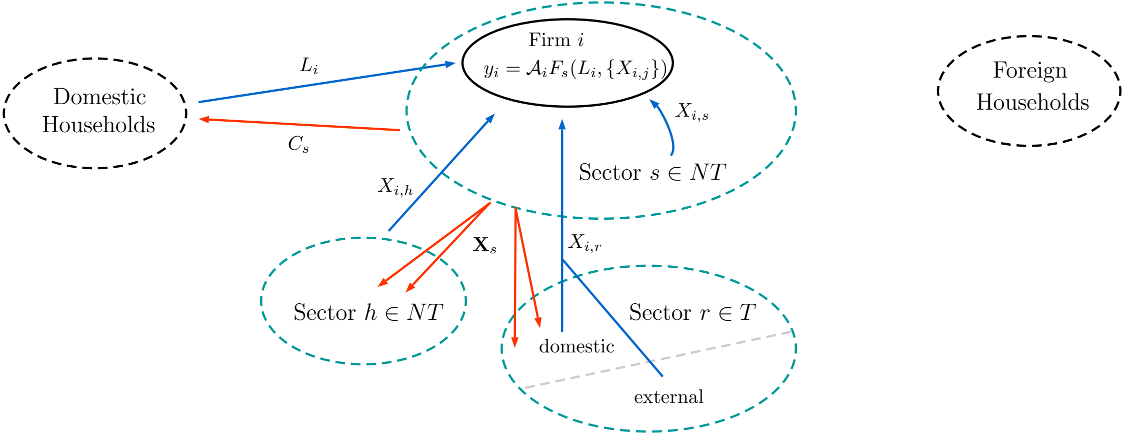
- Sectoral channel can't explain decline in volatility differences , but has higher contribution

Final Remarks

- Structural model applied quantitatively (using sufficient statistic approach) to explain differences in GDP volatility between EM and DEV
- Includes several channels (macro, sector, firm distribution, int. prices)
- Sectoral distribution strongest channel, while international prices the weakest
- Relevant extensions:
  - Second order moments (i.e., changes in Domar weights and trade imbalances)
  - Inefficient economies (markups, labor reallocation costs, etc)

Extra Slides

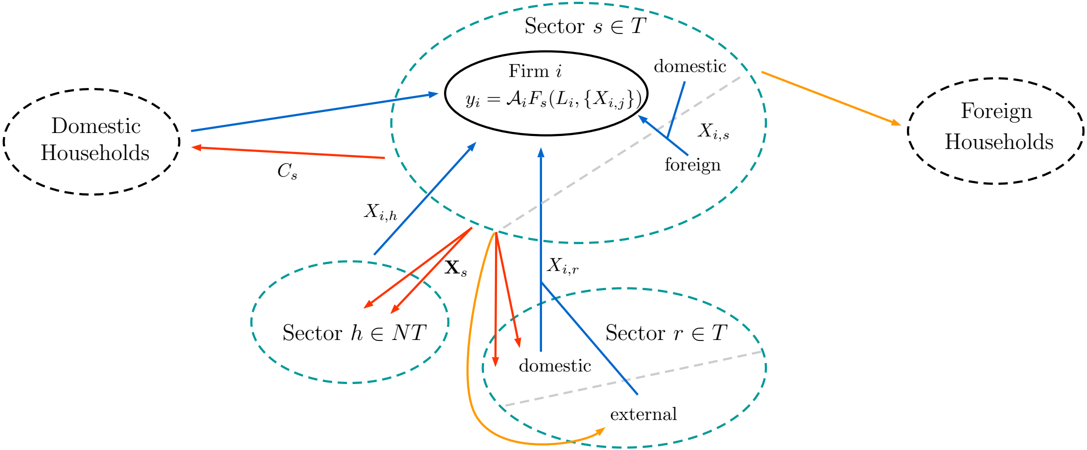
The problem of a firm in the non-tradable sector



$$\sum_{i \in s} \mathcal{A}_i F_s(L_i, \{X_{i,j}\}) = C_s + \sum_{j \in \mathcal{S}} \sum_{h \in \mathcal{I}_j} X_{h,s}$$

back

The problem of a firm in the tradable sector



$$\sum_{i \in s} \mathcal{A}_i F_s(L_i, \{X_{i,j}\}) = C_s + \sum_{j \in \mathcal{S}} \sum_{h \in \mathcal{I}_j} X_{h,s} + B_s$$

back

Planner's Problem

$$
\begin{aligned}
\mathcal{Y}(\mathcal{A}_i, B^*, \mathbf{p}^T) = \max_{\{X_{i,s}\}, L_i, C_s} & \; U\left(\{C_s\}_{s=1}^{S}\right) + B^* \\
& + \sum_{s \in \mathcal{S}^{NT}} \mu_s \left[\sum_{i \in \mathcal{I}_s} \mathcal{A}_i F_s \left(L_i, \{X_{i,j}\}_{j=1}^{S}\right) - C_s - \sum_{j \in \mathcal{S}} \sum_{i \in \mathcal{I}_j} X_{i,s} \right] \\
& + \lambda \left(1 - \sum_{j \in \mathcal{S}} \sum_{i \in \mathcal{I}_j} L_i \right) \\
& + \mu^T \left[\sum_{s \in \mathcal{S}^T} p_s \left(\sum_{i \in \mathcal{I}_s} \mathcal{A}_i F_s \left(L_i, \{X_{i,j}\}_{j=1}^{S}\right) - C_s - \sum_{j \in \mathcal{S}} \sum_{i \in \mathcal{I}_j} X_{i,s} \right) - B^* \right]
\end{aligned}
$$

back

Mechanisms behind sectoral and granular channels

Impact of changes in A_i (granular) or A_s (sectoral):

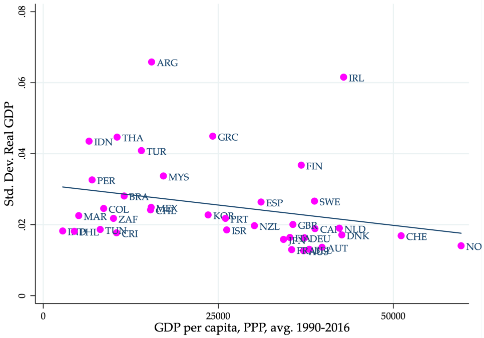
- Closed economy
  - changes in w,
  - changes in p_s for $s \in \mathcal{S}_{NT}$.

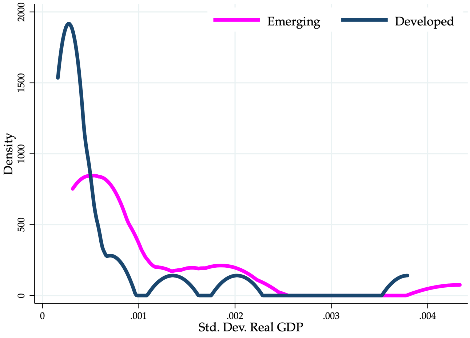
- Small open economy (*Farhi Baqaee 2019*):
  - changes in w,
  - no changes in p_s for $s \in \mathcal{S}_T$ since exogenous,
  - changes in p_s for $s \in \mathcal{S}_{NT}$.

In both cases *Domar Weight* is sufficient statistic, but underlying forces differ.

back planner's problem

GDP Volatility





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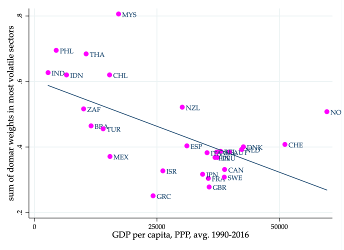
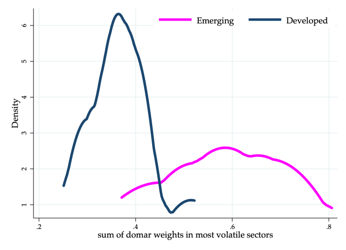
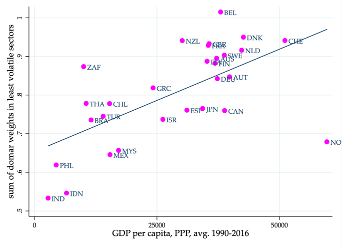
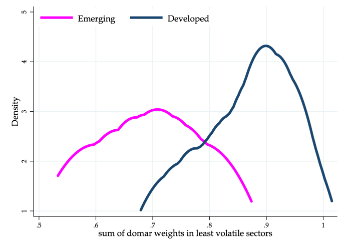
Micro channel: sectoral distribution









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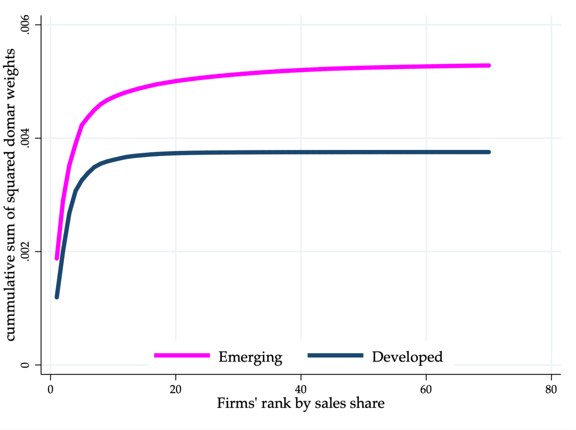
Micro channel: firm size distribution

Firm distribution differences across the development spectrum



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Intrinsic Firm-level Volatility Differences

To infer indirectly the firm-level volatility differential assume

1. idiosyncratic volatilities are different: $\sigma^2_{A_i,EM} \neq \sigma^2_{A_i,DEV}$
2. no macro channel: $\sigma^2_A = 0$

such that

$$\underbrace{\sum_i \lambda^2_{i,EM}\sigma^2_{A_i,EM} - \sum_i \lambda^2_{i,DEV}\sigma^2_{A_i,DEV}}_{\text{granular}} = \underbrace{\left(\sum_i \lambda^2_{i,EM} - \sum_i \lambda^2_{i,DEV}\right)\sigma^2_{A_i,DEV}}_{\text{baseline}} + \underbrace{\left(\sigma^2_{A_i,EM} - \sigma^2_{A_i,DEV}\right)\sum_i \lambda^2_{i,EM}}_{\text{granular residual = residual}}$$

	w/o correlation	with correlation
$\sigma_{A_i,EM}/\sigma_{A_i,DEV}$	1.79	1.31

back

Exchange Rate and International Prices

Using LOOP $p_s = Ep^*_s$ then we can decompose the international price channel by

$$\sum_{s\in\mathcal{S}^T} b_s^2\sigma_{p_s}^2 = \sum_{s\in\mathcal{S}^T} b_s^2\sigma_{p^*_s}^2 + \underbrace{\left(\frac{B^*}{Y}\right)^2\sigma_E^2 + \sum_{s\in\mathcal{S}^T}\frac{B^*}{Y}b_s\rho_{(p^*_s,E)}\sigma_{p^*_s}\sigma_E}_{\text{exchange rate channel}}$$

if exchange rate is fixed then $\sigma_E = \rho_{(p^*_s,E)} = 0 \rightarrow \sigma_{p_s}^2 = \sigma_{p^*_s}^2$

- How does different XR regimes and correlation with p^T affect Y volatility?

back