Multi-Product Pricing: Theory and Evidence From Large Retailers in Israel

Marco Bonomo
Insper

Carlos Carvalho
PUC-Rio, Central Bank of Brazil

Oleksiy Kryvtsov
Bank of Canada

Sigal Ribon
Bank of Israel

Rodolfo Rigato
Harvard

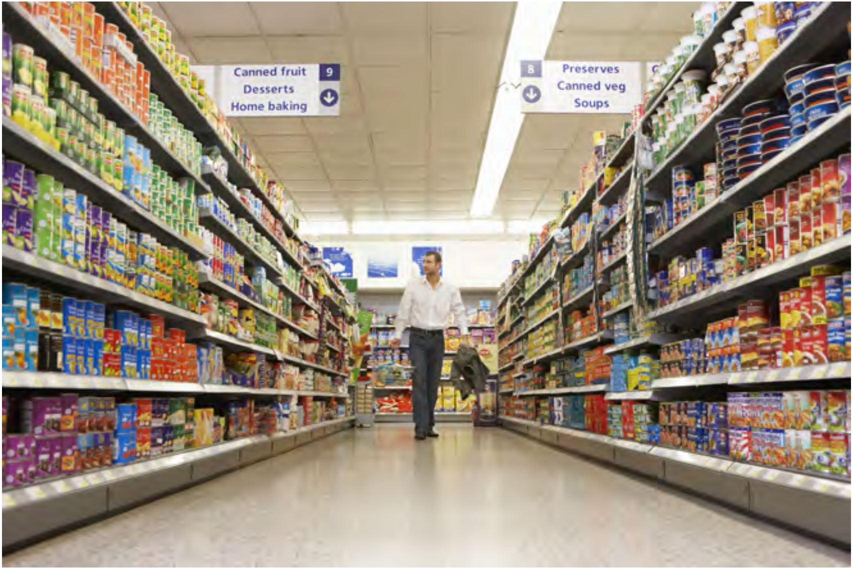
ECB "Inflation in a changing economic environment", 23 September 2019

The views expressed here are ours, and they do not necessarily reflect the views of Central Bank of Brazil, Bank of Canada or Bank of Israel

Inflation and micro price adjustments

- **Price adjustments:** important for inflation and allocation of goods
  - Why inflation is stable, persistent, little sensitive to shocks?
  - Effects of monetary policy changes on the economy?
- **(Lots of) Data:** product prices change infrequently, volatile, transient
- **Standard theory** based on single-product monopolistic firms
  - Face cost of adjusting prices—decide when to adjust

Can a standard sticky price model account for this?



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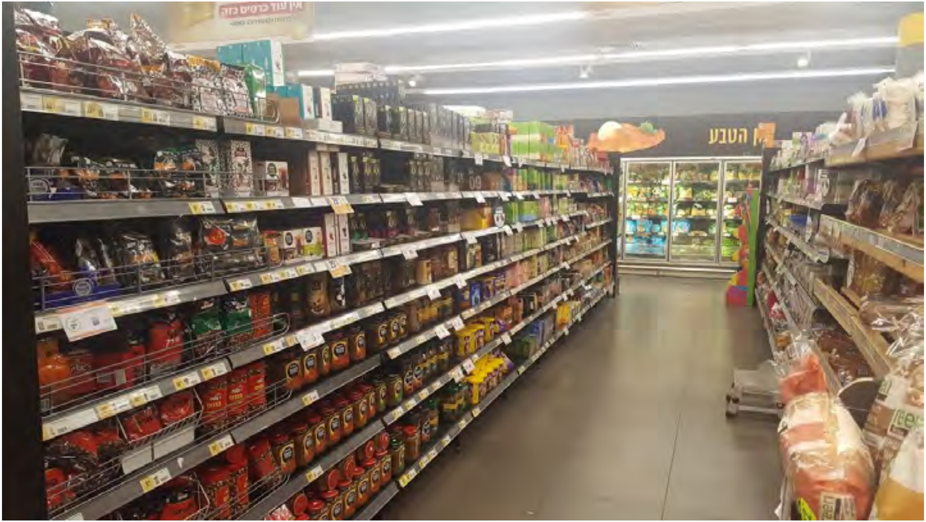

Can a standard sticky price model account for this?

Question in this paper

- Study pricing behavior of large multi-product firms
  - Adjust prices along two dimensions: over time *and* across products
  - What are macro implications?

- Main mechanism: Selection vs Synchronization of price changes

Selection vs Synchronization of price changes

Simple Illustration of Multi-Product Pricing

10 ₪/unit

8 ₪/unit

Selection vs Synchronization of price changes

Simple Illustration of Multi-Product Pricing

10 ₪/unit

Desired price
p_0^* = 10 ₪/unit

8 ₪/unit

Selection vs Synchronization of price changes

Simple Illustration of Multi-Product Pricing

New desired price

$p_1^* = 10.1$ ₪/unit

↑ shock

Desired price

$p_0^* = 10$ ₪/unit

10 ₪/unit

8 ₪/unit

Selection vs Synchronization of price changes

Simple Illustration of Multi-Product Pricing

New desired price

p_1^* = 10.1 ₪/unit

shock

Desired price

p_0^* = 10 ₪/unit

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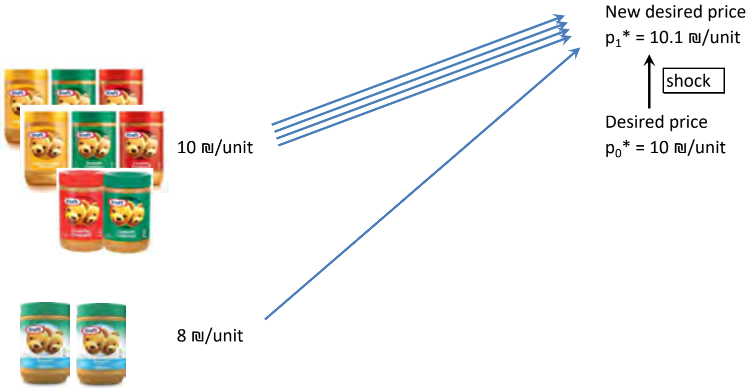
Selection

adjust misaligned prices

ΔP = 2.4%

Selection vs Synchronization of price changes

Simple Illustration of Multi-Product Pricing



Selection

adjust misaligned prices

$\Delta P = 2.4\%$

Synchronization

adjust many prices

$\Delta P = 1.6\%$

This paper

- Study pricing behavior for **large food retailers in Israel**
  - Daily prices for most products from June 2015
  - Focus on price adjustments over time and across products
  - Find **partial synchronization** of price changes within store/chain
- Develop a **multi-product price-setting model** with
  - Economies of scope in price adjustment
  - Endogenous trade-off between Selection and Synchronization
  - Calibrate the model to match partial synchronization and other facts
- **Main result: weak non-neutrality**
  - Partial synchronization does not materially reduce price flexibility

Existing work on multi-product pricing

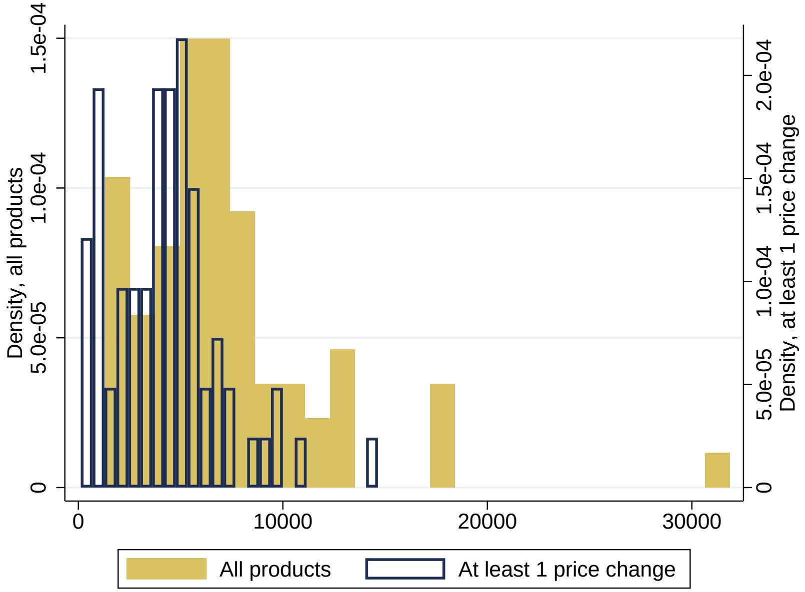
1. Is price setting behaviour systematically related to N?
   Goldberg and Hellerstein (2011), Bhattarai and Schoenle (2014)
2. Staggering vs synchronization of price changes across products/stores/chains
   Lach and Tsiddon (1996), Fisher and Konieczny (2000), Gentzkow and Dellavigna (2019)
3. Economies of scope in menu costs vs information frictions
   Sheshinski and Weiss (1992), Midrigan (2010), Stella (2013), Alvarez and Lippi (2014, 2018)

Retail Chain Data for Israel

- **Price disclosure law** for large retail stores (online/offline)
  - Stores started uploading prices online daily in May 2015
  - Detailed across products, stores/chains, location, time
  - Collected and processed by the Bank of Israel

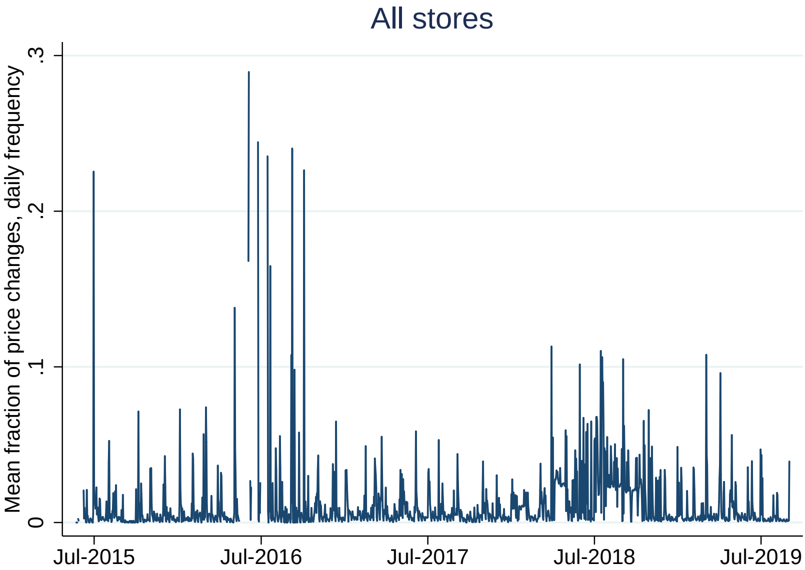
- **Analyze 5% sample of stores**:
  - Daily prices for May 22, 2015 – September 1, 2019 (1563 days)
  - Excluded: fruits & veg, bakery goods; pharmacy retailers
  - 21 chains, 71 stores, 451.7 million daily observations
  - Regular prices (price discounts are collected separately)
  - Discounts for 10 stores of the largest chain, *Shufersal*

Number of products per store per day



Daily fraction of price changes: re-pricing peaks

Daily fraction of price changes: aggregate

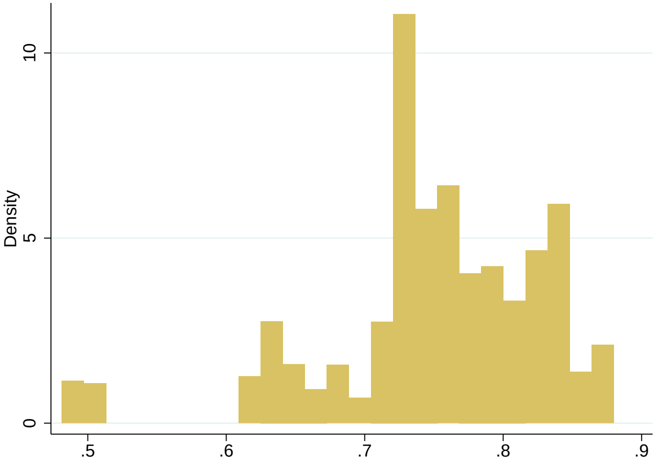


Repricing peaks are NOT ...

- ... driven by day-of-week or day-of-month effects
- ... driven by Jewish holidays
- ... closely related to retail discounts

Synchronization of price changes: store Gini index

Gini index across stores



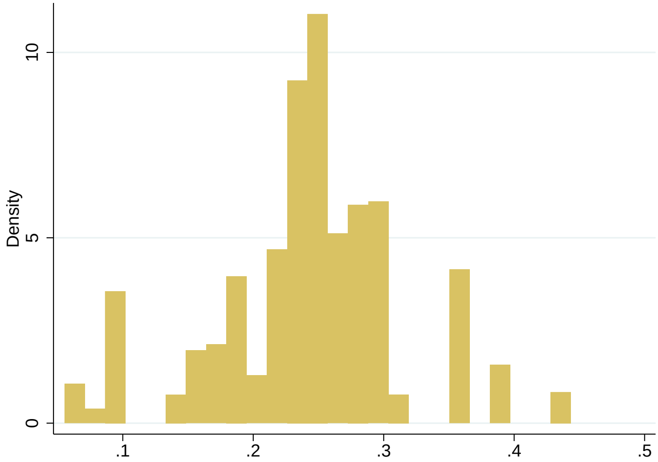
Synchronization: Ficher-Konieczny index

$$FK_s \equiv \sqrt{\frac{\frac{1}{N_s}\sum_t \left(Fr_{s,t} - \overline{Fr_s}\right)^2}{\overline{Fr_s} \cdot \left(1 - \overline{Fr_s}\right)}}$$

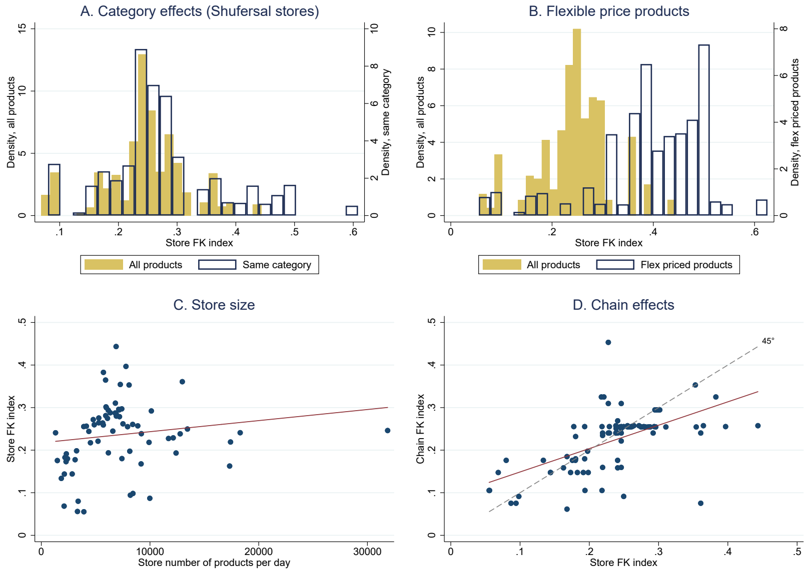
$Fr_{s,t}$ – fraction of p-changes in store s period t
$\overline{Fr_s}$ – mean over t
N_s – number of p-changes in store s

- $FK_s = 0$ – perfect staggering
- $FK_s = 1$ – perfect synchronization

Synchronization of price changes: store FK index



FK index and product/store characteristics



Data Summary

- **Large food retailers**
  - Infrequent/large price changes over time (similar to existing studies)
- **Partial synchronization of price changes**
  - Recurring peaks in fraction of price changes
  - Store/chain specific
  - Not closely related to calendar events

Model

- Continuous time, t; continuum of differentiated goods, $i \in [0,1]$
- Monopolistically competitive multi-product firms, each sells all goods
- Firm sets price $p_{i,t}$ and incurs **instantaneous loss**

$$L_t = \int_0^1 (p_{i,t} - p^*_{i,t})^2 \, di$$

where **frictionless optimal price**, $p^*_{i,t}$ follows

$$dp^*_{i,t} = -\sigma_i dW_{i,t}$$

$W_{i,t}$ is a standard Brownian motion, independent across i

Economies of scope in price adjustment

- Two types of fixed cost of adjusting prices:
  - c for changing a single price, cm for changing measure m
  - K to make any number of price adjustments

- Equivalence (up to 1 order) to model where K is cost of observing all $p^*_{i,t}$
  - multi-product generalization of Alvarez, Lippi, Paciello (2011)

- Infrequent price adjustments if $K > 0$

- Not optimal to adjust all prices if $c > 0$

Solving the model

- Define **price gaps** for non-adjusting prices, $x_{i,t} = p_{i,t} - p^*_{i,t}$
- Distribution (pdf) of gaps at t, $g_t(x)$
- Re-write **instantaneous loss**

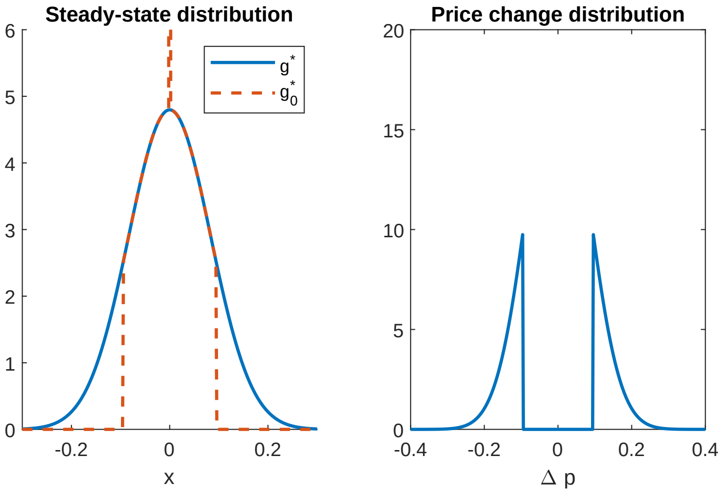
$$L_t = \int x^2 g_t(x)\, dx$$

- Given initial $g_0(x)$, optimal $g_t(x)$ solves **Kolmogorov forward equation**

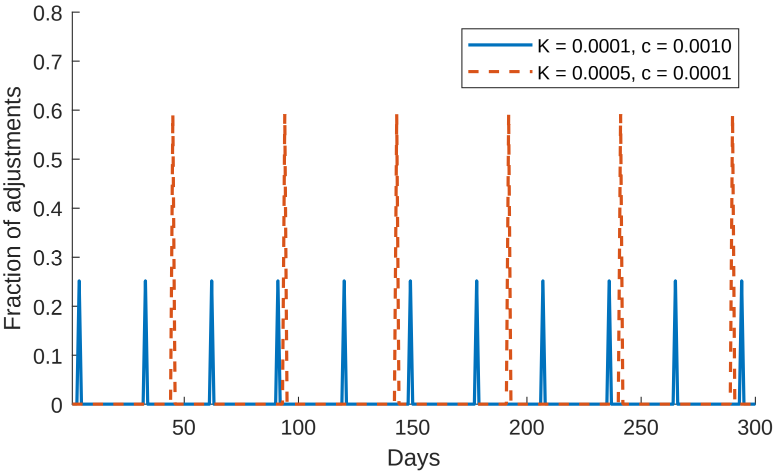
$$\frac{\partial g_t}{\partial t}(x) = \frac{\sigma_i^2}{2} \frac{\partial^2 g_t}{\partial x^2}(x)$$

- Deterministic optimal policy: adj dates $\{T_k\}_{k=1}^{\infty}$ and thresholds $\{\bar{x}_k\}_{k=1}^{\infty}$

Price change distributions



Daily fraction of prices changes



- **Steady state**: firms adjust prices every τ^* periods

Two nesting cases

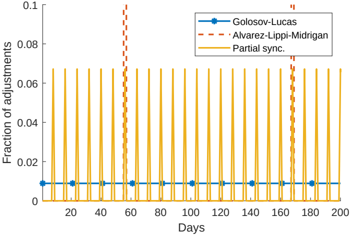
- $K = 0$: single price adjustments (Golosov-Lucas, 2007)
  - no synchronization, max selection
- $c = 0$: adjustments of all firm's prices (Midrigan, 2010, Alvarez-Lippi, 2014)
  - max synchronization, no selection

Calibration

Moment	Data	GL	ALM	Partial sync.
Daily fraction of price changes	0.0089	0.0089	0.0089	0.0084
Avg. size of price changes	0.209	0.209	0.209	0.216
Fisher-Konieczny index	0.236	0.000	1.000	0.236

Parameter	GL	ALM	Partial sync.
σ_i	0.3774	0.4730	0.3834
K	-	0.0106	3.24e-05
c	0.0022	-	0.0020

Daily fraction of adjusted prices: models vs data



Effects of monetary shocks

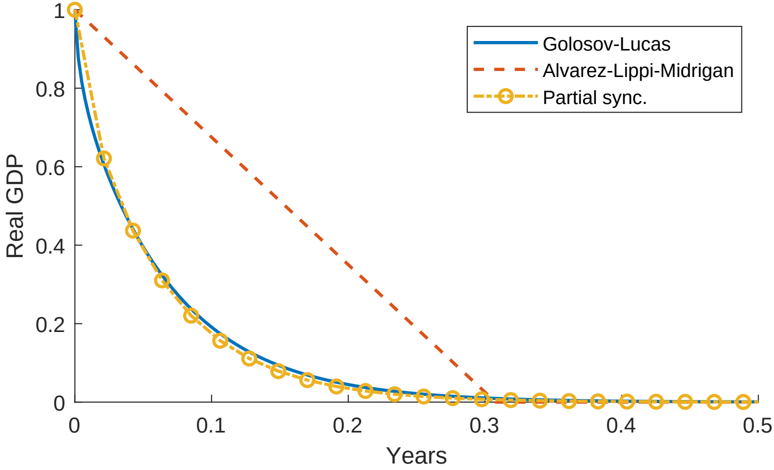
- Eqm for real log output Y_t, agg log price level P_t , log money supply M_t:

$$Y_t = M_t - P_t$$

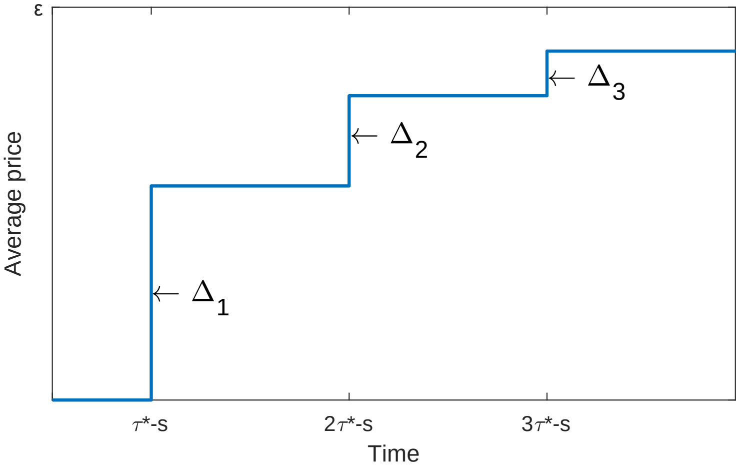
- **One-time unanticipated shock** $M_t + \varepsilon$
  - Small shock: $\varepsilon \to 0$ (same adjustment dates as in steady-state)

- Sluggish P_t response leads to response in Y_t (monetary non-neutrality)

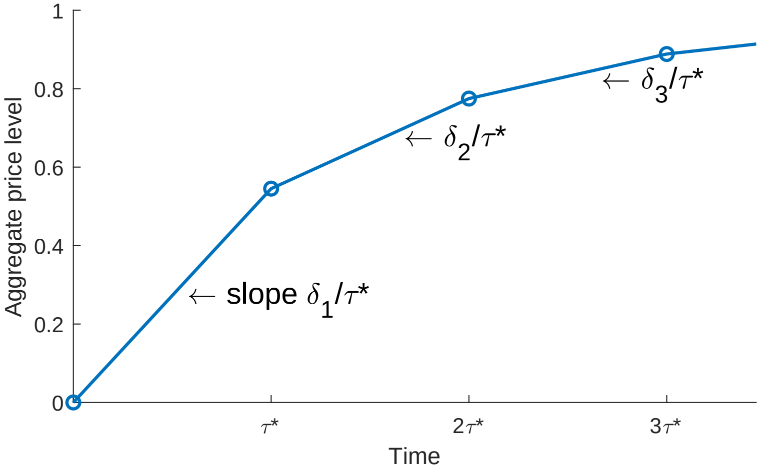
Output responses



Firm's price response

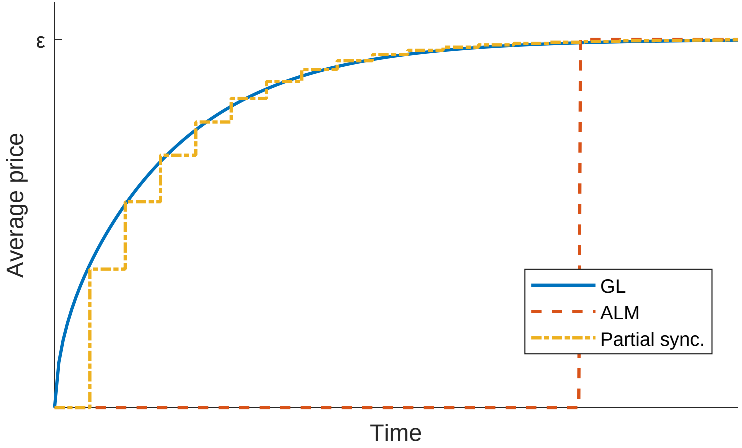


Aggregate price response

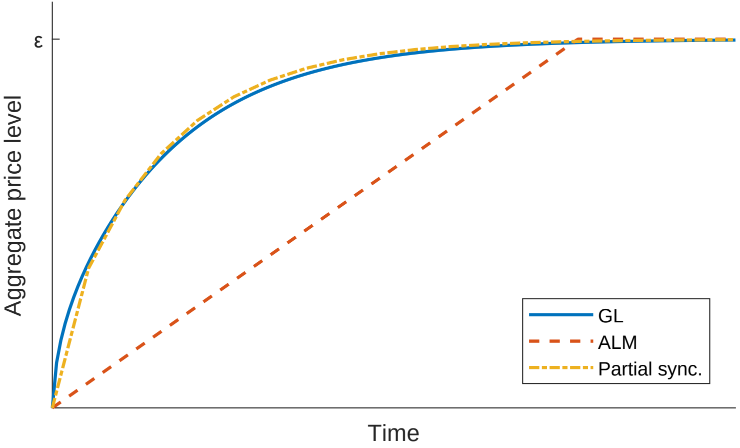


- Speed of response depends on **selection**: $\frac{\delta_1}{\tau^*} = \mathit{Fraction} \times [1 + \bar{x}^* f(\bar{x}^*)]$

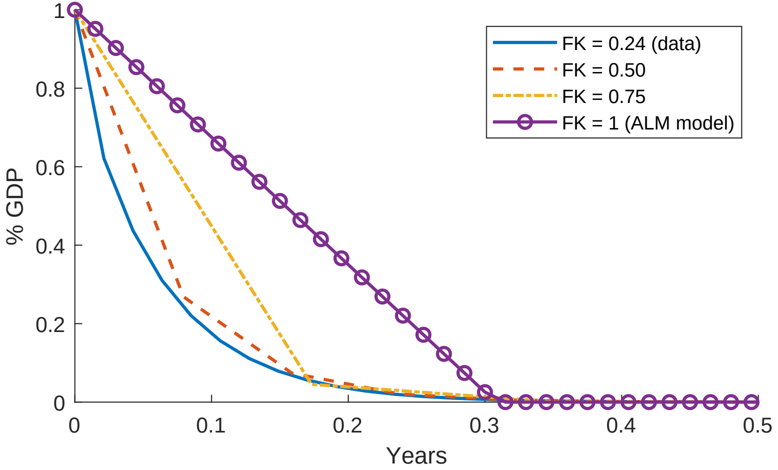
Firm's price responses



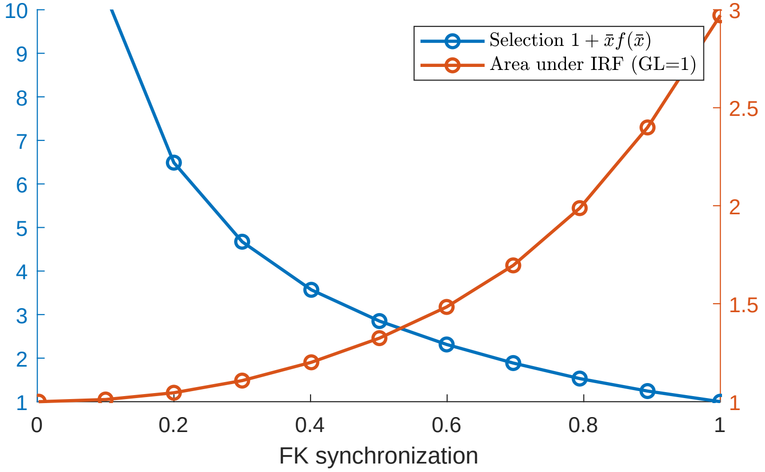
Aggregate price responses



Synchronization and non-neutrality



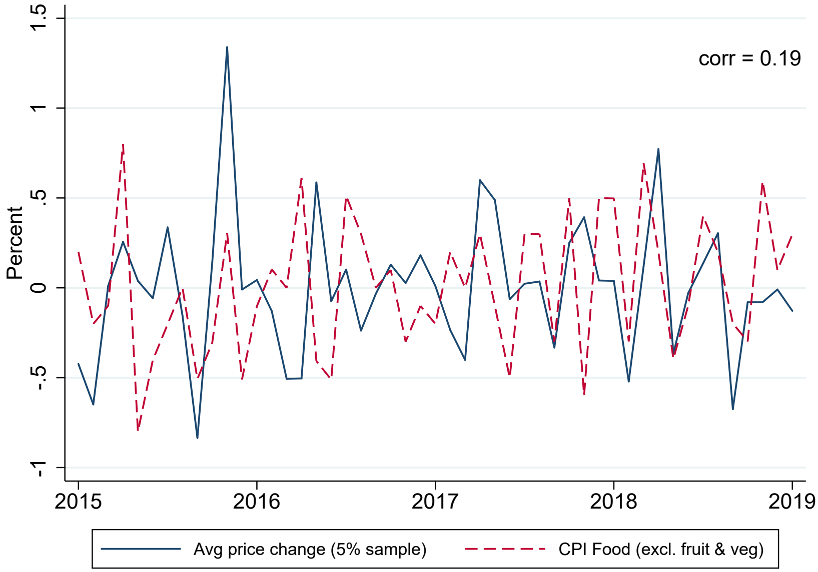
Selection vs Synchronization



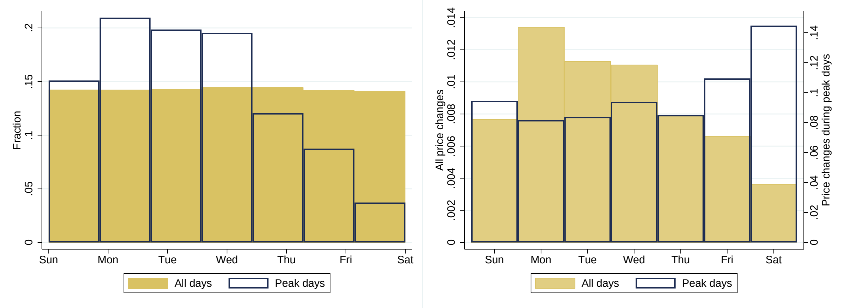
Conclusions

- Study price adjustment problem for **large retailers**
  - two dimensions: over time *and* across products
- Evidence on daily prices of **large food retailers in Israel**
  - **Partial synchronization** of price changes within store/chain
- Develop a **multi-product price-setting model** with
  - Economies of scope in price adjustment
  - Endogenous trade-off between Selection and Synchronization
- **Main result: weak non-neutrality**
  - Partial price sync does not deter multi-product firms from responding to shocks

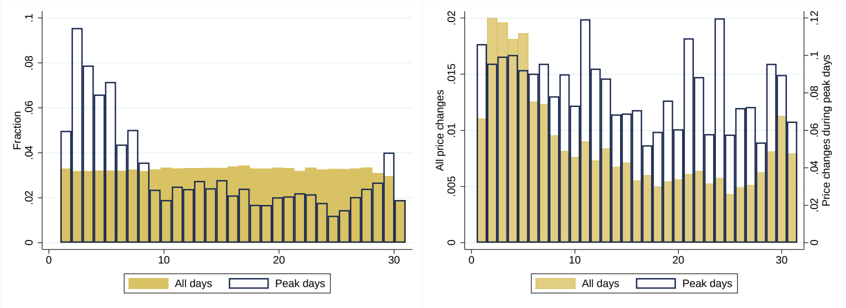
Food inflation in Israel



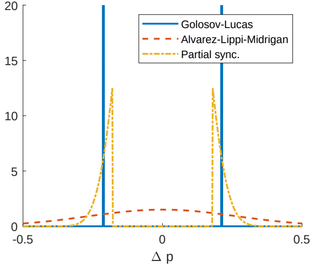
Peaks: day of the week

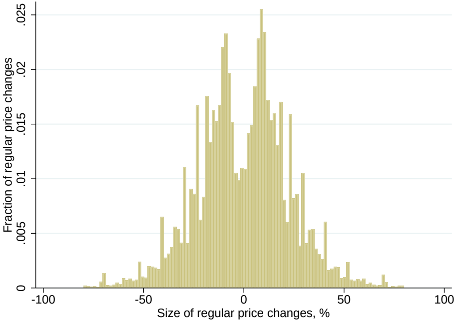


Peaks: day of the month



Distribution of price changes





Hazard rate, weighted