The Granular Origins of Inflation and its International Comovement

Santiago E. Alvarez-Blaser, Raphael Auer, Sarah M. Lein, Andrei Levchenko

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Preliminary

*The views expressed here are those of the authors and not necessarily those of the BIS.
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Can large firms’ idiosyncratic shocks influence aggregate inflation dynamics?
Roadmap

In this project, we study

- granularities in inflation dynamics using large multi-country product-level homescan data
- different sources of granular inflation (firms, products, and categories)
- the role of granularities for the international comovement of inflation

Preview of results

- the firm component explains a relevant share of aggregate retail price inflation
- inflation comovement is larger when including the firm granular component (work in progress)

Important: we focus at the firm level, not brand level, ...
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1. Introduction

2. Data

3. Granular residual
   Decomposition
   Granular residuals and country-level inflation
   (Comovement across countries)

4. Next step

5. Taking stock
Data source: Homescan Data Aimark

- 16 countries: AR, AT, BE, BR, CN, DE, ES, FR, IT, MX, NL, PT, RU, SE, UK, US
- 2005-2020, 2008-2020 for most countries
- one entry for each product purchase that households make in supermarkets and drugstores
- household id, purchase date, retailer, barcode, price, units, category, firm

Aggregation to product-level inflation rates and weights

aggregate entries at the country, product and quarter level and calculate \( \Delta p_{\text{igfct}} \) for product \( i \), with category \( g \), from firm \( f \)

compute \( w_{\text{igfct}} \) as the country-product-quarter expenditure weight

Aggregate quarterly (y-o-y) inflation in quarter \( t \) and country \( c \):

\[
\Delta p_{ct} = \sum_i w_{\text{igfct}} - 4 \Delta p_{\text{igfct}}
\]

⇒ Inflation is sample inflation (food, beverages, personal care items,...)

Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
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Data - compared to official data (Germany)

Category inflation computed from our data comoves closely with official statistics (Eurostat):

![Graph showing inflation trends](image-url)
Heterogeneity in firm size

High concentration of expenditures in a few firms which are often multinationals

Source: Aimark homescan data.
Heterogeneity in firm size

High concentration of expenditures in a few firms which are often multinationals

- Across all countries ten firms cover 27% of expenditures (e.g., Nestle, Unilever, Procter&Gamble, Mondelez, Mars...).
- US (Germany): ten firms cover 31% (44%) of expenditures.

Source: Aimark homescan data.
1. Introduction

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3. Granular residual
   Decomposition
   Granular residuals and country-level inflation
   (Comovement across countries)

4. Next step

5. Taking stock
Suppose $\Delta p_{it}$ is the sum of only aggregate $\eta_t$ and product-specific shocks $\xi_{it}$

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\Delta p_t = \sum_i w_{it-4} \Delta p_{it} = \sum_i w_{it-4} (\eta_t + \xi_{it})
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Decomposition - simple granular residual

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Simple granular residual decomposition:

$$
\Delta p_{ct} = \frac{1}{N} \sum_i \Delta p_{it} + \sum_i \left( w_{it-4} - \frac{1}{N} \right) \Delta p_{it}
$$

$U_t$ and $\Gamma_t$
Decomposition - simple granular residual dynamics (Germany)

Other countries

Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
Decomposition - simple granular residual dynamics (Argentina)
Decomposition - shortcomings of simple granular residual

\[ \Delta p_{ct} = \frac{1}{N_i} \sum_i \Delta p_{igfct} + \sum_i \left( w_{igfct} - 4 \frac{1}{N_i} \right) \Delta p_{igfct} \]

\[ \text{\underline{U}_{ct}} \quad \text{\underline{\Gamma}_{ct}} \]

Shortcomings of this decomposition:

1. Large firms not only cover a big share of the weight, but also of the observations: \( U_t \) can still be driven by large firms.

2. Impossible to distinguish the role of sectoral shocks from the role of firm shocks (or products)
Decomposition - shortcomings of simple granular residual

\[ \Delta p_{ct} = \frac{1}{N_i} \sum_i \Delta p_{igfct} + \sum_i \left( w_{igfct} - 4 - \frac{1}{N_i} \right) \Delta p_{igfct} \]

Shortcomings of this decomposition:

1. Large firms not only cover a big share of the weight, but also of the observations: \( U_t \) can still be driven by large firms.

2. Impossible to distinguish the role of sectoral shocks from the role of firm shocks (or products)

What exactly is driving the granular component?
Decomposition - shortcomings of simple granular residual

\[ \Delta p_{ct} = \frac{1}{N_i} \sum_i \Delta p_{igfct} + \sum_i \left( w_{igfct-4} - \frac{1}{N_i} \right) \Delta p_{igfct} \]

\( U_{ct} \) \( \Gamma_{ct} \)

Shortcomings of this decomposition:

1. Large firms not only cover a big share of the weight, but also of the observations: \( U_t \) can still be driven by large firms.

2. Impossible to distinguish the role of sectoral shocks from the role of firm shocks (or products)

What exactly is driving the granular component?

We decompose inflation in different “granular layers” to better understand the granular origin of inflation.
Decomposition - granular layers

Decomposition steps:

i. Product inflation depends on 5 components (estimation on next slide):

\[ \Delta p_{igfct} = \delta_{ct} + \lambda_{gc} \eta_{ct}^G + \lambda_{fc} \eta_{ct}^F + \delta_{gct} + \delta_{fct} + \varepsilon_{igfct} \]

where \( \delta_{fct} \) is our firm-specific idiosyncratic shock.
Decomposition - granular layers

Decomposition steps:

i  Product inflation depends on 5 components (estimation on next slide):

\[ \Delta p_{igfct} = \delta_{ct} + \lambda_{gc} \eta_{ct}^G + \lambda_{fc} \eta_{ct}^F + \delta_{gct} + \delta_{fct} + \varepsilon_{igfct} \]

where \( \delta_{fct} \) is our firm-specific idiosyncratic shock.

ii Insert this process in \( \Delta p_{ct} = \sum_i w_{ifgt-4} \Delta p_{igfct} \) and rewrite:

\[
\Delta p_{ct} = \delta_{ct} + \sum_g w_{gt-4} \lambda_{gc} \eta_{ct}^G + \sum_f w_{fct-4} \lambda_{fc} \eta_{ct}^F + \sum_g w_{gt-4} \delta_{gt} + \sum_m w_{fct-4} \delta_{fct} + \sum_i w_{igfct-4} \varepsilon_{igfct}
\]

\[ = U_{ct} + \Gamma_{ct}^g + \Gamma_{ct}^f + \Gamma_{ct}^\varepsilon \]

\( \Gamma_{ct}^f \) (\( \Gamma_{ct}^g \)) captures the granularities at the firm (category) level
Decomposition - estimation of shocks

Steps for estimating $\delta_{ct}$, $\lambda_{gc}\eta_{ct}^G$, $\lambda_{fc}\eta_{ct}^M$, $\delta_{gct}$, $\delta_{fct}$ and $\varepsilon_{igfct}$:

i. Estimate regression with category-time and firm-time FEs: $\Delta p_{igfct} = \hat{\delta}_{gct} + \hat{\delta}_{fct} + \hat{\varepsilon}_{igfct}$

ii. Define $\tilde{\delta}_{dct} = \hat{\delta}_{dct} - \frac{1}{N_d} \sum_d \hat{\delta}_{dct}$ for $d = g, f$ so that the average category and firm shocks are zero in each period. Similarly $\varepsilon_{igfct} = \hat{\varepsilon}_{igfct} - \frac{1}{N_i} \hat{\varepsilon}_{igfct}$.

iii. Allow firms and categories different loadings on an latent aggregate component by estimating a common factor using EM PCA:

$$\tilde{\delta}_{fct} = \lambda_{fc}\eta_{ct}^F + \delta_{fct} \text{ and } \tilde{\delta}_{gct} = \lambda_{gc}\eta_{ct}^G + \delta_{gct}$$

iv. The aggregate shock (common to all $g$ and $f$) is then:

$$\delta_{ct} = \frac{1}{N_g} \sum_g \hat{\delta}_{gct} + \frac{1}{N_f} \sum_f \hat{\delta}_{fct} + \frac{1}{N_i} \sum_f \hat{\varepsilon}_{igfct}$$
1. Introduction

2. Data

3. Granular residual
   Decomposition
   Granular residuals and country-level inflation
   (Comovement across countries)

4. Next step

5. Taking stock
Explanatory power of $\Gamma_{ct}^{f}$? Estimate Gabaix (2011)-type regression:

$$\Delta p_{ct} = \alpha_c + \beta_f \Gamma_{ct}^{f} + \varepsilon_{ct}$$

→ Calculate (within) $R^2 = 1 - \frac{RSS}{RSS_{onlyFE}}$ (share of variation in $p_{ct}$ explained by $\Gamma$ when subtracting the explanatory power of country FE $\alpha_c$)
Granular residuals and country-level inflation - explanatory power of $\Gamma^f$

Explanatory power of $\Gamma^f_{ct}$? Estimate Gabaix (2011)-type regression:

$$\Delta p_{ct} = \alpha_c + \beta_f \Gamma^f_{ct} + \varepsilon_{ct}$$

→ Calculate (within) $R^2 = 1 - \frac{RSS}{RSS_{onlyFE}}$ (share of variation in $p_{ct}$ explained by $\Gamma$ when subtracting the explanatory power of country FE $\alpha_c$)

Also estimate a regression controlling for the aggregate component $U_{ct}$:

$$\Delta p_{ct} = \alpha_c + \beta_U U_{ct} + \beta_f \Gamma^f_{ct} + \varepsilon_{ct}$$

→ Calculate partial $R^2 = 1 - \frac{RSS_F}{RSS_P}$, where $RSS_F$ is the sum of squared residuals from the full model and $RSS_P$ from the partial model including only $\alpha_c + \beta_U U_{ct}$.
## Granular residuals and country-level inflation - explanatory power $\Gamma^f$ (AE)

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<td>$\Gamma^g_{ct}$</td>
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<td>$U_{ct}$</td>
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<td></td>
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<td>$R^2$</td>
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<td>0.10</td>
<td>0.64</td>
<td>0.34</td>
<td>0.90</td>
<td>0.78</td>
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Notes: $R^2$ computed subtracting the explanatory power of the country fixed-effects. Standard errors in parenthesis and partial $R^2$ in square brackets. Following emerging markets (EM) excluded: AR, BR, CN, MX and RU. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Other summary statistics
Granular residuals and country-level inflation - explanatory power $\Gamma^f$ (all)

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<tr>
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<td>(0.04)</td>
<td>[0.69]</td>
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<td></td>
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<tr>
<td>$\Gamma^g_{ct}$</td>
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<td>1.001*</td>
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<td></td>
<td>(0.42)</td>
<td></td>
<td>(0.08)</td>
<td>[0.37]</td>
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</tr>
<tr>
<td>$U_{ct}$</td>
<td></td>
<td></td>
<td>1.058***</td>
<td></td>
<td>0.991***</td>
<td>1.064***</td>
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<tr>
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<td></td>
<td></td>
<td>(0.05)</td>
<td>(0.03)</td>
<td></td>
<td>(0.02)</td>
</tr>
<tr>
<td>$\Gamma^{top\ 10f}_{ct}$</td>
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<tr>
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<td></td>
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<td>(0.02)</td>
</tr>
</tbody>
</table>

| $N$    | 709     | 709     | 709     | 709     | 709     | 709     |
| $R^2$  | 0.24    | 0.06    | 0.82    | 0.14    | 0.94    | 0.89    |

Notes: $R^2$ computed subtracting the explanatory power of the country fixed-effects. Standard errors in parenthesis and partial $R^2$ in square brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 

Other summary statistics
Granular residuals and country-level inflation - coefficients by horizon

$\Gamma_{ct}^f$ does not seem to be the capturing a reaction on aggregate pre-trends.
Granular residuals and country-level inflation - dynamics Germany

Inflation $\Gamma_t$, $\Gamma_t^g$, $\Gamma_t^f$
Granular residuals and country-level inflation - dynamics US

Other countries, including retailer component

Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
Granular residuals and country-level inflation - dynamics Argentina

Inflation

Other countries, including retailer component

Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
1. Introduction

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   Granular residuals and country-level inflation
   *(Comovement across countries)*

4. Next step

5. Taking stock
Comovement across countries - country correlations

Expenditure share in common firms and pairwise correlations of inflation (distance/EA adj.)

$\rho(\Delta \rho_{At}, \Delta \rho_{Ct})$ drops by -0.05 within AEs and increases by 0.02 within the other other countries
Comovement across countries - correlation with global inflation

Define “global” \((G)\) retail inflation as the average inflation in the countries other than \(A\):

\[
\Delta p^A_{Gt} = \frac{1}{N_c - 1} \sum_{c \neq A} \Delta p_{ct}
\]  

How much does \(\Gamma^f_{ct}\) contribute to the correlation of retail inflation with the other countries?

\[
\rho(\Delta p_{At}, \Delta p^A_{Gt}) = \frac{\text{cov}(\Delta \bar{p}_{At} + \Gamma^f_{At}, \Delta \bar{p}_{Gt} + \Gamma^f_{Gt})}{\sigma_{At} \sigma_{Gt}} = \rho(\Delta \bar{p}_{At}, \Delta \bar{p}_{Gt}) \frac{\sigma_{A, \Delta \bar{p}}}{\sigma_A^2} \frac{\sigma_{G, \Delta \bar{p}}}{\sigma_C^2} + \rho(\Gamma^f_{At}, \Gamma^f_{Gt}) \frac{\sigma_{A, \Gamma^f}}{\sigma_A^2} \frac{\sigma_{G, \Gamma^f}}{\sigma_C^2}
\]

Contribution of \(\Delta \bar{p}_{ct}\)

\[+ Z + Y\]

Terms containing small cross-term correlations
Comovement across countries - correlation with global inflation

Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
1. Introduction

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   Decomposition
   Granular residuals and country-level inflation
   (Comovement across countries)

4. Next step

5. Taking stock
Next step - firm size and $\text{corr}(\delta_{fct}, \Gamma_{ct}^-)$

\[
\Delta p_{ft} = \alpha_f \Delta mc_{ft} + \gamma_f \Delta p_{-ft} + \varepsilon_{it}
\]

Amiti, Itskhoki, and Konings (2019) report higher $\gamma_f$ for large firms, do we also observe size dependent price complementarities?
Next step - firm size and corr($\delta_{ft}, \Gamma_{ct}^{-f}$)

$$\Delta p_{ft} = \alpha_f \Delta m_{cf} + \gamma_f \Delta p_{-ft} + \epsilon_{it}$$

Amiti, Itskovich, and Konings (2019) report higher $\gamma_f$ for large firms, do we also observe size dependent price complementarities?

$\gamma$ measured as $\rho(\delta_{fct}, \Gamma_{t-f})$

$\delta_{fct}$ might be capturing complementarities with other firms shocks: next step, follow GLV approach similar to Chodorow-Reich, Gabaix and Koijen (soon)
1. Introduction

2. Data

3. Granular residual
   Decomposition
   Granular residuals and country-level inflation
   (Comovement across countries)

4. Next step

5. Taking stock
• Distribution of firm size (market shares) is right skewed in retail sector
  ➔ 30-60 % expenditures go to 10 firms

• Granular residuals contribute to aggregate inflation (especially in low-inflation countries)
  ➔ 24-40 % of the variance in retail inflation can be explained by $\Gamma_{fct}$

• Granularity (most) important at the layer of firms
  ➔ e.g. only 6-10 % of the variance in retail inflation can be explained by $\Gamma_{gct}$

• Firms shocks contribute to the comovement of retail inflation
  ➔ AE: $\Gamma_{fct}$ increases the correlation of country inflation with global inflation by around 0.10


——— (2020): “Foreign shocks as granular fluctuations,”.


Granularities shown to be important for


Large firms & inflation inequality: Faber and Fally (2021)

<table>
<thead>
<tr>
<th>Country</th>
<th>A: Firms in original data</th>
<th>B: Firms after matching</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Obs</td>
<td>Missing</td>
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<tr>
<td>SE</td>
<td>785,042</td>
<td>0.00</td>
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<td>AT</td>
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<td>5,920,231</td>
<td>0.01</td>
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<td>NL</td>
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<td>0.01</td>
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<td>BR</td>
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<tr>
<td>MX</td>
<td>830,765</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>48,085,628</strong></td>
<td><strong>0.06</strong></td>
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</tbody>
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Data - before and after matching process

Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
Market share of the 10 largest firms in each country

Note: Top 10 firms selected based on total expenditure share across all periods. Market shares from expenditures on products with identified firm.
Synchronization of price adjustments within \( m, s, g \)

i Do products from the same firm adjust prices in a synchronized manner indicating that \( m \)-specific shocks explain part of the price adjustments of all products?

ii Estimate multinomial logit similar to the one used in Bhattarai and Schoenle (2014):

\[
Pr(Y_{igmst} = 1, 0, -1 | X_{igmst} = \chi) = \phi(\beta X_{igmst})
\]

where \( Y_{igmst} \) is an indicator variable for positive, no, or negative (modal) price adjustment between quarter \( t \) and \( t - 1 \) for product \( i \), produced by firm \( f \) and sold by retailer \( s \).
Synchronization of price adjustments within $m, s, g$

i. Do products from the same firm adjust prices in a synchronized manner indicating that $m$-specific shocks explain part of the price adjustments of all products?

ii. Estimate multinomial logit similar to the one used in Bhattarai and Schoenle (2014):

$$Pr(Y_{igmst} = 1, 0, -1|X_{igmst} = \chi) = \phi(\beta X_{igmst})$$

where $Y_{igmst}$ is an indicator variable for positive, no, or negative (modal) price adjustment between quarter $t$ and $t-1$ for product $i$, produced by firm $f$ and sold by retailer $s$.

iii. $X_{igmst}$ includes the share of same-signed price changes within the same $m, s$ and $g$ (excluding the product we try to explain) and control variables (quarter FE, aggregate country inflation and as measure of MC, average price change of products in the same $m, s$ and $g$).

iv. We set as base category no change and weight each product with expenditure weights.
Synchronization of price adjustments within $m, s, g$ – marginal effects

ME in pp. of $\pm 1/2\text{Std. Dev.}$ change around the mean on the probability of a Q-o-Q price change:

<table>
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<th>Country</th>
<th>$g$</th>
<th>$m$</th>
<th>$s$</th>
<th>$p_{ct}$</th>
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<th>$m$</th>
<th>$s$</th>
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In the US if the fraction of positive price changes of products from the same firm increases by one SD around its mean, the probability of a positive price change increases by 3.89 pp.
Data - compared to official data (US)

Category inflation computed from our data comoves closely with official statistics (BLS):

Inflation
Official inflation
Official inflation food & beverages
Category inflation computed from our data comoves closely with official statistics (Eurostat):

![Graph showing beer y-on-y inflation for official index and AiMark data from 2006q1 to 2016q1](image)
$\Gamma^s_t$ is small in magnitude and less relevant for aggregate inflation than the other granular components and it does not diminish the role of $\Gamma^m_t$. 

![Graph showing Inflation and various components over time](image-url)
The CEO of firm “MX” said in February 2015 that a number of their multinational competitors had lagged a little bit in pricing response, do we see this in the data?

⇒ Plot dynamics of $\delta_{mct}$ for top 10 $m$ in Germany

(i)
Table: Summary statistics and correlations of total inflation and different components

<table>
<thead>
<tr>
<th></th>
<th>Obs.</th>
<th>Mean</th>
<th>Corr</th>
<th>St. Dev</th>
<th>Relative St. Dev</th>
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<tr>
<td><strong>AE</strong></td>
<td><strong>Inflation</strong></td>
<td>529</td>
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<td></td>
<td>$U_t$</td>
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<td>.7877</td>
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</table>

Notes: AE values computed pooling all advanced economies and EM all emerging markets. Correlation is of the component with total inflation and relative standard deviation is wrt to total inflation.
Decomposition - simple granular residual dynamics (AT)
Decomposition: inflation and manufacturer granular component (AT)
Decomposition - simple granular residual dynamics (AR)

![Graph showing inflation and \( \Gamma_i \) over time]

- Alvarez-Blaser S., Auer R., Lein S. M., Levchenko A.
Decomposition: inflation and manufacturer granular component (AR)
Decomposition - simple granular residual dynamics (BE)
Decomposition: inflation and manufacturer granular component (BE)
Decomposition - simple granular residual dynamics (BR)

![Graph showing inflation and \( \Gamma_i \) trends over time from 2012q1 to 2020q1.](image)
Decomposition: inflation and manufacturer granular component (BR)
Decomposition - simple granular residual dynamics (CN)
Decomposition: inflation and manufacturer granular component (CN)
Decomposition - simple granular residual dynamics (DE)
Decomposition: inflation and manufacturer granular component (DE)
Decomposition - simple granular residual dynamics (ES)
Decomposition: inflation and manufacturer granular component (ES)
Decomposition - simple granular residual dynamics (FR)
Decomposition: inflation and manufacturer granular component (FR)
Decomposition: inflation and manufacturer granular component (IT)
Decomposition - simple granular residual dynamics (MX)
Decomposition: inflation and manufacturer granular component (MX)
Decomposition - simple granular residual dynamics (NL)
Decomposition: inflation and manufacturer granular component (NL)
Decomposition - simple granular residual dynamics (PT)
Decomposition: inflation and manufacturer granular component (PT)
Decomposition - simple granular residual dynamics (RU)
Decomposition: inflation and manufacturer granular component (RU)
Decomposition: inflation and manufacturer granular component (SE)
Decomposition - simple granular residual dynamics (UK)

Take me back
Decomposition: inflation and manufacturer granular component (UK)
Decomposition - simple granular residual dynamics (US)
Decomposition: inflation and manufacturer granular component (US)