How Important are Trade Prices for Trade Flows?

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Introduction

- International trade has a muted response to changes in exchange rates.
- Recent work focuses on trade *pricing*, with limited pass-through of exchange rate changes generated by various frictions
- Basic idea: if destination prices don't respond to exchange rates, neither will trade quantities
- This paper: if we get trade prices right, how well do we do for trade values?

Introduction (continued)

- Start with a model capable of matching the new stylized facts we know about U.S. international trade prices
- The price response depends on 1.) how *often* and 2.) how *much* destination prices change in response to an exchange rate change
  - If prices stuck in the local currency, exchange rate movements will not affect trade values
  - If firms change their price but do not fully incorporate the exchange rate change, trade response dampened
    1. Costs may not be entirely subject to the exchange rate (imported intermediates, distribution costs)
    2. Firms may face strategic complementarities in price setting
- Compare simulated data from the model against highly disaggregated, bilateral U.S. trade (value) data, using the same estimation procedure on each set of data.

Preview of results

- A modern menu cost model designed to match the behavior of trade prices still implies too large of a response of both imports and exports to exchange rate shocks
  - Time-dependent (Calvo) price setting comes closest to explaining imports compared to flexible prices or menu costs, but is worst in explaining exports
    $\Rightarrow$ Making imports fit better with greater price stickiness makes exports fit worse
- Important parameters of the model, like the long-run elasticity of substitution, make little difference in the estimated response of trade flows to exchange rate shocks in the data

Background

- **Estimating trade elasticities:** Broda et al. (2008), Broda and Weinstein (2006), Feenstra et al. (2012), Hooper et al. (2000)
- **Elasticity puzzle:** Arkolakis et al. (2012), Drozd and Nosal (2012), Leibovici and Waugh (2012), Ruhl (2008)
- **Exchange rate pass-through:** Alessandria (2004), Campa and Goldberg (2005), Goldberg and Campa (2010), Gust et al. (2009)
- **Micro-level trade price behavior:** Berman et al. (2012), Chatterjee et al. (2012), Gopinath and Rigobon (2008), Gopinath and Itskhoki (2010), Gopinath et al. (2010), Schoenle (2010)

Model environment

- Partial equilibrium model with two countries and one sector, as in Gopinath et al. (2010), Schoenle (2010)
- Large number of foreign firms compete monopolistically in the home sector against "home" firms.
- Firms face exchange rate shocks, idiosyncratic productivity shocks, and potentially costs to changing their prices
- Exogenous: real demand, wages/input costs, exchange rate

LCP imports, PCP exports

- Micro price data for the U.S. provides strong evidence for the vast majority of U.S. trade being denominated in dollars
  - 97% of exports, 90% of imports (Gopinath and Rigobon 2008)

  $\Rightarrow$ Model U.S. exports as PCP and U.S. imports as LCP
- With a stuck price, this means that imports have zero pass-through and exports have full pass-through.

Model: demand

- Typical constant elasticity of substitution (CES) demand does not match pricing facts well
  - Upon adjustment, firms adjust to a function of their own costs, with no consideration of competitor's pricing
- Strategic complementarities introduce sluggishness in the average responses that help match import pass-through dynamics
- Can be generated from micro sources (e.g. Atkeson and Burstein 2008), but inclusion in a reduced form framework is desirable for computational reasons
- I follow Gopinath et. al (2010) and use the Klenow and Willis (2006) aggregator and calibration
- The effective elasticity becomes:

$$\tilde{\theta} = \frac{\theta}{1 - \epsilon \ln(\frac{p_i}{P})},$$

Model: firm's problem

- State variables: firm's price p, exchange rate e (destination currency per source currency), idiosyncratic productivity a.

$$V^a(p, e, a) = \max_{p'} \pi(p', e, a) - f_{mc} + \beta E[V(p', e', a')],$$
$$V^n(p, e, a) = \pi(p, e, a) + \beta E[V(p, e', a')],$$

$$V(p, e, a) = \max\{V^a(p, e, a), V^n(p, e, a)\}$$

- $\pi = pq - \frac{qe^{\phi}}{a}$, $q = \left[1 - \epsilon \ln \frac{p}{P}\right]^{\frac{\theta}{\epsilon}}$ if firm is LCP
- $\pi = epq - \frac{qe^{\phi}}{a}$, $q = \left[1 - \epsilon \ln \frac{ep}{P}\right]^{\frac{\theta}{\epsilon}}$ if firm is PCP
- Flexible pricing: $f_{mc} = 0$
- Calvo pricing: $f_{mc} \in \{0, \infty\}$, with fixed probability of each
- Output, labor costs fixed.

Model: aggregate conditions

- The sectoral price follows an endogenously determined path, assumed to take the form

$$\ln P' = \mu_1 + \mu_2 \ln P + \mu_3 \ln e^+ + \mu_4 \ln e^-.$$

  where e^+ indicates an increase in the exchange rate relative to the previous period and e^- indicates a decrease.

- Shock processes:

$$\ln e' = \rho_e \ln e + \epsilon_e$$
$$\ln a_i' = \rho_a \ln a_i + \epsilon_{a,i}$$

Model parameters

Table: Model parameters

		Description	Source
θ	4	Elasticity of substitution	Low-end trade estimate
ϕ	0.75	25% of input costs in foreign currency	Gopinath et al. (2010)
ϵ	3	Super-elasticity of demand	Gopinath et al. (2010)
f_{mc}	0.047 (0.135)	Menu cost	9% (7%) frequency of price changes
ρ_a	0.96	Persistence of idiosyncratic shocks	Schoenle (2010), Gopinath et al. (2010)
ρ_e	0.99	Persistence of exchange rate shocks	Near random walk
σ_a	0.045 (0.06)	Std. dev. of idiosyncratic shocks	8% median abs. price change
σ_e	0.025	Std. dev. of exchange rate shocks	U.S./U.K. exchange rate volatility

Export/PCP calibration in parentheses

Estimation strategy

- Use disaggregated, quarterly, bilateral U.S. import and export data. (avoids Imbs and Mejean 2011 aggregation critique)
- Eliminate U.S. conditions with industry-time dummies; explicitly modeling the substitution across countries stemming from their relative exchange rate changes
  - Foreign vs. foreign has fewer compositional concerns than home vs. foreign
- Use OECD countries (non-zero trade values, data limitations, substitutability)
- Separate industries into bins based on price duration, long-run elasticity, pricing type, etc.

Estimation strategy cont'd

- On each bin, run panel estimation with sector i, country j, time t:

$$\Delta \ln Trade_{ijt} = \beta_0 + \sum_{k=0}^{8} \beta_{e,k} \Delta \ln e_{jt-k} + \sum_{k=0}^{8} \beta_{y,k} \Delta \ln y_{jt-k} + Z_{ijt} + \epsilon_{ijt}.$$

- y nominal GDP of country j, Z a series of sector-time and country dummies.
- Impulse response at horizon h is simply $\sum_{k=0}^{h} \beta_{e,k}$
- Confidence bands on data are constructed with simple Wald tests of the summed coefficients.

Average results: imports

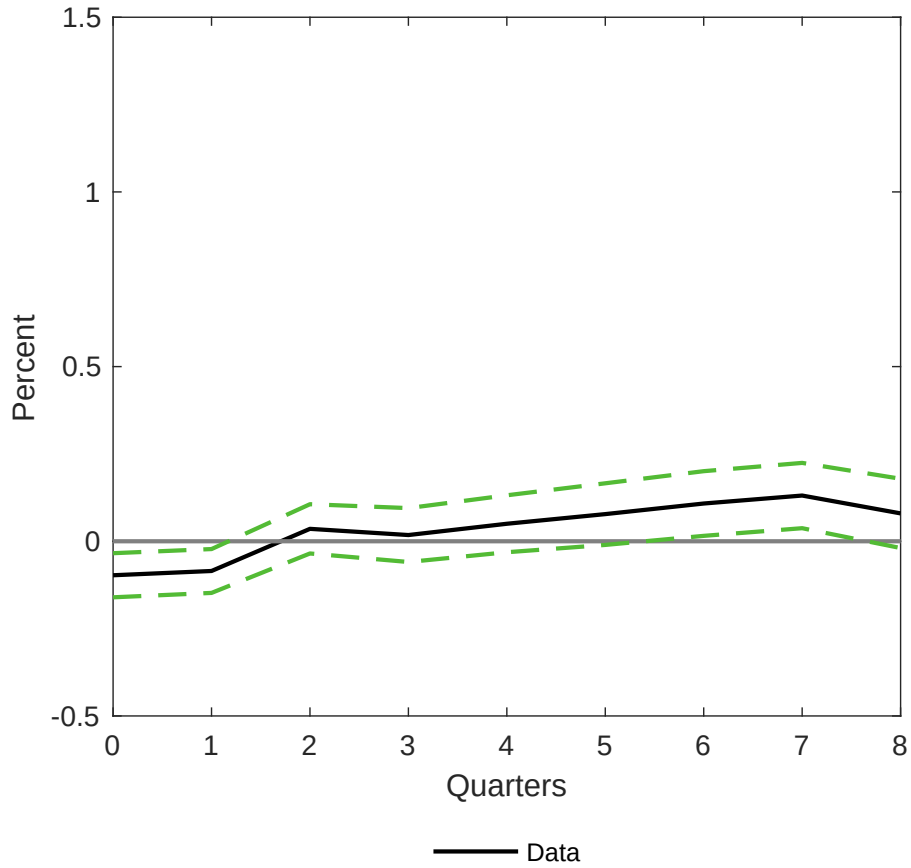
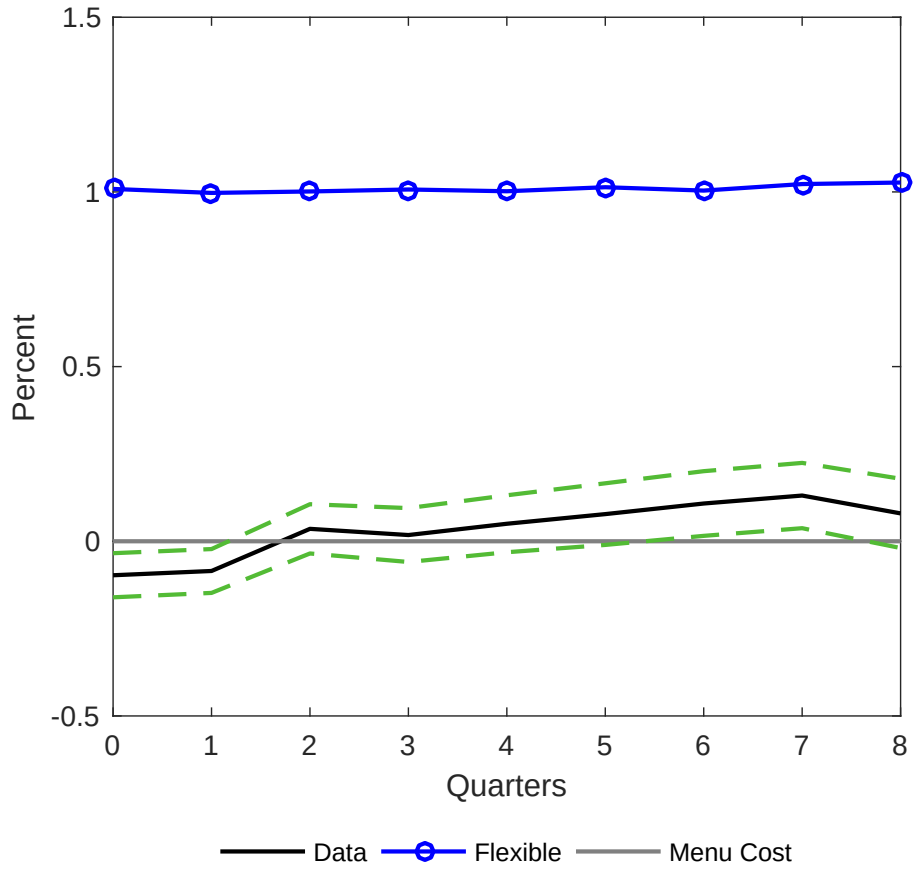


Figure: Impulse responses to a 1% exchange rate appreciation for pooled import HS4 categories with baseline model results

Regression table

Average results: imports



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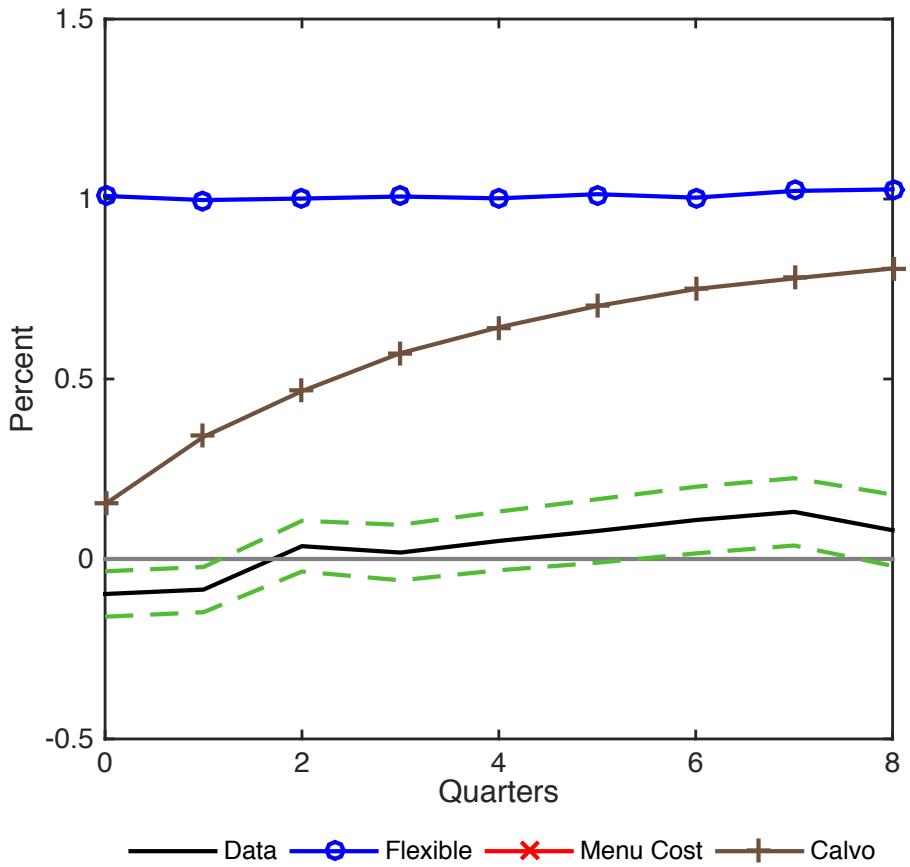
Average results: imports



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Average results: imports

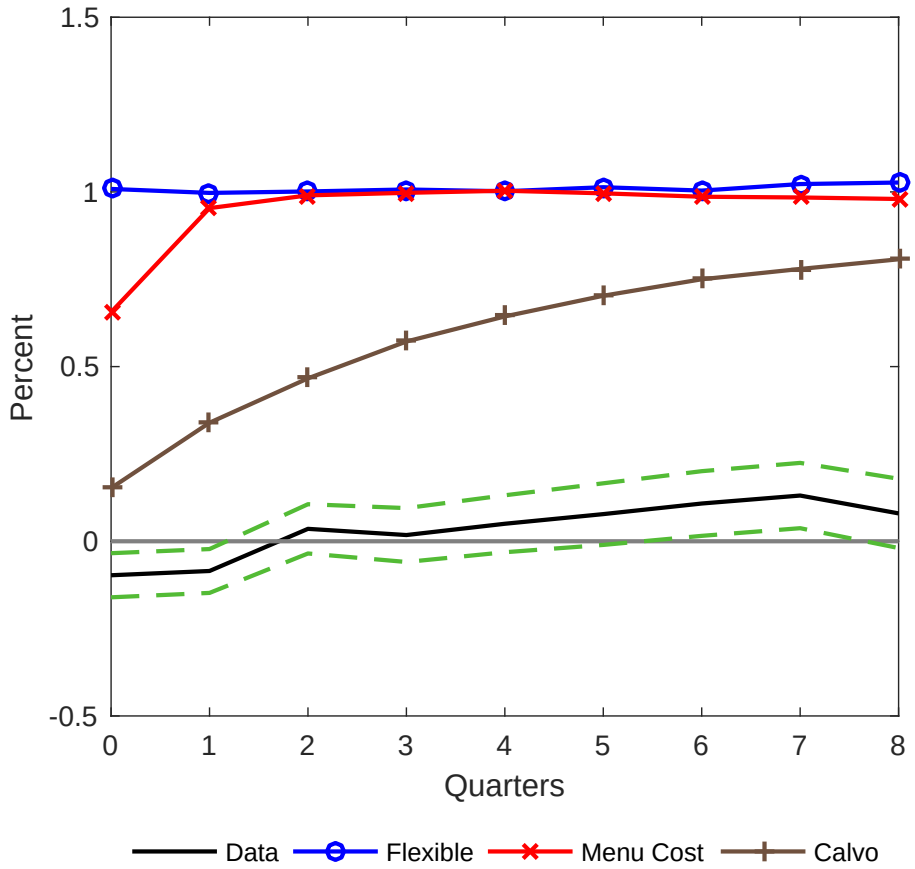


Figure: Impulse responses to a 1% exchange rate appreciation for pooled import HS4 categories with baseline model results

Regression table

Average results: exports

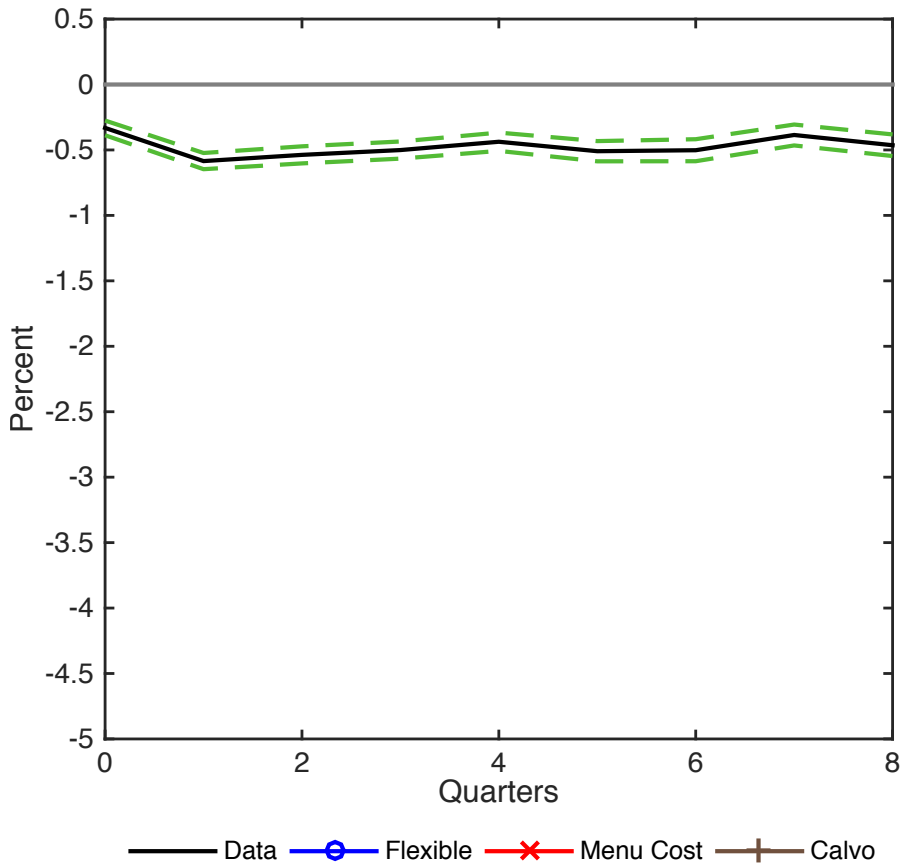


Figure: Impulse responses to a 1% exchange rate appreciation for pooled export HS4 categories with baseline model results

Regression table

Average results: exports

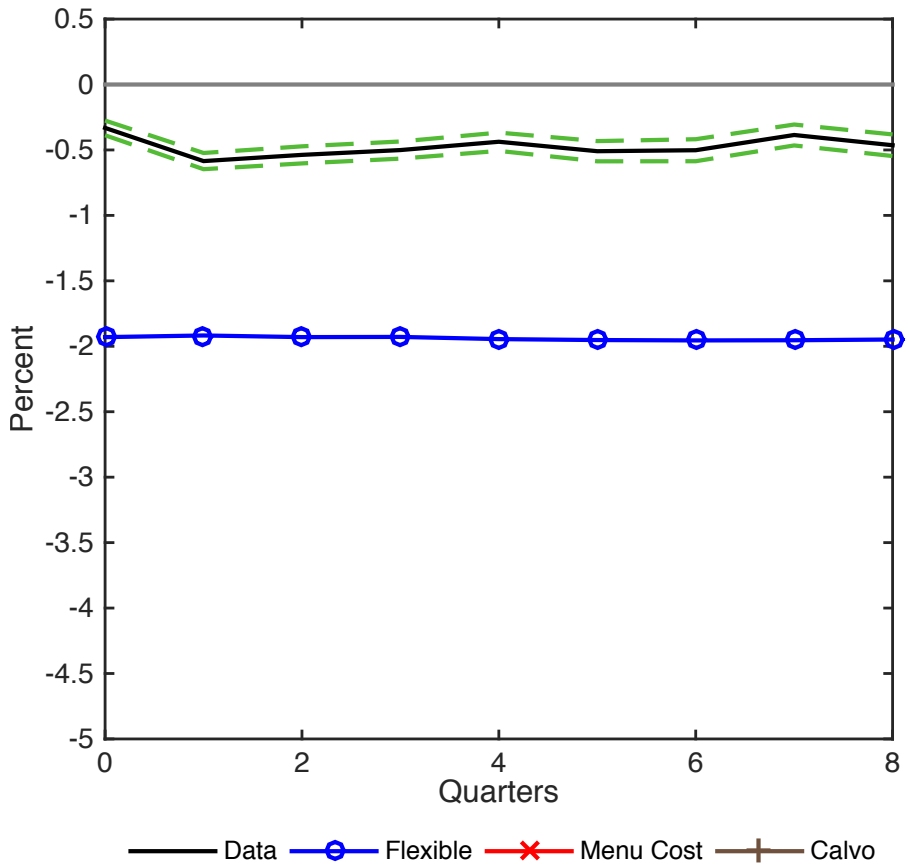
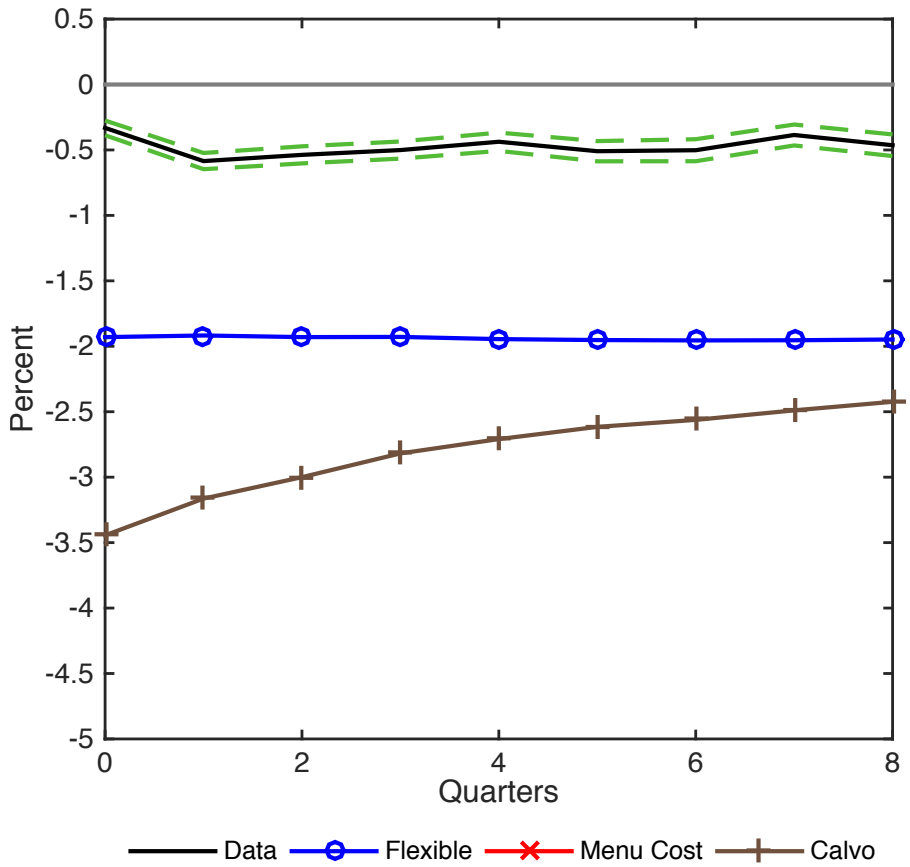


Figure: Impulse responses to a 1% exchange rate appreciation for pooled export HS4 categories with baseline model results

Regression table

Average results: exports



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Average results: exports

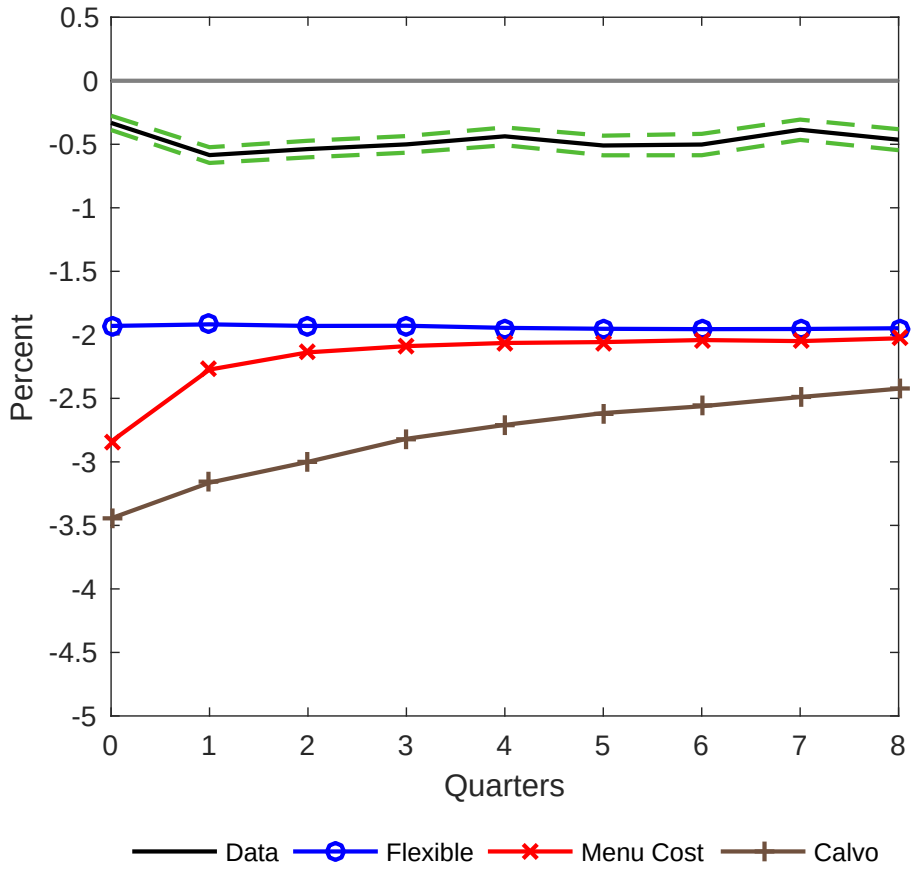

Figure: Impulse responses to a 1% exchange rate appreciation for pooled export HS4 categories with baseline model results

Regression table

Strategic complementarities

- Strategic complementarities and imported intermediates are two mechanisms which work to reduce the response of *both* imports and exports.
- How much are strategic complementarities contributing?

Strategic complementarities (continued)

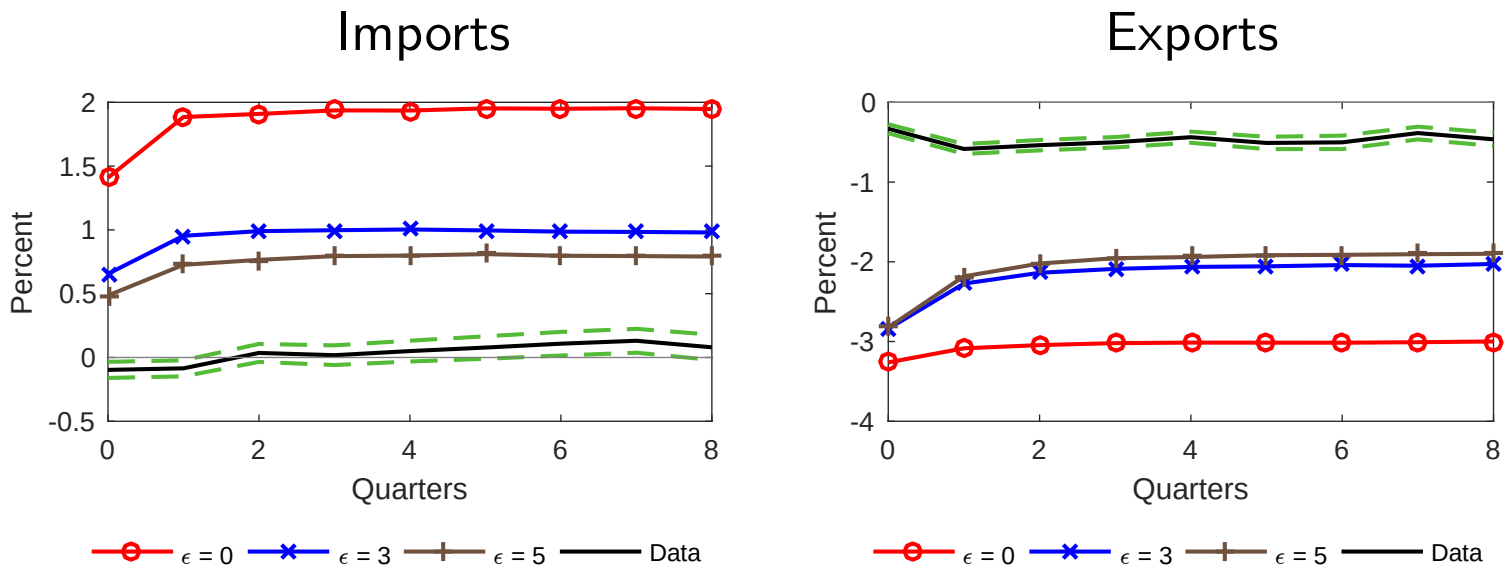

Figure: Impulse responses to a 1% exchange rate appreciation by super elasticity of demand

Industry heterogeneity in longer-run elasticity of substitution

- Elasticities of substitution can be measured with medium/long-run data (e.g. Broda and Weinstein 2006)
- Premise: long-run elasticities more indicative of "true" elasticity
  - Group SITC4 categories into 3 bins, take average elasticity within each bin.

Elasticity: imports

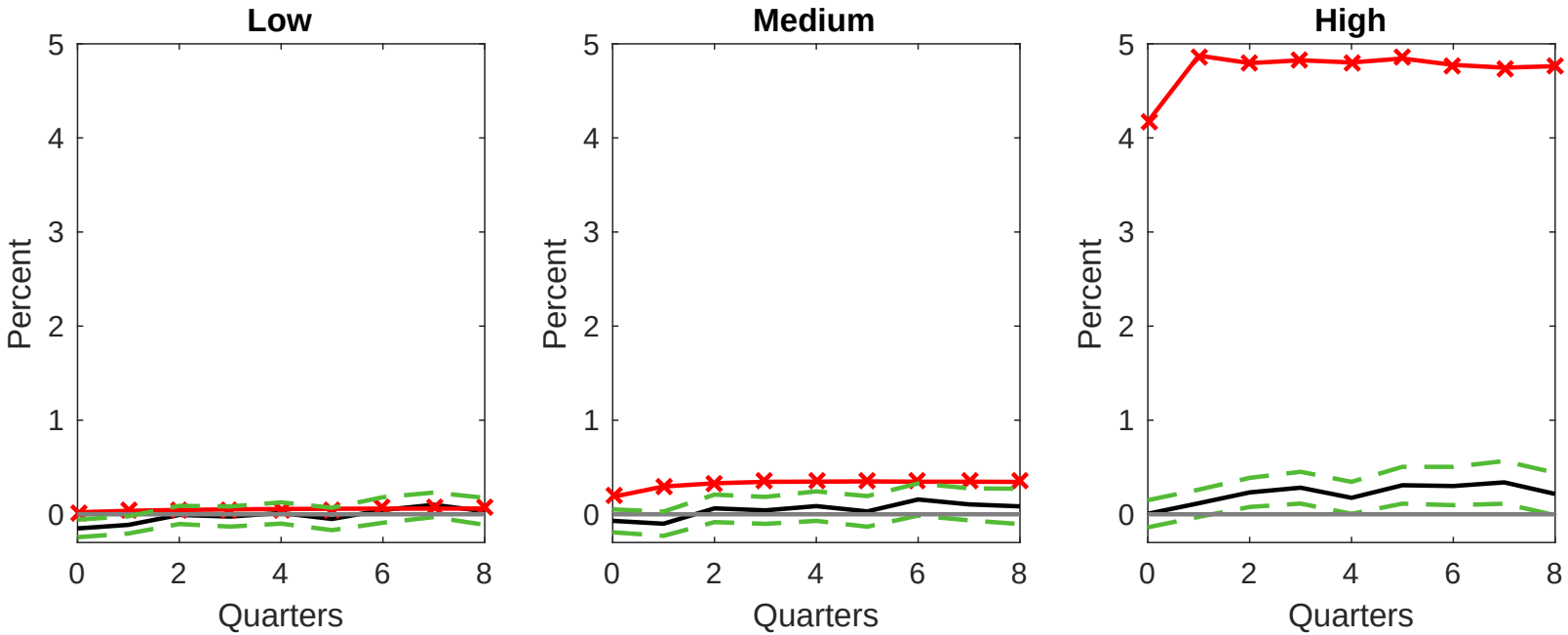

Figure: Impulse responses to a 1% exchange rate appreciation by elasticity bins (solid: 1.6, 2.6, 12.3), and the menu cost model IRF (with markers)

Elasticity: exports

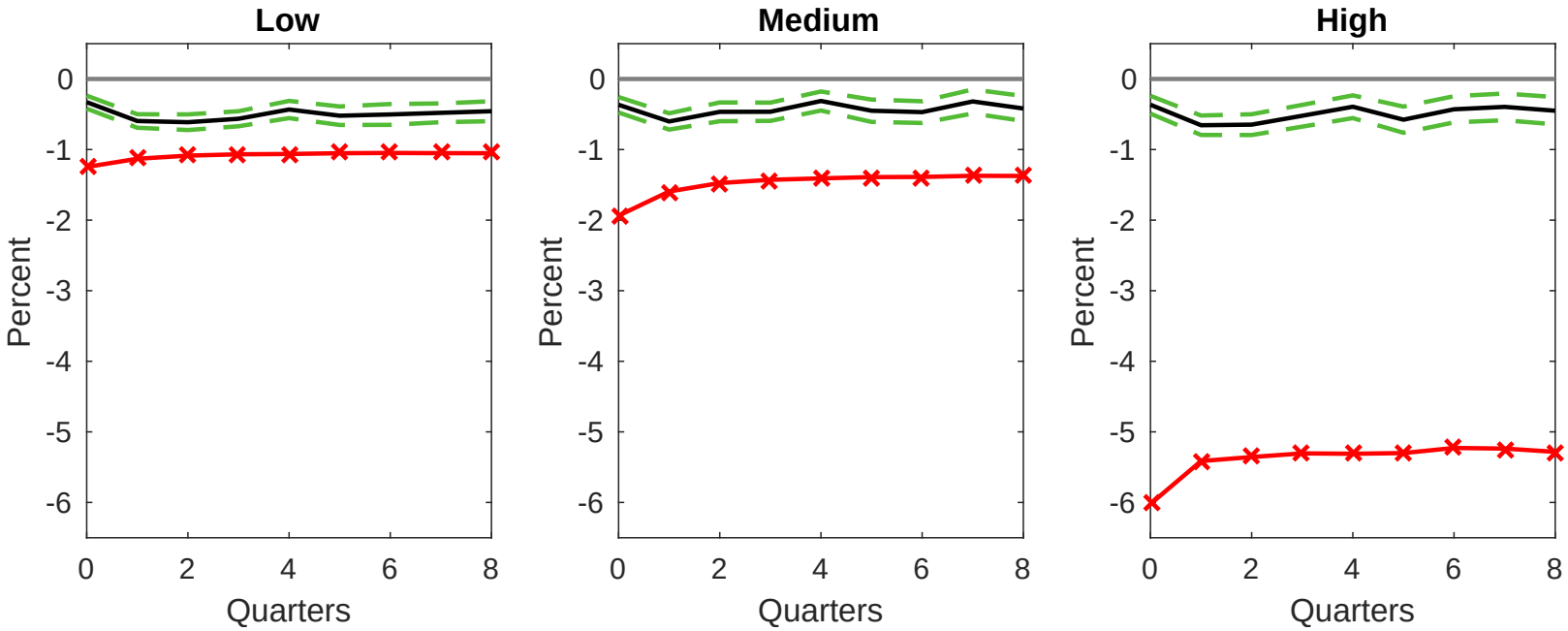

Figure: Impulse responses to a 1% exchange rate appreciation by elasticity bins (solid: 1.6, 2.6, 13.6), and the menu cost model IRF (with markers)

Alt. axes

Rauch pricing classification

- Sticky price models essentially require firms to have pricing power through a mechanism like monopolistic competition
- Some sectors are priced on exchanges (e.g. commodities)
- Others have some kind of reference price, listed in trade magazines (e.g. chemicals)
- Rest are differentiated

Rauch: imports

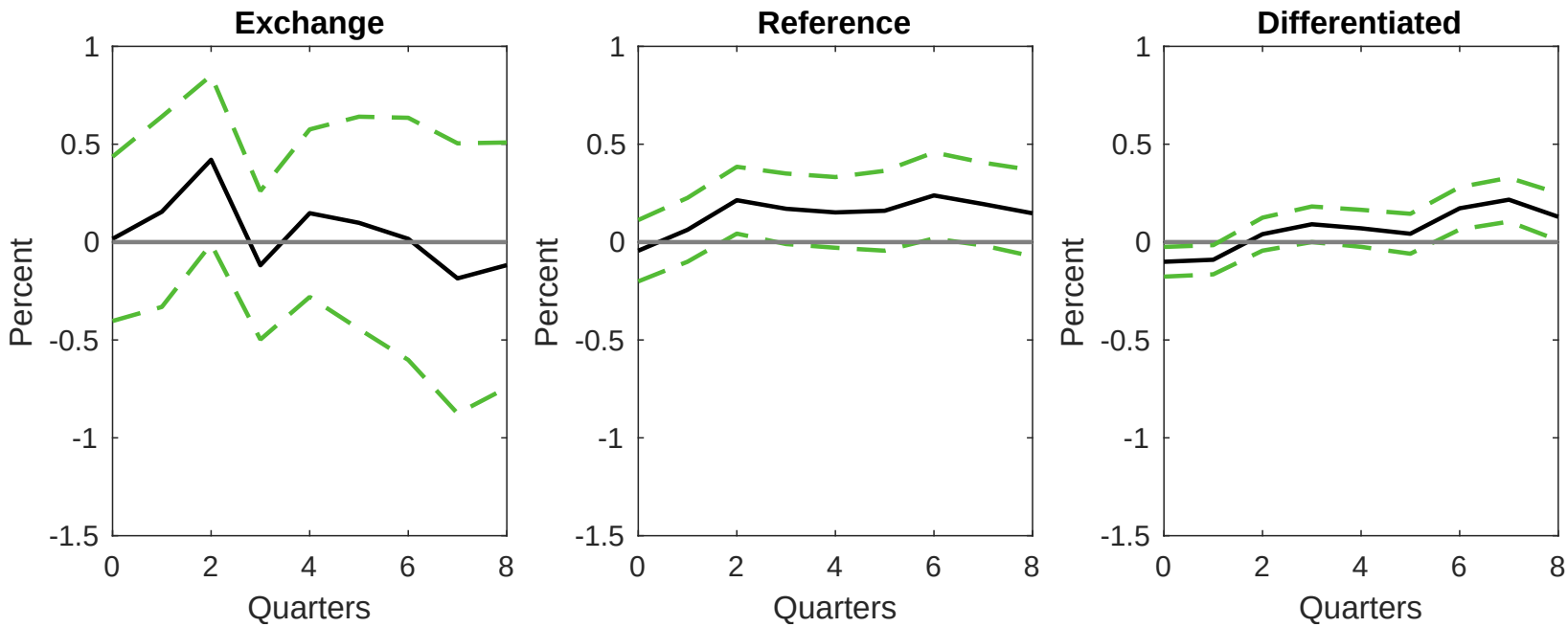

Figure: Impulse responses to a 1% exchange rate appreciation by pricing type

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Rauch: exports

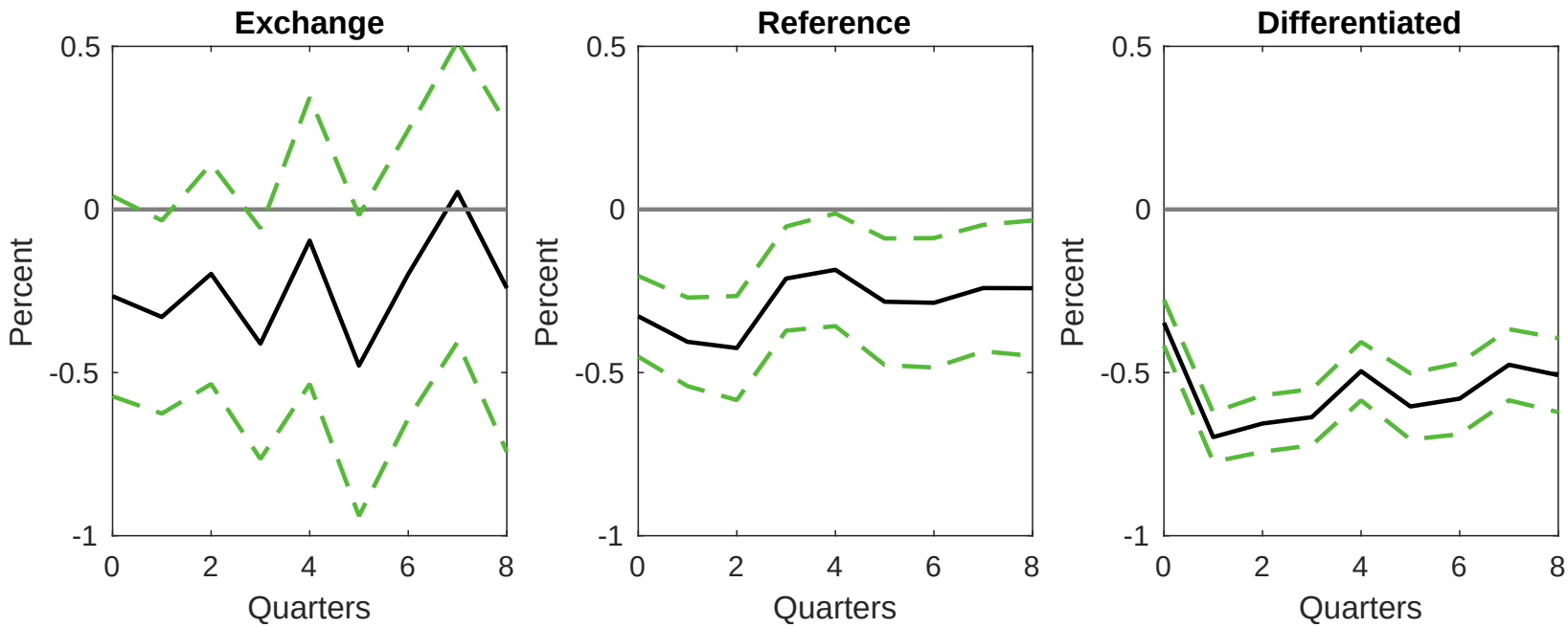

Figure: Impulse responses to a 1% exchange rate appreciation by pricing type

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Other types of heterogeneity

- Other testable hypotheses from this model and related models
- Duration of prices
- Related-party trade
- Imported intermediates
- Fixed capital
- Durable/non-durable goods
- No evidence that these mechanisms are essential in reducing the response
- Evidence of asymmetric response, especially with imports

Conclusion

- Use sector-level data to test trade response of exchange rates compared to models which can accurately match pass through and other price setting characteristics
- Average trade responses are very low in the data.
  - Despite getting pass-through and price stickiness right, model still implies a much stronger response.
  - Sticky prices can do better on imports but do worse on exports
- Even if the "true" average elasticity is much lower, the model implies different responses across industries which have little support in the data
- Pricing frictions and strategic complementarities only go so far, and these models are missing some first-order friction.

Model solution, simulation

- Discretized state space for prices (aggregate and firm), exchange rate, and idiosyncratic productivity.
  1. Guess values μ
  2. Derive the value function for home and foreign firms via iteration
  3. Simulate 9000 home and 1000 foreign firms to obtain a sectoral price index P, and estimate $\hat{\mu}$.
  4. If $\hat{\mu}$ are close to the previous guess, continue, otherwise update the guess and go back to step 2
  5. Simulate countries for 376 months, dropping the first 100 (leaving 23 years).
  6. Aggregate the data to quarterly sector-level series, and perform the same estimation procedure as for the data.

Table: Pooled regression results

	Imports			*Exports*		
	Data		Model	Data		Model
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln \text{exrate}_0$	-0.097***	-0.083***	0.525***	-0.332***	-0.167***	-2.873***
	(0.032)	(0.015)	(0.026)	(0.029)	(0.014)	(0.072)
$\sum_{k=0}^{4} \Delta \ln \text{exrate}_k$	0.05	-0.034	0.962***	-0.437***	-0.237***	-2.071***
	(0.042)	(0.025)	(0.04)	(0.036)	(0.025)	(0.052)
$\sum_{k=0}^{8} \Delta \ln \text{exrate}_k$	0.08	0.046	0.968***	-0.464***	-0.222***	-2.036***
	(0.051)	(0.033)	(0.037)	(0.042)	(0.032)	(0.047)
$\Delta \ln \text{nom GDP}_0$	0.073	0.084***		0.237***	0.149***	
	(0.062)	(0.03)		(0.056)	(0.028)	
$\sum_{k=0}^{4} \Delta \ln \text{nom GDP}_k$	-0.066	-0.086		0.295***	0.233***	
	(0.086)	(0.054)		(0.073)	(0.053)	
$\sum_{k=0}^{8} \Delta \ln \text{nom GDP}_k$	0.06	-0.01		0.295***	0.152***	
	(0.072)	(0.05)		(0.056)	(0.048)	
Observations	1,135,983	904,218	2,158	1,312,096	1,011,717	2,158
R^2	0.13	0.15	0.85	0.11	0.12	0.96

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Industry heterogeneity in price duration

- Average price durations varies substantially across sectors
  - Gopinath and Rigobon report for 85 import sectors and 71 export sectors
  - Duration ranges from 1 month for imported goods like aluminum to 27.8 months for unset diamonds
  - Export durations range from 1 month for wheat to 24.3 months for transformers
- Caveat: average price duration in a menu cost model can vary through many parameters
  - This exercise: generate desired duration by varying menu costs alone
  - Model predicts stronger export responses and weaker import responses for sectors with longer duration

Duration: imports

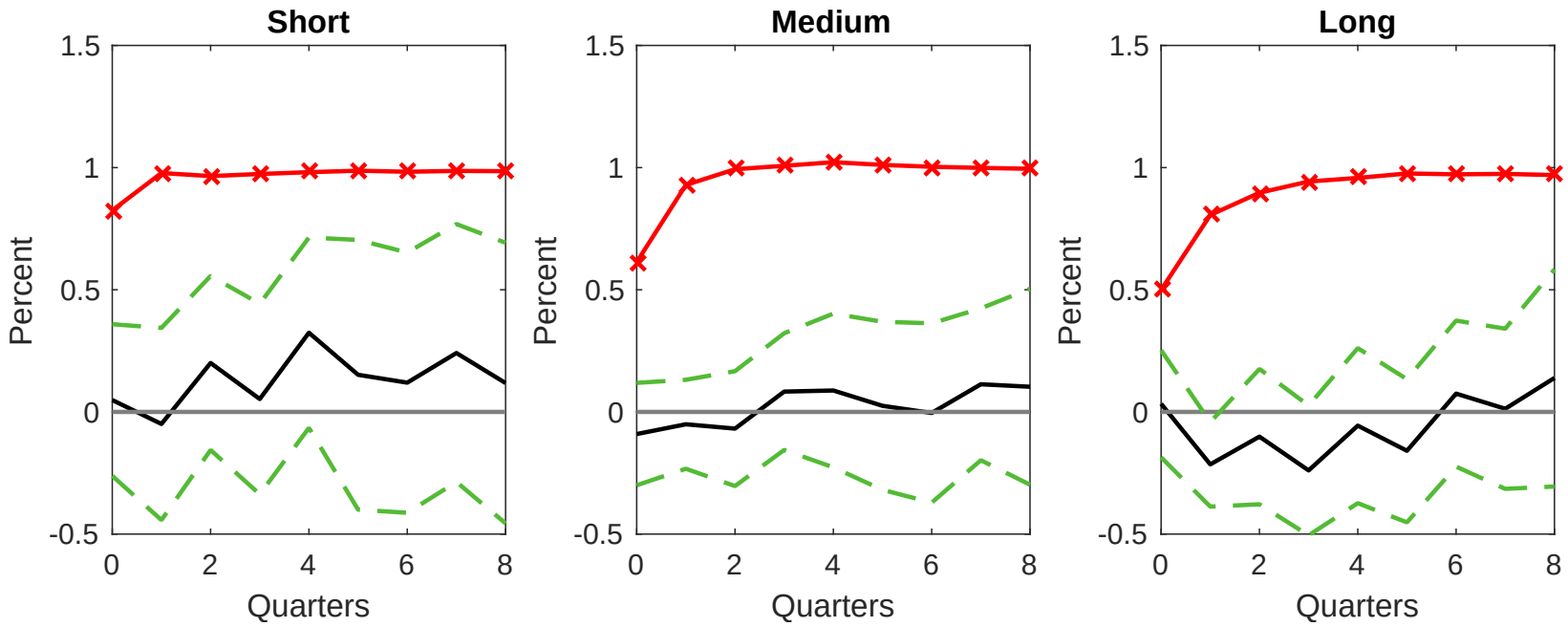

Figure: Impulse responses to a 1% exchange rate appreciation by duration bins (solid: 5, 12, 17 months), and the menu cost model IRF (with markers)

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Duration: exports

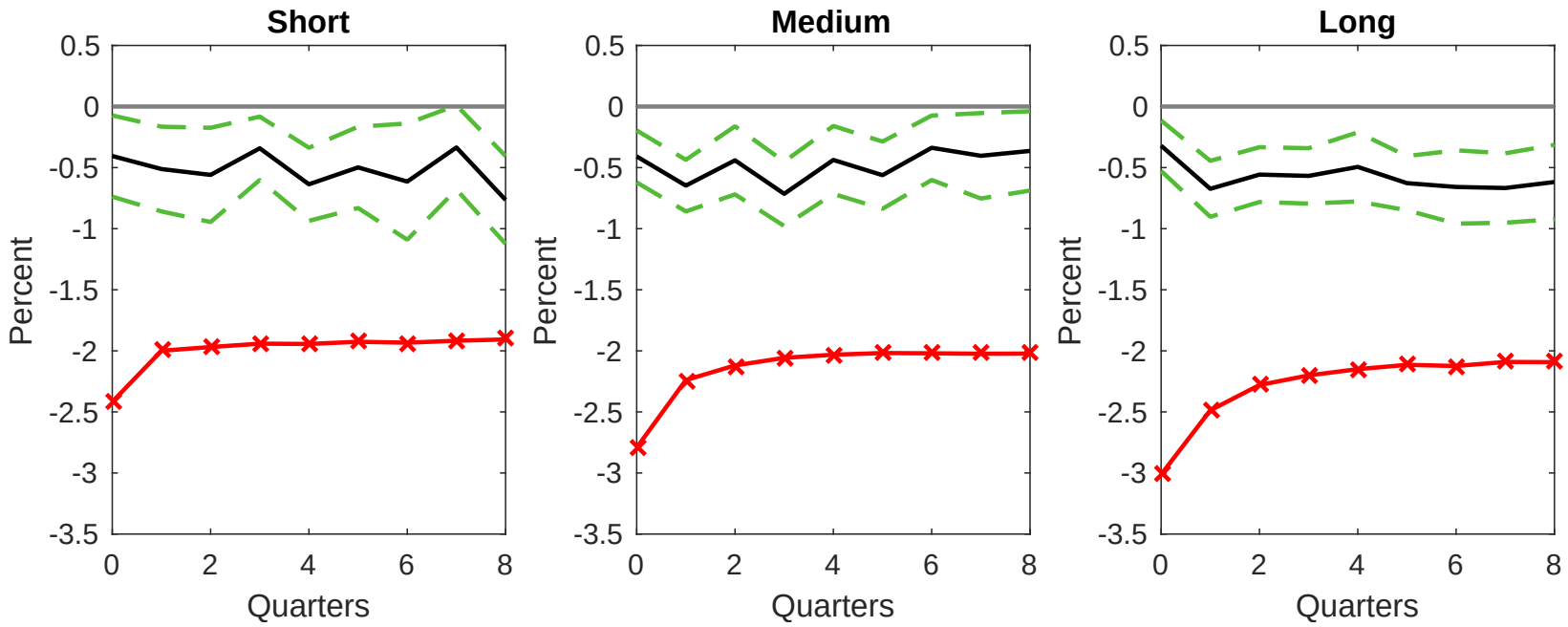

Figure: Impulse responses to a 1% exchange rate appreciation by duration bins (solid: 7, 14, 20 months), and the menu cost model IRF (with markers)

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Related party trade

- For multinationals, idiosyncratic exchange rate movements might be for within-firm trade, especially if the trade is simply of a "round-tripping" form.
- Use (annual) related-party trade from Census to classify NAICS6-country pairs as low, medium, and high related-party trade.

Related party trade: imports

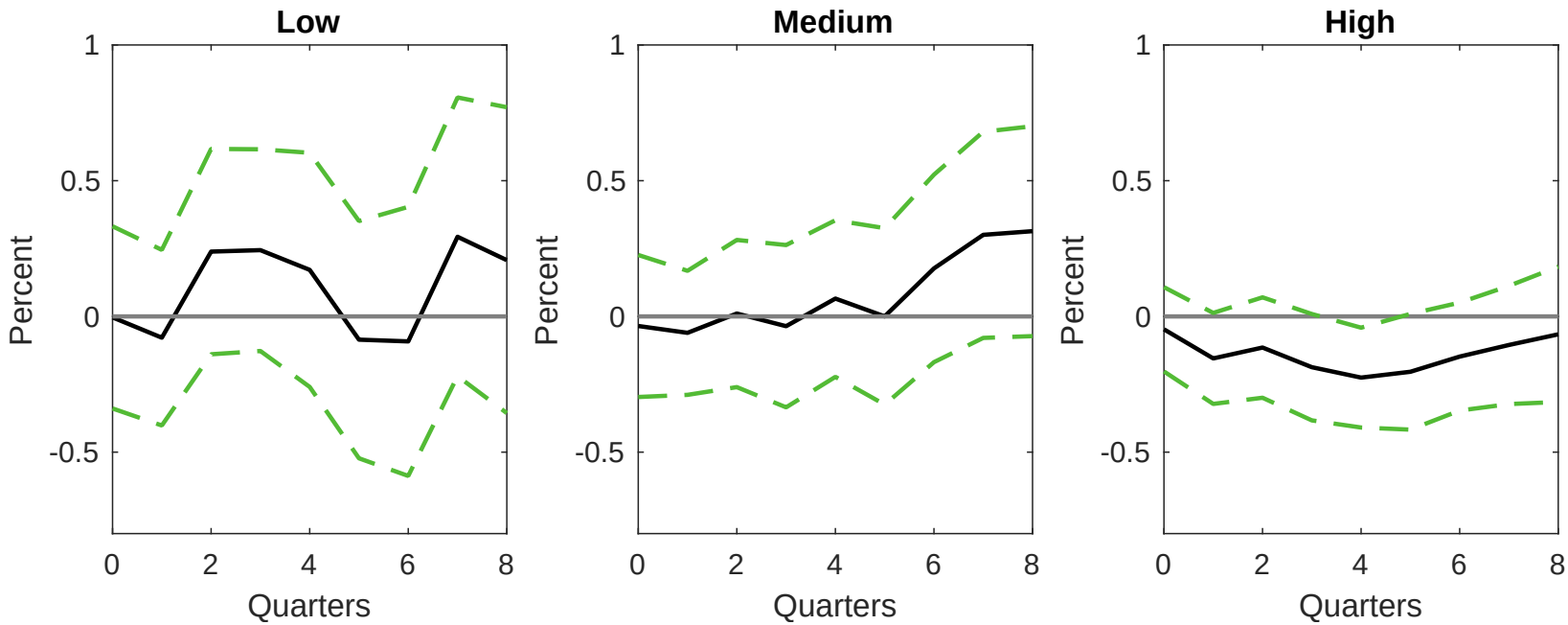

Figure: Impulse responses to a 1% exchange rate appreciation by pricing type

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Related party trade: exports

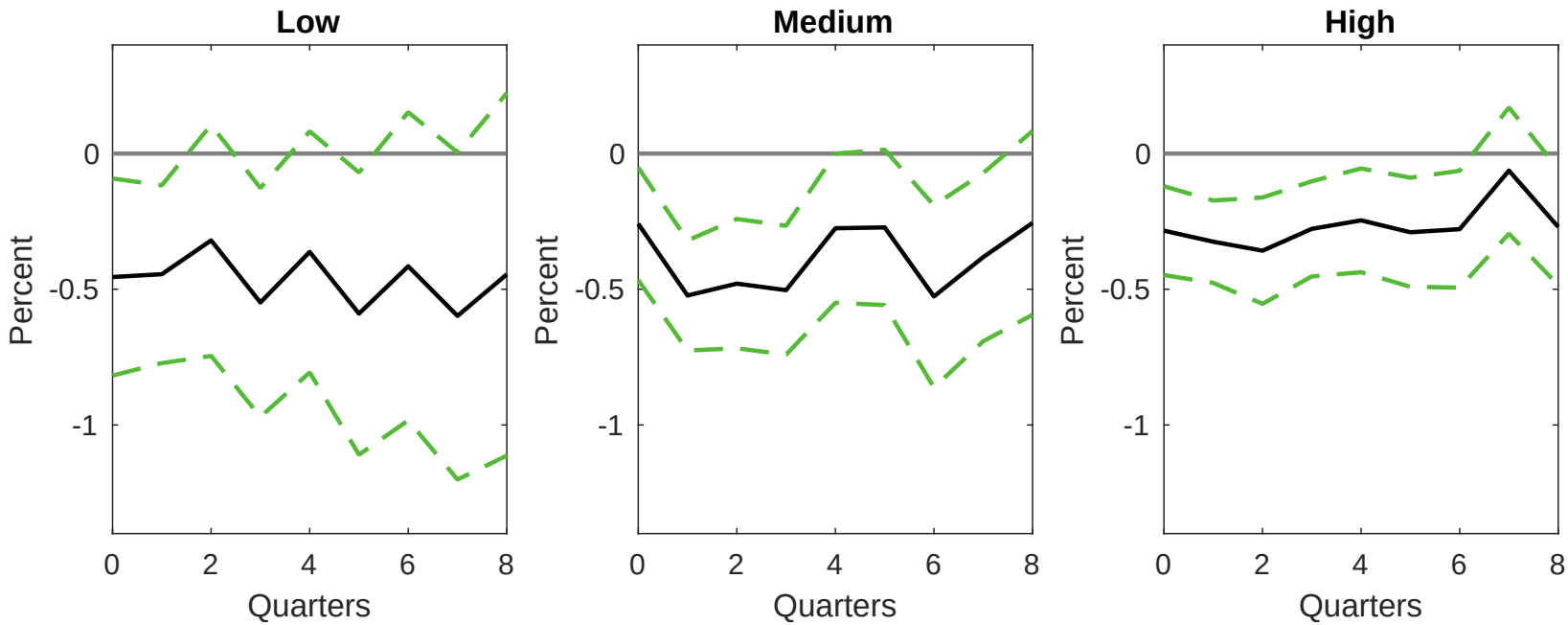

Figure: Impulse responses to a 1% exchange rate appreciation by pricing type

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Comparative static: Imported intermediates

- To the extent costs are denominated in the foreign currency, local currency price response to movements in the exchange rate will be muted.
- Using I-O tables, can directly measure ϕ in the model for 282 (roughly) NAICS6 sectors:

$$1 - \phi = \frac{\text{Imported Intermediates}}{\text{All intermediates} + \text{Employee compensation}}$$

- For the U.S., the average is very low (about 9%), but significant variation across sectors.
- Use the lowest, middle, and highest deciles to maximize variation.

Imported intermediates: exports

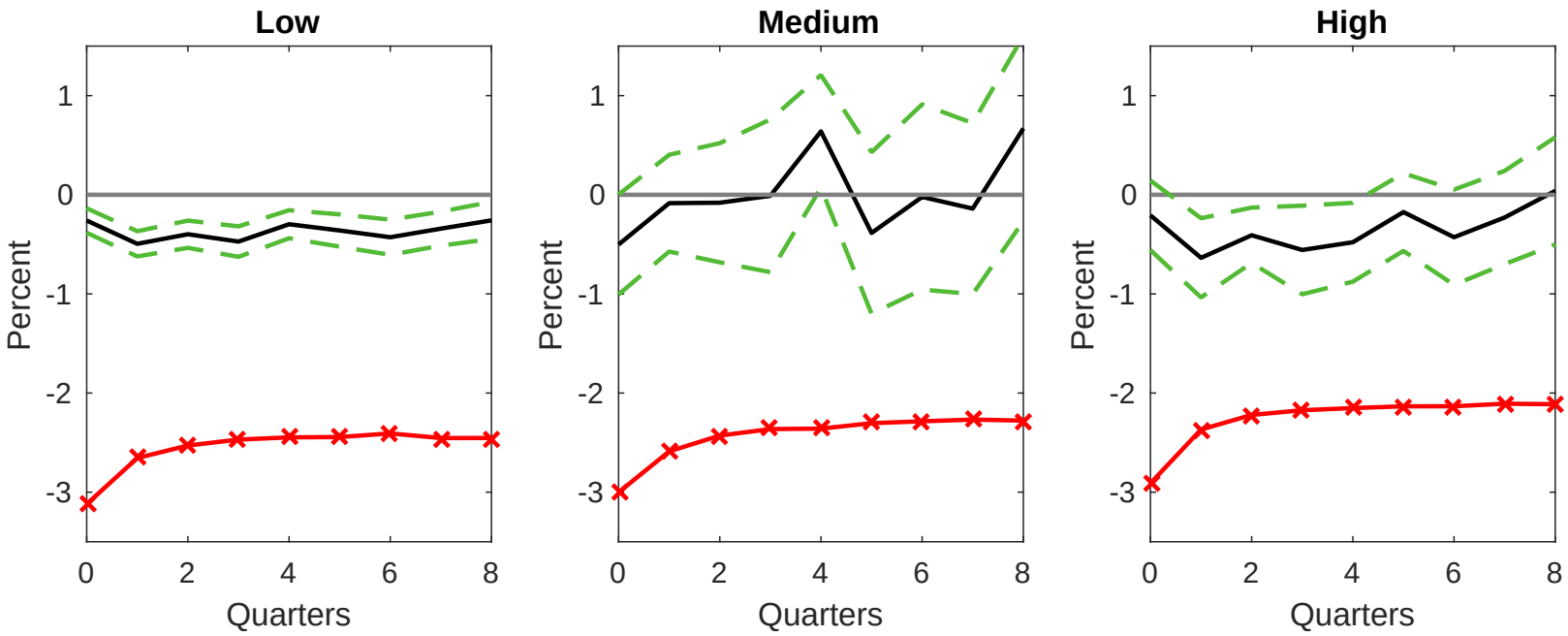

Figure: Impulse responses to a 1% exchange rate appreciation by imported intermediates (2.5%, 7.2%, 20.8%)

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Shipping mode: imports

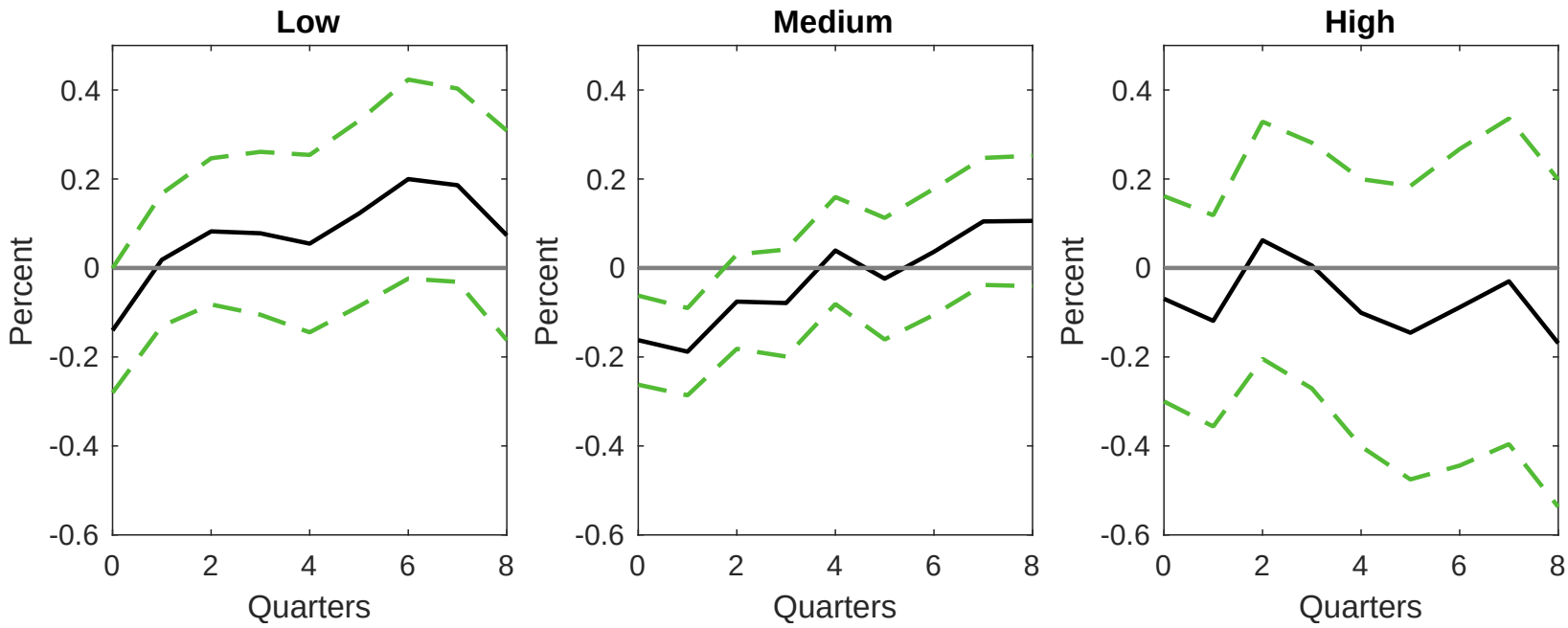

Figure: Impulse responses to a 1% exchange rate appreciation by fraction shipped by vessel (0%, 54%, 99%)

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Shipping mode: exports

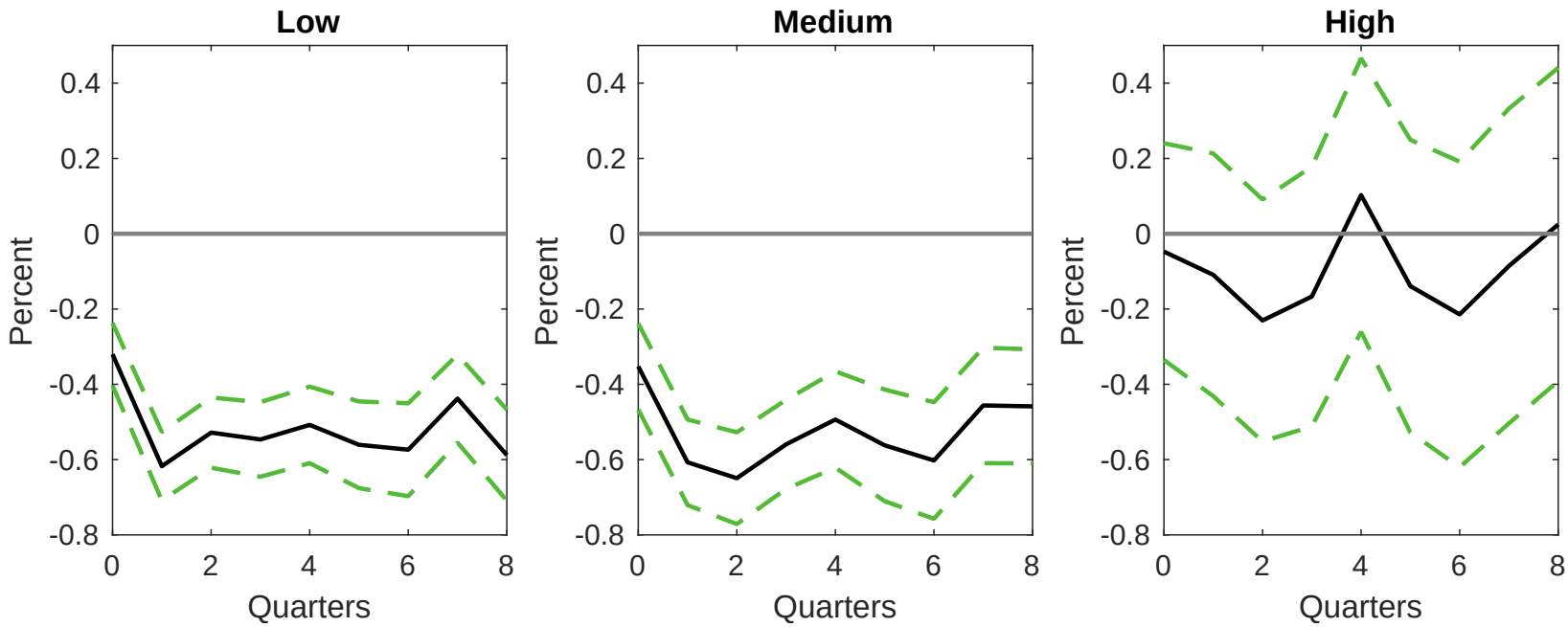

Figure: Impulse responses to a 1% exchange rate appreciation by fraction shipped by vessel (6%, 71%, 100%)

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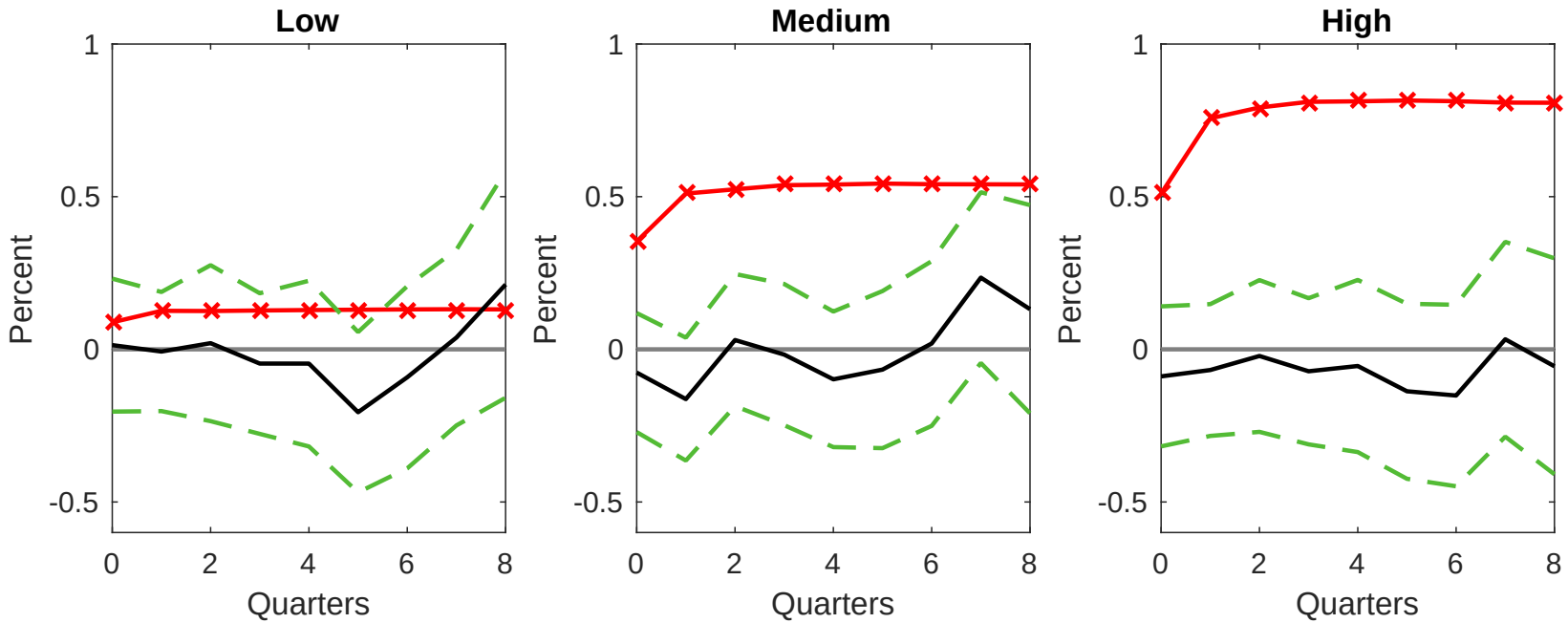
Labor intensity: imports



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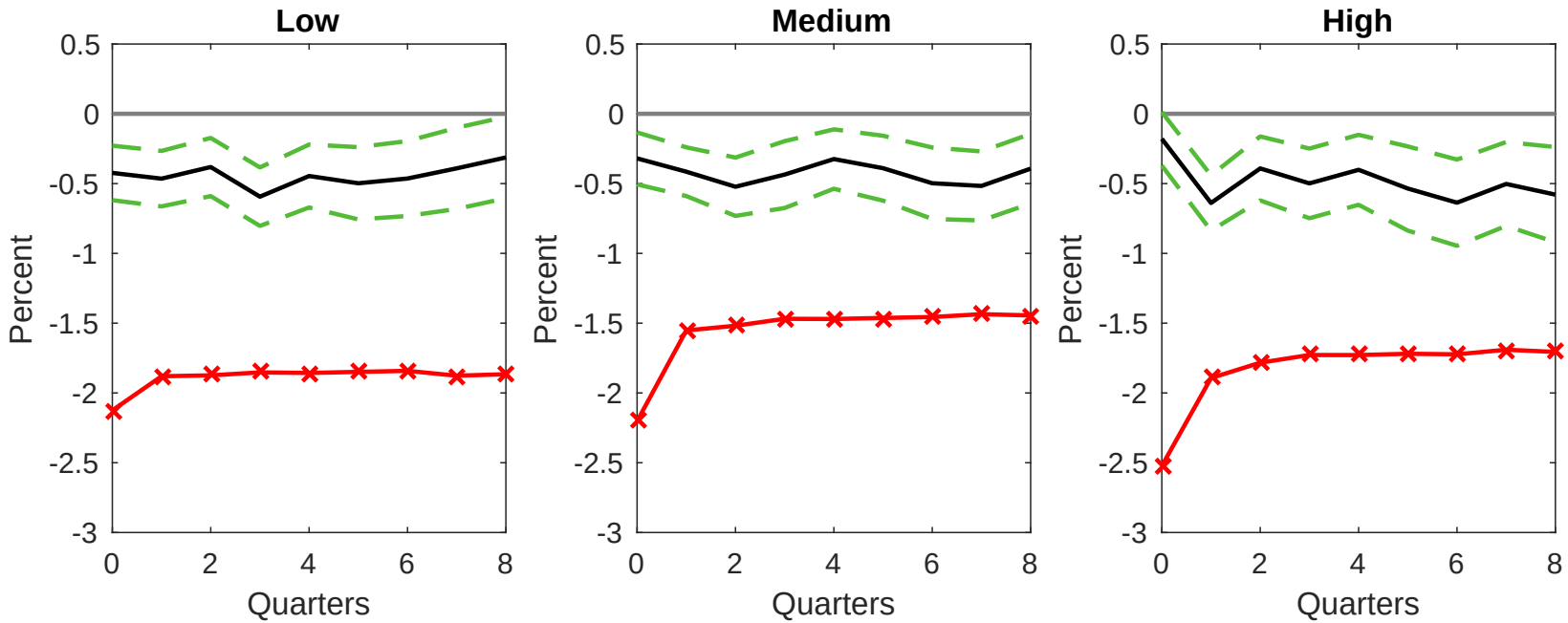
Labor intensity: exports



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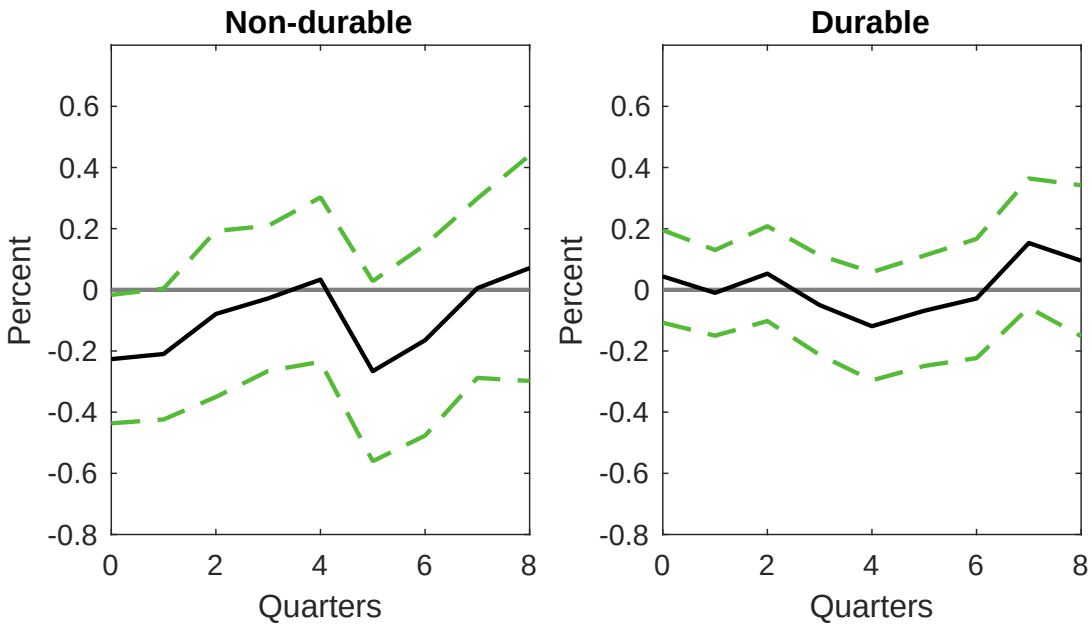
Durable: imports



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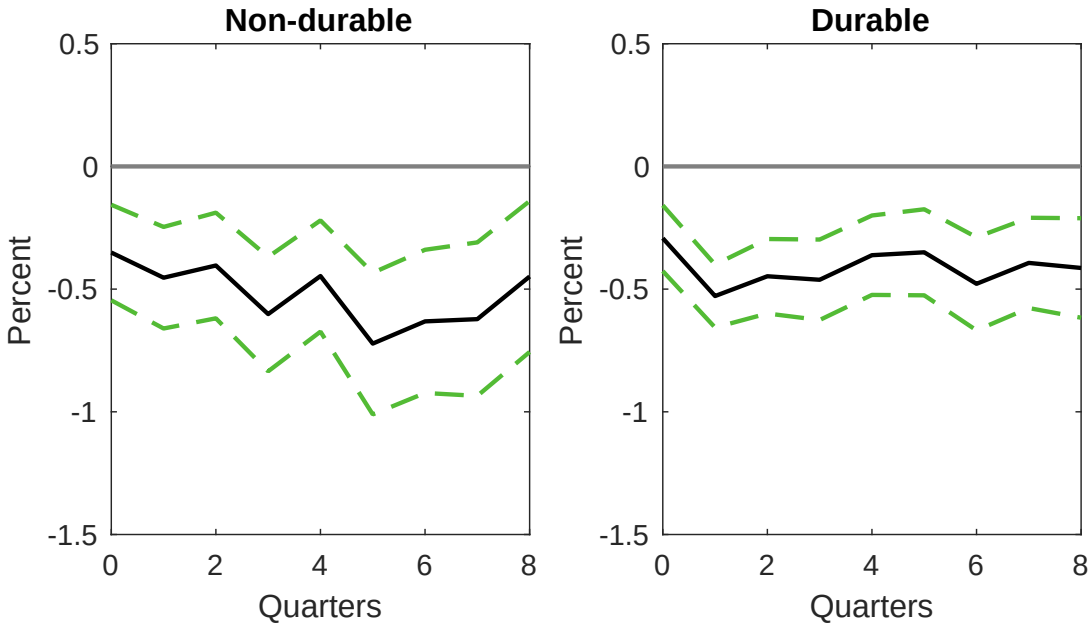
Durable: exports



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Model: Flexible price benchmark

- With flexible prices, firm chooses p to maximize:

$$\max_{p} q(p)(p - c(e, a)).$$

- Price is simply a markup over marginal costs, where $\tilde{\theta}$ is the effective elasticity of substitution

$$p = \frac{\tilde{\theta}}{\tilde{\theta} - 1} c(e, a).$$

- Pass-through of changes in the exchange rate e into prices is:

$$\Psi \equiv \frac{\partial \ln p}{\partial \ln e} = \phi \left[1 + \frac{\tilde{\epsilon}}{\tilde{\theta} - 1} \right]^{-1}.$$

- ϕ is the fraction of costs paid in the exporter's currency.
- Note that $\frac{\partial \Psi}{\partial \tilde{\epsilon}} < 0$ and $\frac{\partial \Psi}{\partial \tilde{\theta}} > 0$.

Model: Flexible price benchmark (continued)

- The elasticity of nominal trade with respect to exchange rates is then:

$$\frac{\partial \ln(pq(p))}{\partial \ln e} = -\Psi(\tilde{\theta} - 1). \tag{1}$$

- In the producer's (exporter's) currency, the response is a unit greater in magnitude:

$$\frac{\partial ln \frac{pq(p)}{e}}{\partial \ln e} = -1 - \Psi(\tilde{\theta} - 1).$$

Average results: exports price versus quantity

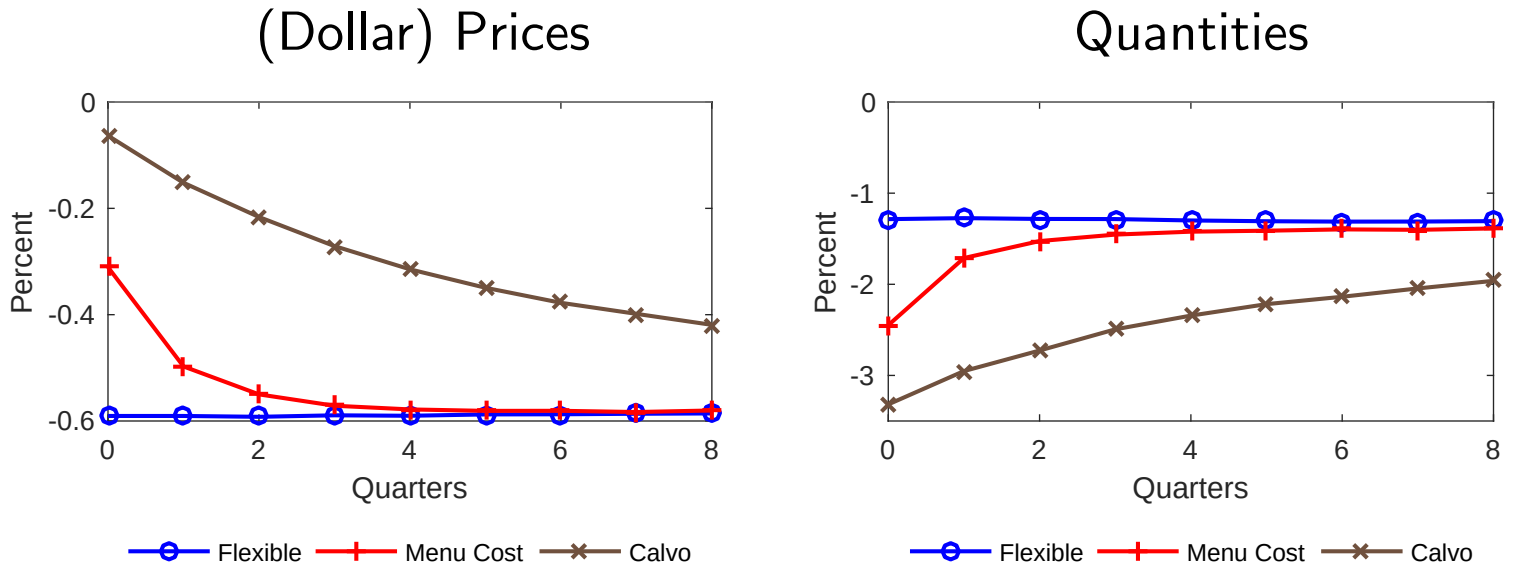


Figure: Impulse responses of export prices and real export quantities to a 1% exchange rate appreciation

Average results: imports price versus quantity

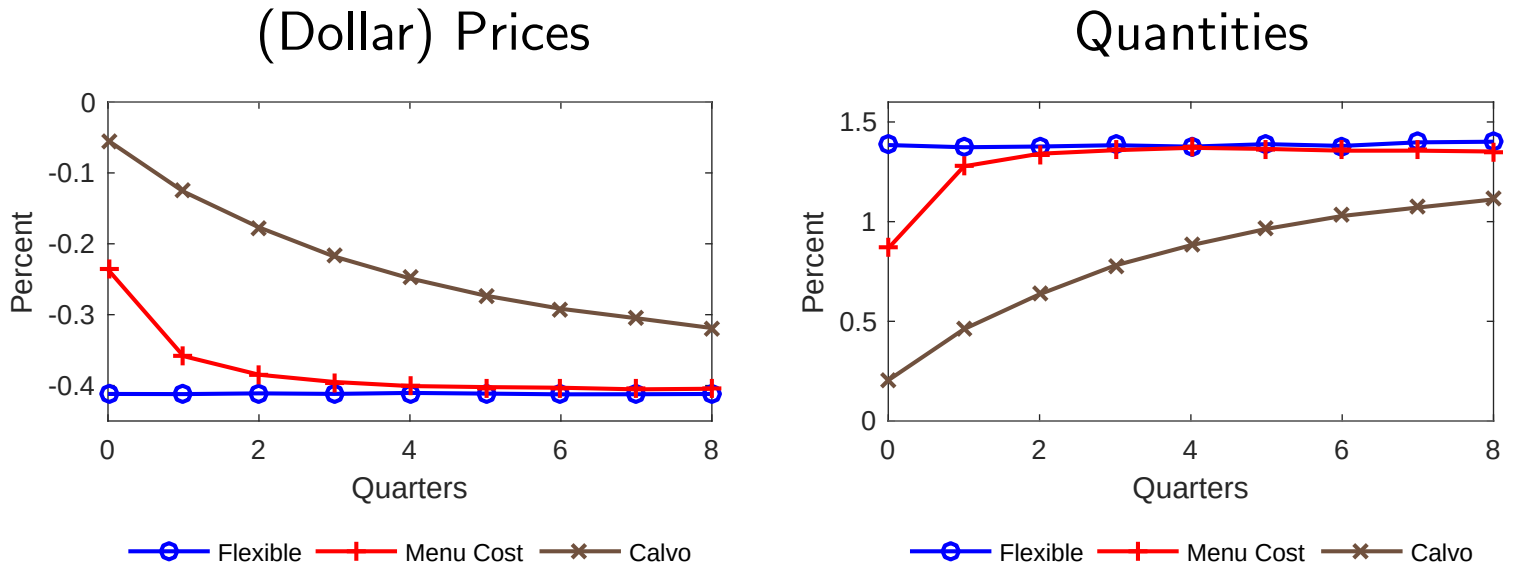


Figure: Impulse responses of import prices and real import quantities to a 1% exchange rate appreciation

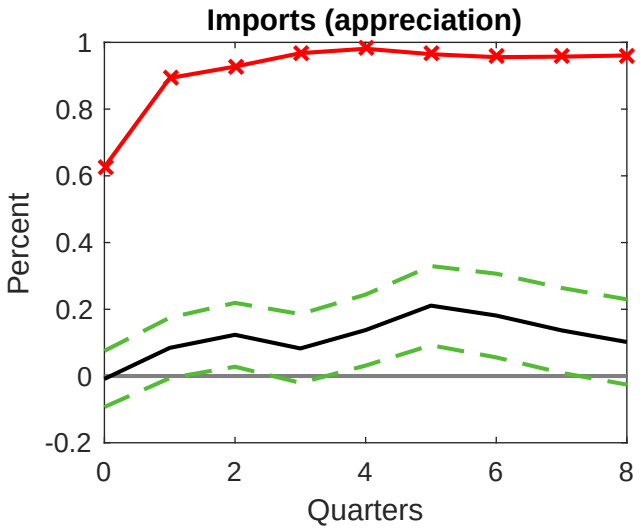
Asymmetric responses

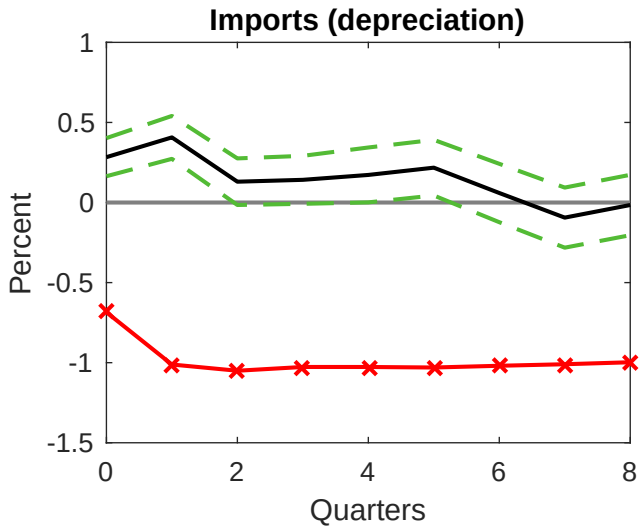
- Trade may respond more to exchange rate changes in one direction than the other.
- Replace the estimating equation with:

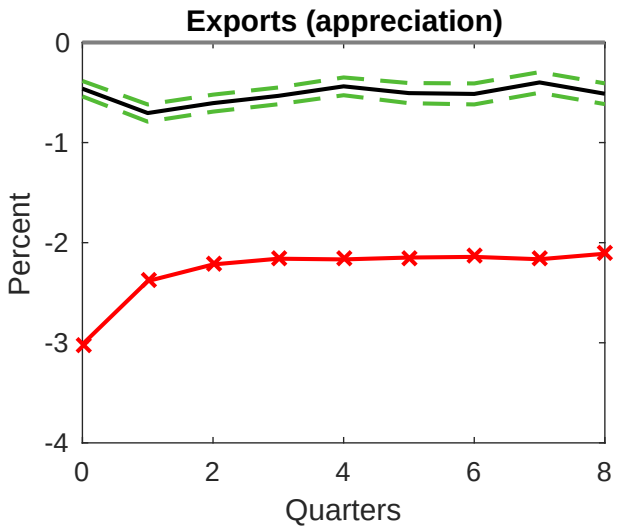
$$\Delta \ln Trade_{ijt} = \beta_0 + \sum_{k=0}^{8} \beta_{1,k} \Delta^{+} \ln e_{jt-k} + \sum_{k=0}^{8} \beta_{2,k} \Delta^{-} \ln e_{jt-k} + \sum_{k=0}^{8} \beta_{3,k} \Delta \ln y_{jt-k} + Z_{ijt} + \epsilon_{ijt}, \quad (2)$$

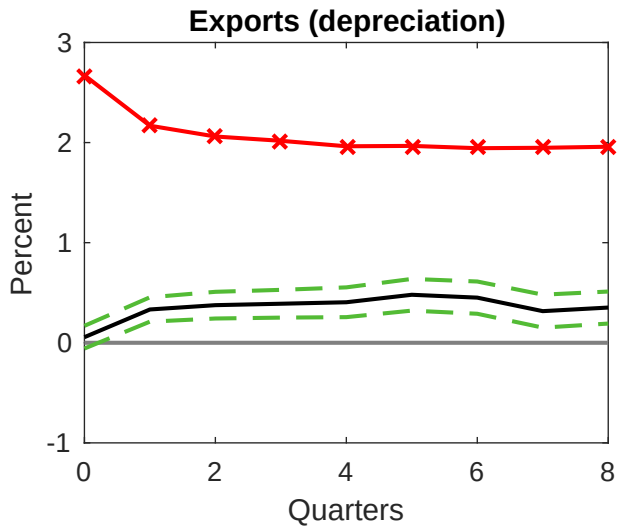
where Δ^{+} has the value of the change in exchange rate if the change is positive, and zero otherwise, with Δ^{-} similarly defined.

Asymmetric responses









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