Volatility and Pass-through

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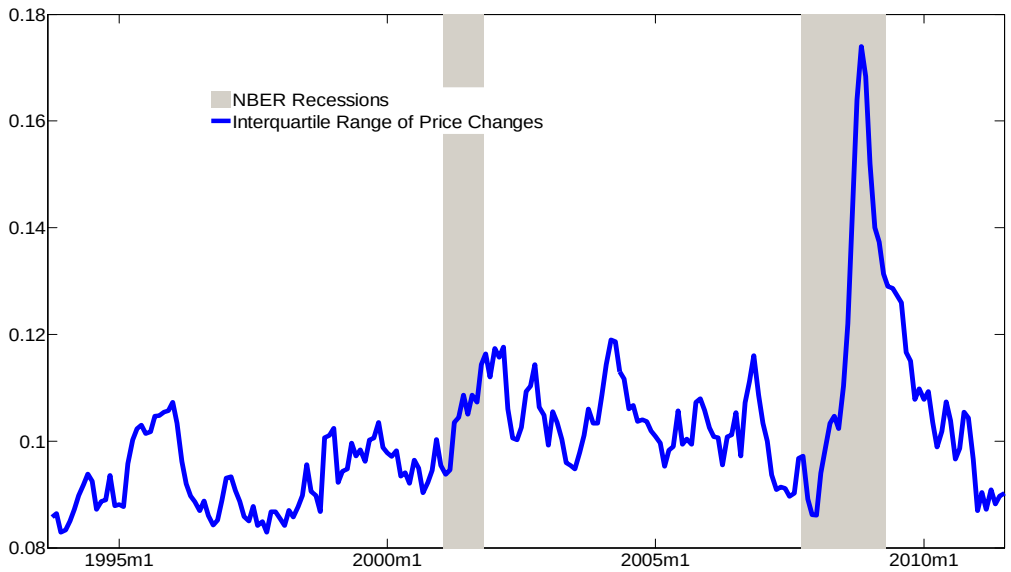
Introduction

We document an robust positive relationship between the dispersion of price changes and exchange rate pass-through:

- Items with high price change dispersion have high pass-through
- Months with high price change dispersion have high pass-through

Pass-through is not a single number: it varies across time

- Average pass-through from 1994-2012 is 15%
- But prices dispersion varies a lot across time and ignoring micro data leads to huge time-varying bias
- Pass-through varies from 8% in 1997 to upwards of 40% in 2008



Empirical evidence that micro heterogeneity matters

- If we want to know the IRF of a macro variable to a shock or change in policy, how much attention needs to be paid to the distribution of agents in the economy?
- Long-standing, largely model driven debate
- What would direct empirical evidence that micro matters for IRF look like?
  - Measure an observed aggregate shock
  - Measure the observed IRF of an aggregate variable
  - Show this observable IRF varies with micro
- We will do exactly this in a particular context where it is feasible
  - The response of import prices to an exchange rate shock depends on the dispersion of price changes that vary across time

Understanding Our Empirical Results

- To now, everything is empirical, but what might explain relationship between price change dispersion and pass-through?
- Imperfect "responsiveness" has been embraced by literature to explain incomplete pass-through
- But if there is heterogeneity, has additional implications
- If some firms are more "responsive" to shocks at some points in time:
  - Should have more disperse price changes
  - Should have higher exchange rate pass-through

Formally Understanding Our Empirical Results

- Quantifying the importance of various channels:
  - Build and formally estimate model of exporting price-setters with heterogeneity affecting price change dispersion and pass-through
  - Cannot explain our empirical results:
    - Heterogeneity in menu costs, calvo frequencies, import intensity, exchange rate volatility
    - Heterogeneity in volatility or "volatility shocks"
  - Can explain our empirical results:
    - Heterogeneity in markup elasticities or other forms of strategic complementarities

Model Implications

- Large literature studying "uncertainty" or "volatility" shocks
- Estimated model says dispersion and pass-through relationship not explained by volatility shocks
- Variable markup/Competition based explanations much more promising

Outline

- Empirical results
- Implications for Time-Varying Pass-Through
- Understand our result
- Quantitative model estimation

Data

- BLS IPP micro data underlying import price indices
- Product data from survey
  - Record various transaction details for particular items including price and country of origin
  - Over 10,000 price observations per month
  - Wide range of imports
- IMF exchange rate data
- Data on US and foreign CPI and US GDP

Data Continued

- Benchmark results:
  - All countries
  - Dollar priced non-petroleum goods
  - Bilateral exchange rates
  - Market based transactions
  - Country-sector fixed effects

Benchmark Pass-through Measure

- How much of cumulated exchange rate movements are passed-through when an item adjusts?
- Let $\Delta_c e_{i,t}$ be the cumulative change in exchange rate since last price adjustment

$$\Delta p_{i,t} = \beta \Delta_c e_{i,t} + Z'_{i,t}\gamma + \epsilon_{i,t}$$

Average medium-run pass-through				
β	$se(\beta)$	t-stat	N_{obs}	R^2
0.144	0.014	10.17	95284	0.067

Measuring Price Change Dispersion

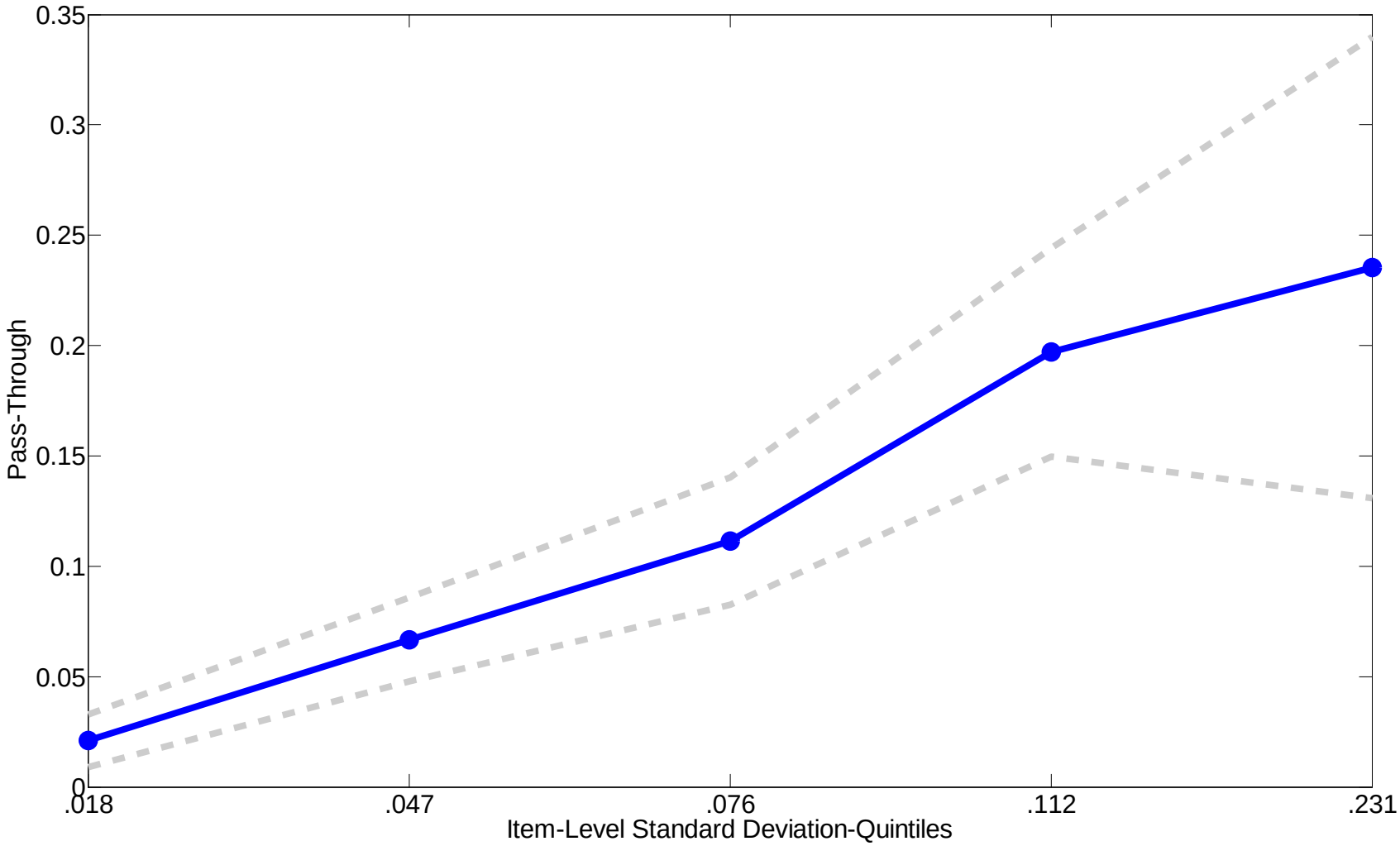
- Want to test if there is a relationship between price change dispersion and pass-through
- Measuring dispersion in the data:
  - Item-level dispersion:
  - Fix item j calculate dispersion of all that item's price changes across time:
  - $DI_j = disp(\Delta p_{i,t} | i = j)$
  - Month-level dispersion:
  - Fix month k, calculate dispersion across the price changes of all items in that month:
  - $DM_k = disp(\Delta p_{i,t} | t = k)$

Item-Level Dispersion and Pass-through

- Let $DI_i = std(\Delta p_i)$ be the standard deviation of item i's price changes (conditional on adjusting)
- Split sample into quintiles by XSD and within each quintile, regress

$$\Delta p_{i,t} = \beta^j \Delta_c e_{i,t} + Z'_{i,t}\gamma + \epsilon_{i,t}$$

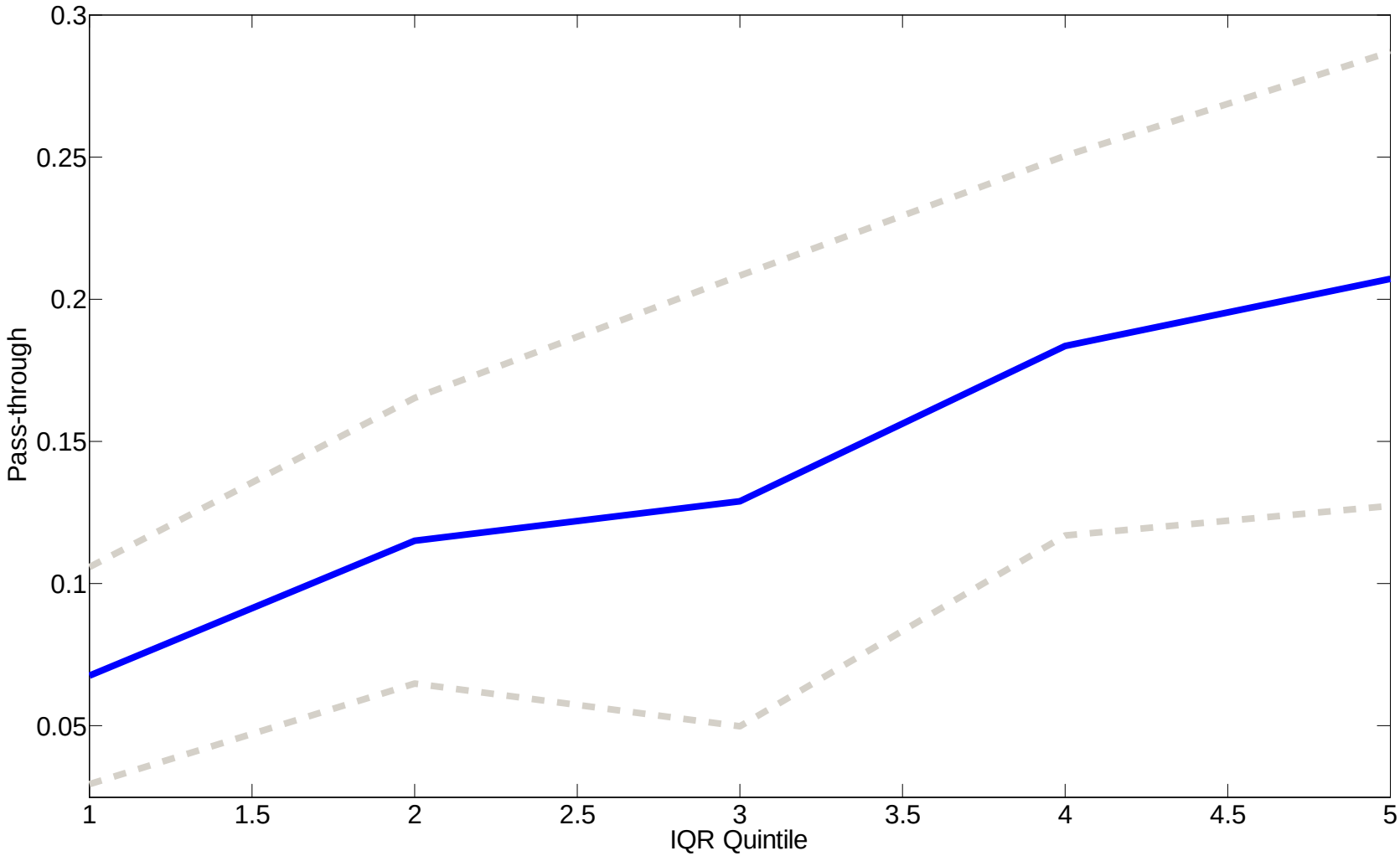
Item-Level Dispersion and Pass-Through



Month-Level Dispersion

- Same relationship in time-series using month-level dispersion?
- For each month, calculate IQR of price changes across items
- Divide time-series quintiles by IQR:

Month-Level Dispersion and Pass-Through



More Formal Test for Significance

- Month-level dispersion standard errors somewhat larger
- But straightforward to do formal test for increasing relationship
- Divide time-series into high and low dispersion months
- Run the regression:

$$\Delta p_{i,t} = \left[\beta^{high}\Delta_c e_{i,t} + Z'_{i,t}\gamma^{high}\right] I_t^{high} + \left[\beta^{low}\Delta_c e_{i,t} + Z'_{i,t}\gamma^{low}\right] I_t^{low} + \epsilon_{i,t}$$

where I_t^{high} and I_t^{low} are indicators for high and low dispersion.

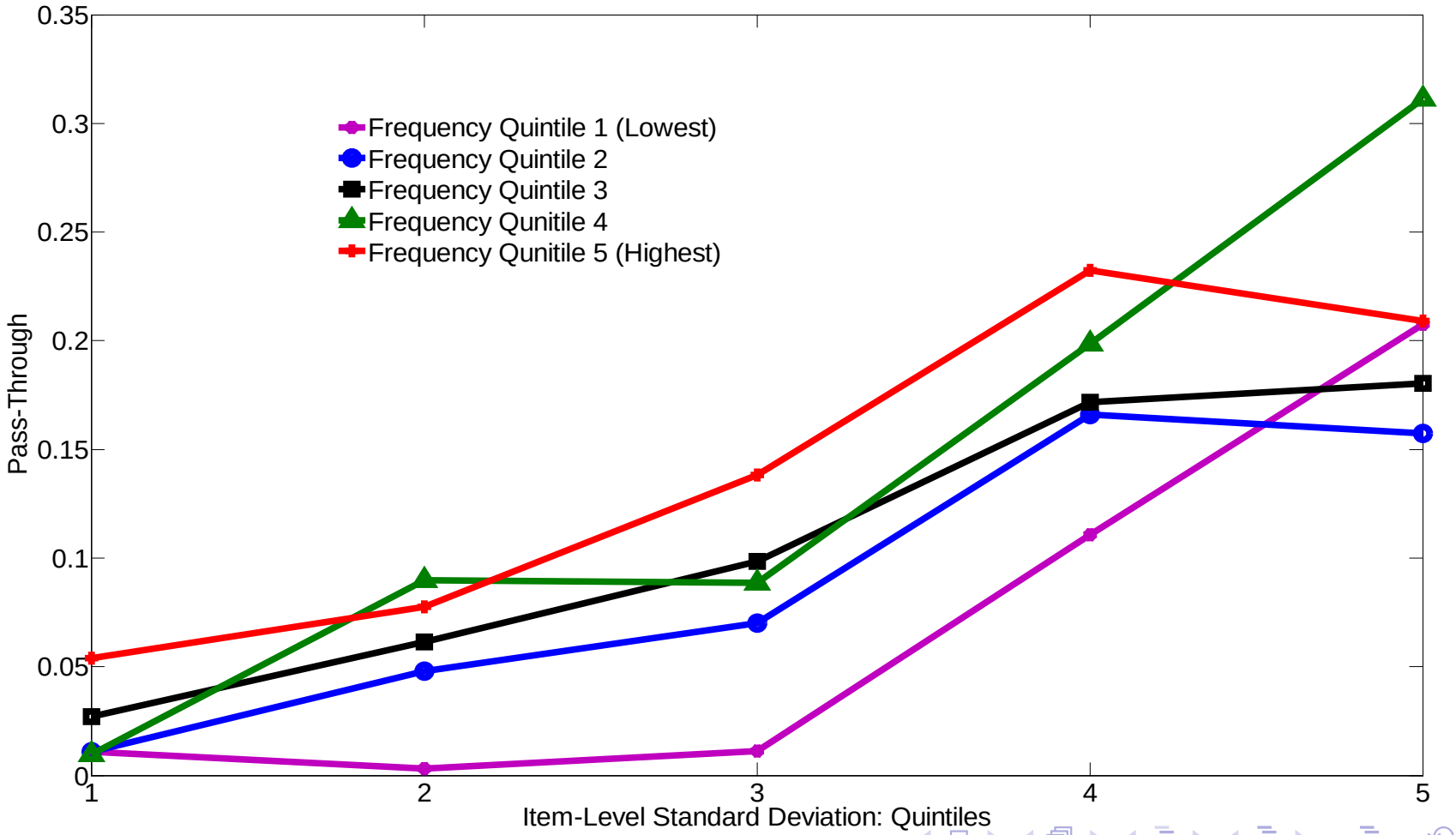
Formal Test for Month-Level Dispersion PT Relationship

- Split time-series in thirds by different dispersion measures:

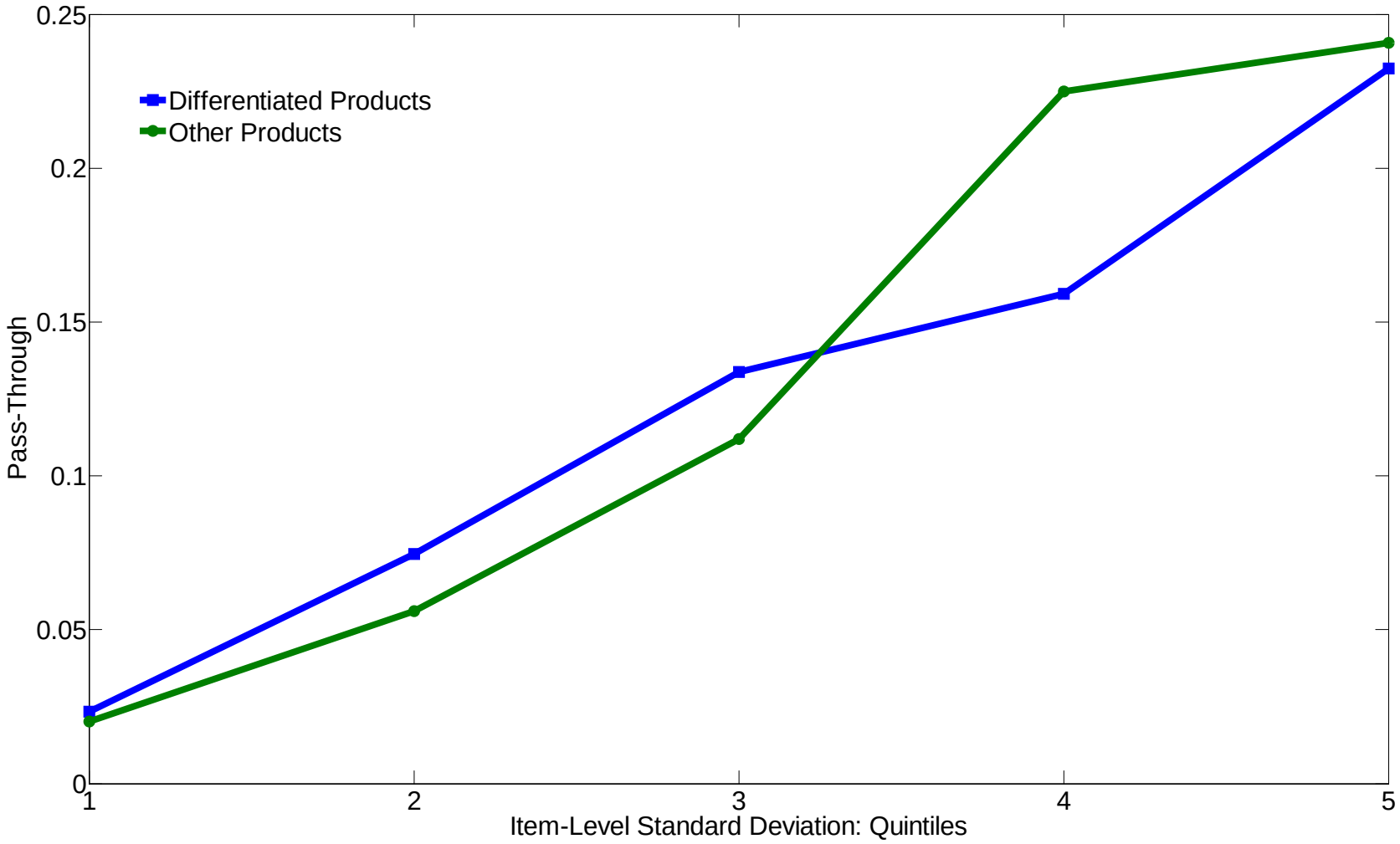
Split	β^{high}	β^{low}	$\beta^{high} - \beta^{low}$	t-stat	n	R^2
IQR	0.21	0.08	0.12	4.35	62395	0.09
XSD	0.17	0.08	0.10	3.89	63095	0.09
Bloom	0.26	0.06	0.20	6.33	64204	0.08

Dispersion or Frequency?

- Run regressions split by *DI* and *freq*



Product type



Robustness: Just the 2008 Recession?

- Lots of things might be special about 2008 Recession
  - Big common shock might increase pass-through
  - Lots of uncertainty might increase dispersion
- Is our result just driven by this outlier?
  - If all driven by one period, maybe just a coincidence
- No: All results go through Pre 2008
  - There is a strong link in cross-section and time-series between dispersion and pass-through over whole sample

Robustness and Additional Controls

- To be less boring, just showed binned regressions. Can rerun all results using interactions with continuous dispersion measures
  - Can then control for other things
  - Run results controlling for item-frequency, aggregate frequency, product substitution, time-trends, seasonality, business cycle measures
  - All results go through
- Have rerun everything for alternative sample selection and exchange rate measures:
  - OECD and various individual countries instead of all-countries
  - Differentiated/Manufactured items instead of all items
  - Trade weighted exchange rates
  - Separately for exchange rate increases and decreases

▸ Various Additional Results

Section 2

Interpretting Our Estimates: Implications for Pass-Through Across Time

What Does Pass-Through Look Like Across Time?

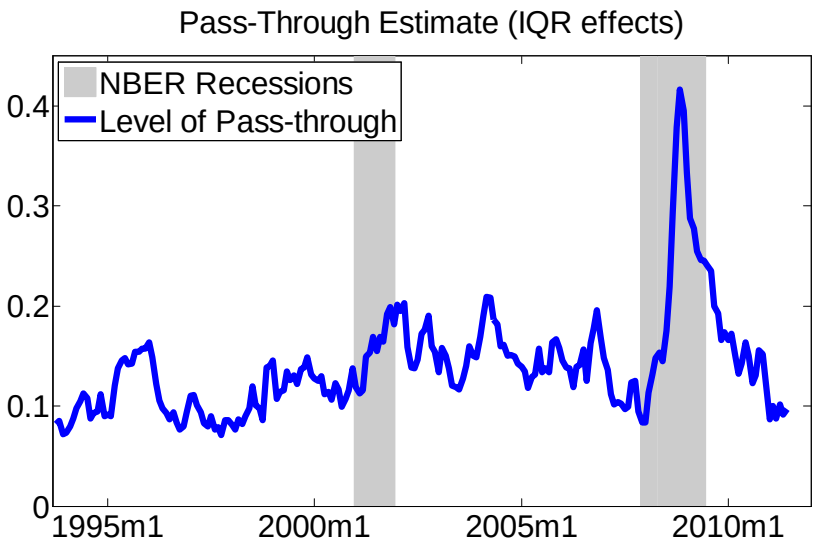
- First, use our empirical specification to back out implied PT across time under alternative parametric assumptions:
- Assuming MRPT only varies because IQR_t varies

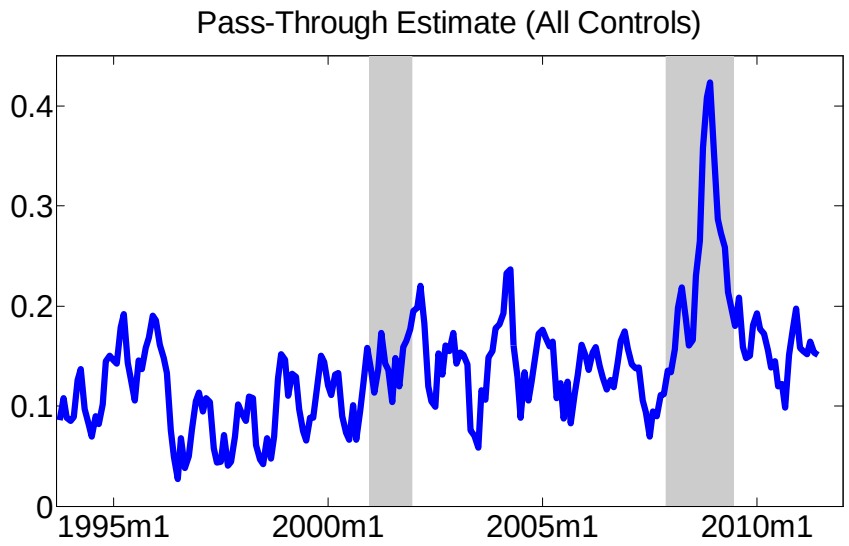
$$\widehat{MRPT}_t = \widehat{\beta}^{ave} + \widehat{\beta}^{IQR} IQR_t$$

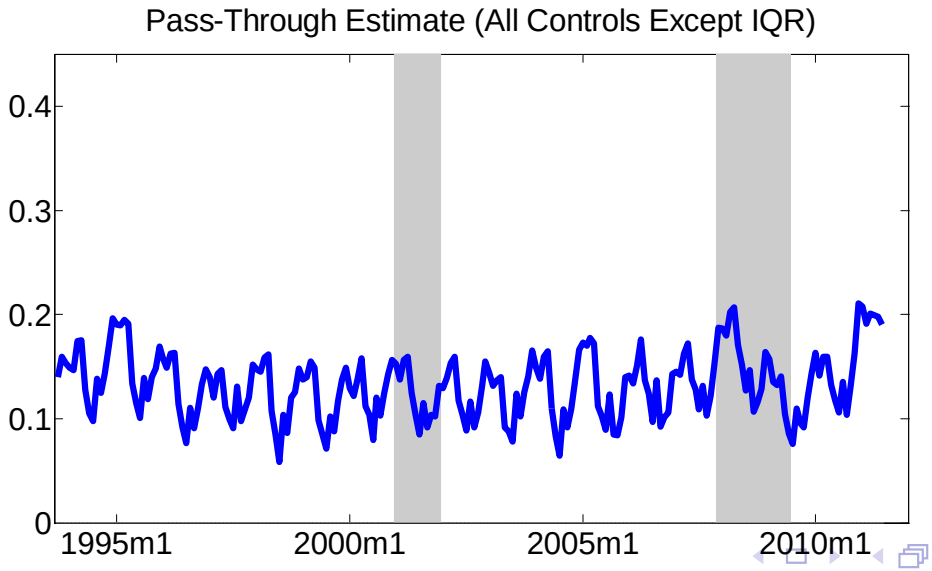
- Assuming MRPT varies for lots of reasons:

$$\begin{aligned}\widehat{MRPT}_t &= \widehat{\beta}^{ave} + \widehat{\beta}^{IQR} IQR_t + \widehat{\beta}^{freq} freq_t + \widehat{\beta}^{subs} subs_t \\ &\quad + \widehat{\beta}^{GDP} GDP_t + \widehat{\beta}_t^{i.Month} i.Month_t\end{aligned}$$

Parametric Results

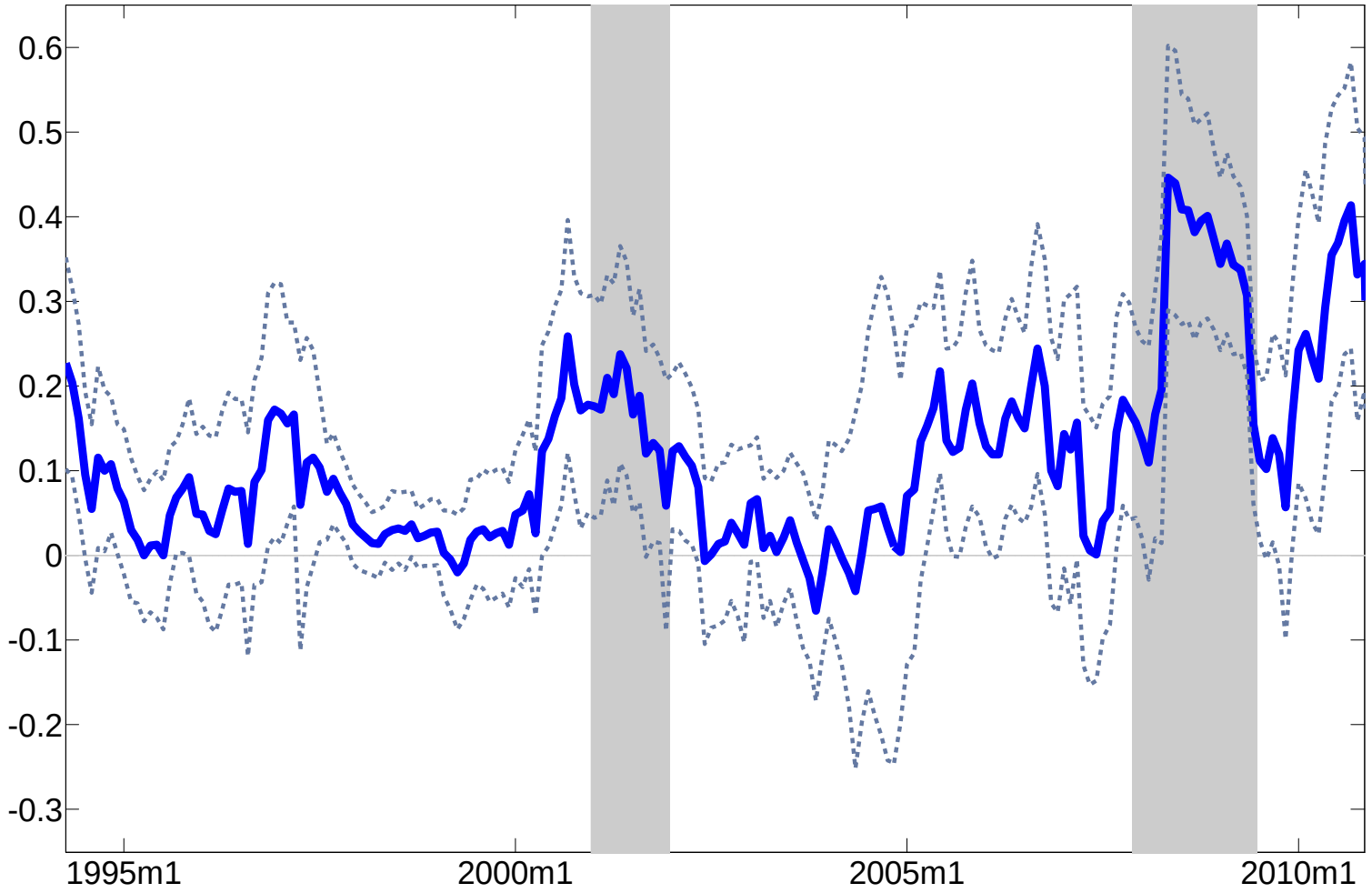






Non-Parametric Results

- Estimate MRPT in rolling 12-month windows



Section 3

Understanding Our Empirical Relationship

Organizing framework: flexible prices

- Optimal price is:

$$p_i = \mu_i + mc_i(e, \eta_i)$$

gross markup (μ_i)
common dollar marginal cost $(mc\,(e))$
idiosyncratic cost $(mc\,(\eta_i))$

- Taking total derivative gives:

$$\Delta p_i = -\Gamma_i(\Delta p_i - \Delta p) + \alpha_i \Delta e + \Delta \eta_i$$

with $\Gamma_{in} \equiv -\frac{\partial \mu_i}{\partial(\Delta p_i - \Delta p)}$ and $\alpha_i \equiv \frac{\partial mc_i}{\partial e}$

Organizing framework: pass-through and variance

- Exchange rate pass-through

$$\frac{\Delta p_i}{\Delta e} = \frac{\alpha_i}{1+\Gamma_i}$$

- Variance of prices

$$var(\Delta p_i) = \left(\frac{\alpha_i}{1+\Gamma_i}\right)^2 var(\Delta e_i) + \left(\frac{1}{1+\Gamma_i}\right)^2 var(\Delta \eta_i)$$

- Theory implies **positive** relationship between PT and variance: factors which increase pass-through ($\alpha \uparrow$ and $\Gamma \downarrow$) also increase variance
- Furthermore, will show α channel doesn't explain our results

Quantitative Models

- As pure empirical statement, micro data on price dispersion is important for predicting pass-through, but...
- What explains the positive relationship between pass-through and price dispersion?
- Estimate a model to assess different possibilities. Heterogeneity in:
  - Menu costs?
  - Volatility?
  - Import intensity?
  - Responsiveness?
  - Exchange rate volatility?
  - "Common-ness" of shocks

Modeling Exchange Rate Pass-through

- Assess Calvo and Menu cost version of model in Gopinath and Itshkhoki (2010)
  - Dynamic price-setting model of import prices
  - Firms set prices to maximize discounted profits
  - Firms face Kimball demand with elasticity σ and super-elasticity ε
    - $C_j = \left[1 - \varepsilon \ln\left(\frac{\sigma}{\sigma-1}\frac{P_j}{P}\right)\right]^{\sigma/\varepsilon}$; $\Gamma = \frac{\varepsilon}{\sigma - 1 + \varepsilon \ln\left(\frac{\sigma x_j}{\sigma-1}\right)}$

Firm Profits

- Firm j's marginal cost depends on idiosyncratic productivity A_j, foreign wages W^* and domestic wages W
  - Firm profits given by $\Pi_j = \left[P_j - \frac{W^{1-\alpha}(W^*)^{\alpha}}{A_j}\right] C_j$
  - Domestic firms have $\alpha = 0$ foreign firms have $\alpha > 0$
- Cost shocks:
  - Real exchange rate $E \equiv \frac{W^*}{W}$ follows a random walk
  - $\log A_j = \rho_A \log A_{j-1} + \sigma_A \epsilon_j$
- Firms face menu costs of price adjustment κ

Calibration

- $\beta = .96^{1/12}$
- Foreign share of sector $= 16.5\%$
- Demand elasticity $= 5$
- Std dev of erate $= .025$
- $\rho_A = 0.85$
- Sensitivity to exchange rates, markup elasticity, menu cost and standard deviation of shocks set to match ave:
  - MRPT, R^2 of MRPT, std dev of price changes, and frequency

What Affects Pass-through?

- $\Delta p_{i,t} = \beta \Delta e + \epsilon$ implies:

$$\widehat{\beta} = \frac{cov\left(\Delta p, \Delta e\right)}{var\left(\Delta e\right)} = \frac{cov\left(\beta \Delta e + \epsilon, \Delta e\right)}{var\left(\Delta e\right)} = \beta + \frac{cov\left(\epsilon, \Delta e\right)}{var\left(\Delta e\right)}$$

- With flex prices:

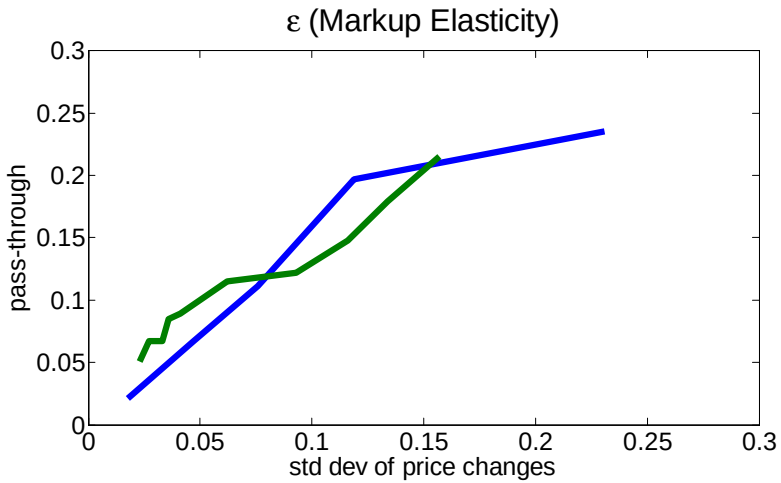
$$\beta = \frac{\alpha}{1 + \Gamma}$$

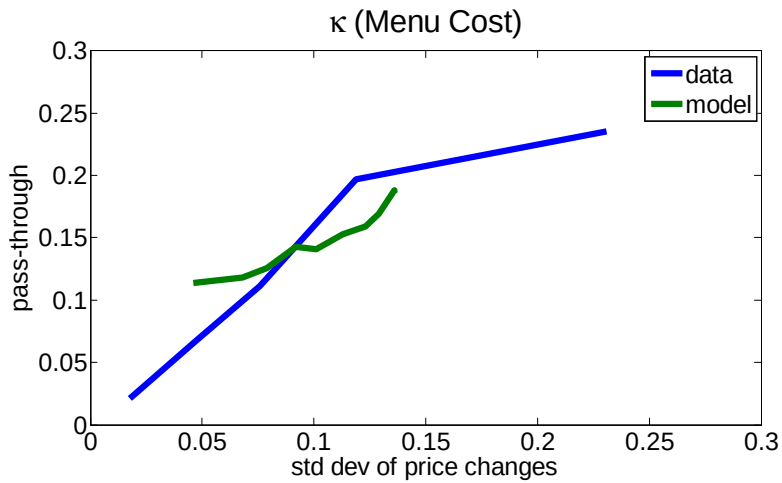
- To increase pass-through
  - Increase α or lower ε (and thus Γ).
  - Increase κ or lower σ_A since increases $cov\left(\epsilon, \Delta e\right)$

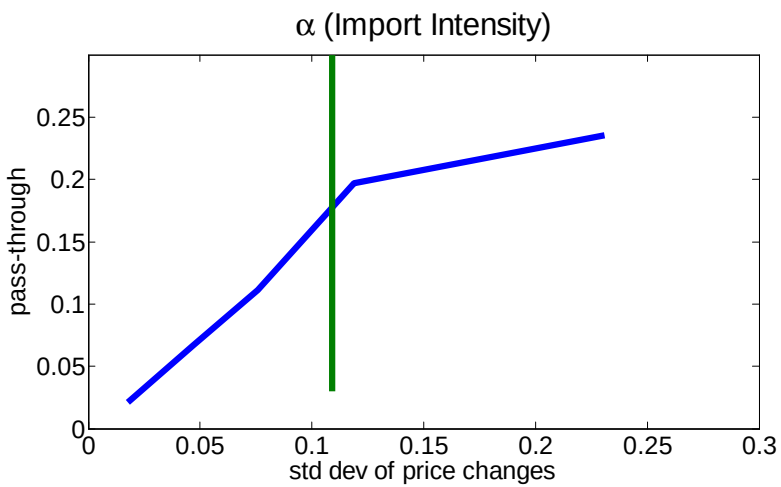
Matching the Cross-Item Dispersion Results

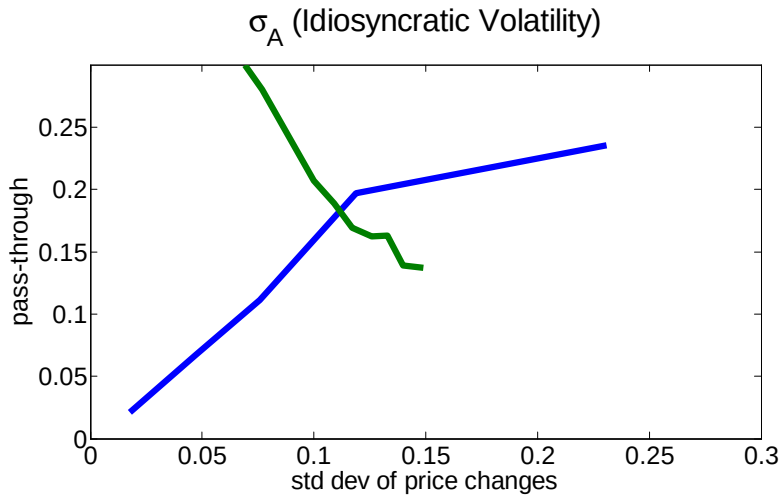
- Holding other parameters at baseline, vary menu costs, volatility and super elasticity and look at effects on MRPT, XSD and freq

Figure: Menu Cost Comparative Statics









Cross-Item dispersion results conclusion

- Variation in either ε or κ can match relationship between XSD and $MRPT$
- Only variation in ε generates (the empirically correct) $corr(freq, XSD) > 0$
- Qualitatively, responsiveness is best able to match cross-sectional facts
- Can we make more formal statements?

Indirect Inference Estimation

- Let firms simultaneously differ in responsiveness, idiosyncratic volatility and menu costs
  - For tractability use binary distribution for each
- Formally estimate importance of each using indirect inference:
  - Match MRPT, XSD and Freq by 5 XSD bins
  - Gives us 15 auxiliary moments and 3 parameters to estimate

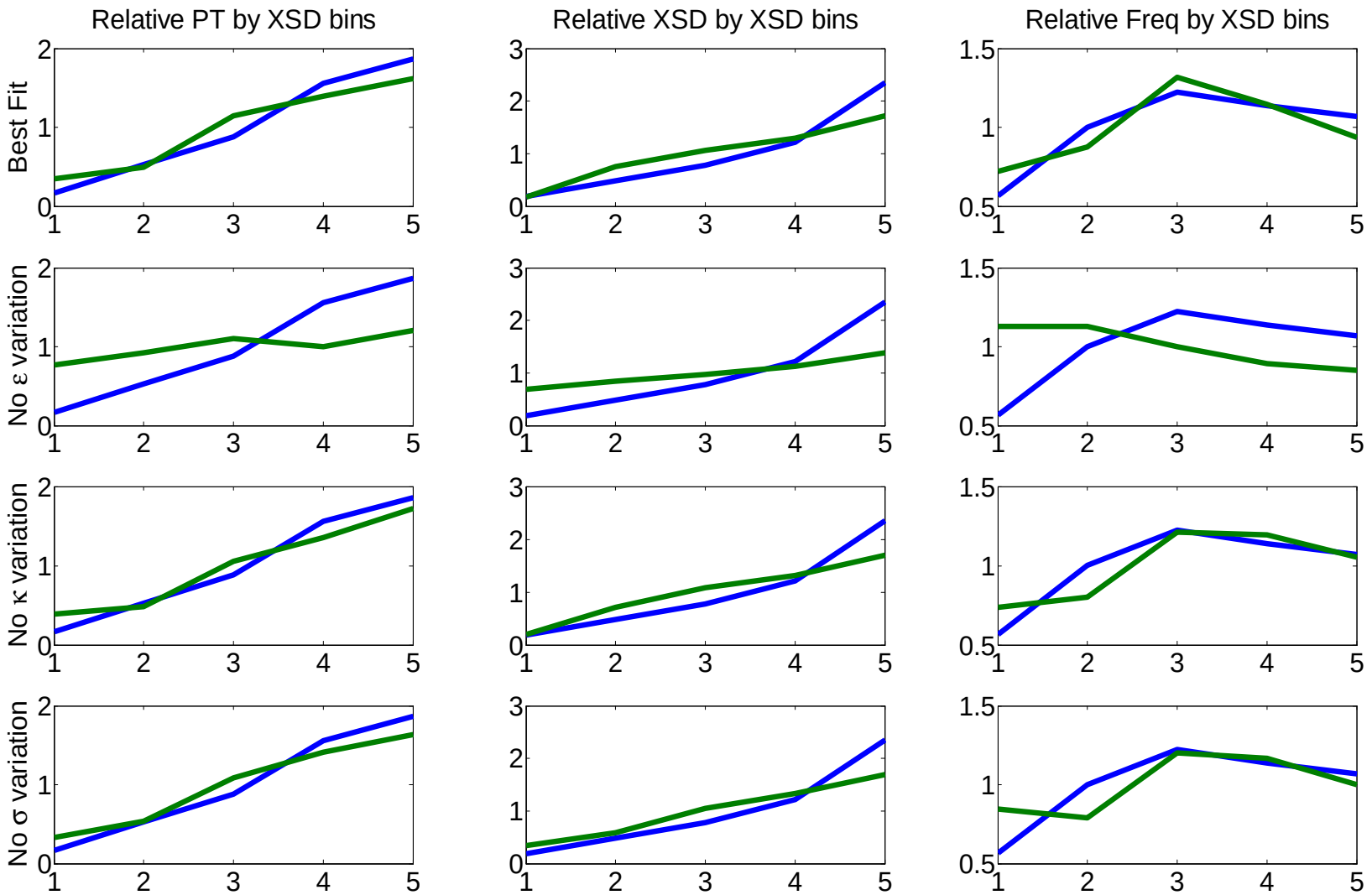
Heterogeneity Estimates

- Estimate how much each parameter varies from mean:

Parameter	Estimated Variation	CI Estimated Variation
ε_Δ	10	(8.14,11.86)
σ_Δ	.03	(.0035,.0565)
κ_Δ	.014	(-.0125,.0405)

- Can also compute goodness of fit
- Formally reject models without ε
- But easier to see all this visually

Estimated Fit to 15 Moments



Aggregate shocks

- In the paper we add aggregate shocks to ε, α, κ, σ_A to try to match time-series regressions
- Don't have strong guidance for modeling the shocks so try different things
- Again find only ε consistent with the data
- Note: what matters is variation in $\Gamma = \frac{\varepsilon}{\sigma - 1}$
  - $=>$ time-variation in elasticity of substitution also works

Aggregate Shocks Continued

- In addition, also explored whether time-varying exchange rate volatility or "commonness" of aggregate shocks can exlain month-level dispersion pass-through relationship
- To make shocks more common, change the fraction of firms whose costs depend on exchange rate
- Neither shock works:
  - Exchange rate volatility
  - Commonality of shocks

Model Implications

- Uncertainty shocks vs time-varying responsiveness
- Existing literature on countercyclical dispersion (e.g. Bloom et al; Vavra; Arellano et al) has implicitly embraced $\sigma_A \uparrow$ as way to explain time series variation in dispersion
- However, variation in Γ also generates time variation in price dispersion
- Our model results suggest only variation in Γ can explain the time-series relationship between MRPT and XSD
  - Our exchange rate shock let's us identify time-varying responsiveness vs. heteroscedastic shocks
  - Model supports time-varying responsiveness: recessions are time of increased competitiveness ($\sigma \uparrow$) which leads to larger price changes and more pass-through

What Drives Responsiveness?

- Our model results tell us in a reduced form sense we should look for things that affect responsiveness
- But lots of mechanisms deliver imperfect responsiveness as reduced form
  - Kimball Demand (This paper)
  - Market share (Atkeson and Burstein 2008)
  - Customer concerns (Paciello, Pozzi and Trachter 2013)
  - Reduced form variation in quadratic adjustment costs
- Hard to disentangle with our data but not hopeless with other data sets
- Our results suggest variation in something like market structure or demand is important for aggregate dynamics

Conclusions

- Empirically, aggregate pass-through moves strongly across time with microeconomic price change dispersion
  - Provides "model-free" evidence that distributions matter for import price IRF to exchange rate shock
- Show that this arises naturally through if there is variation in "responsiveness"
  - Other channels like volatility shocks don't work in estimated model
- Future work:
  - Thinking about what could drive "responsiveness" shocks
  - Thinking about ways to apply empirical strategy to alternative environments

A Mechanical Relationship?

- Flex price benchmark:

$$\begin{aligned} \Delta p_{i,t} &= \beta^j \Delta e_{i,t} + \epsilon_{i,t} \\ &\Rightarrow \\ var\left(\Delta p_{i,t}\right) &= \left(\beta^j\right)^2 var\left(\Delta e_{i,t}\right) + var\left(\epsilon_{i,t}\right) \end{aligned}$$

- What if only β (e.g. import intensity) varies across firms?
  - Can run this experiment and show it explains <0.1% of our results (see paper)
  - Will show also in quantitative model

Section 5

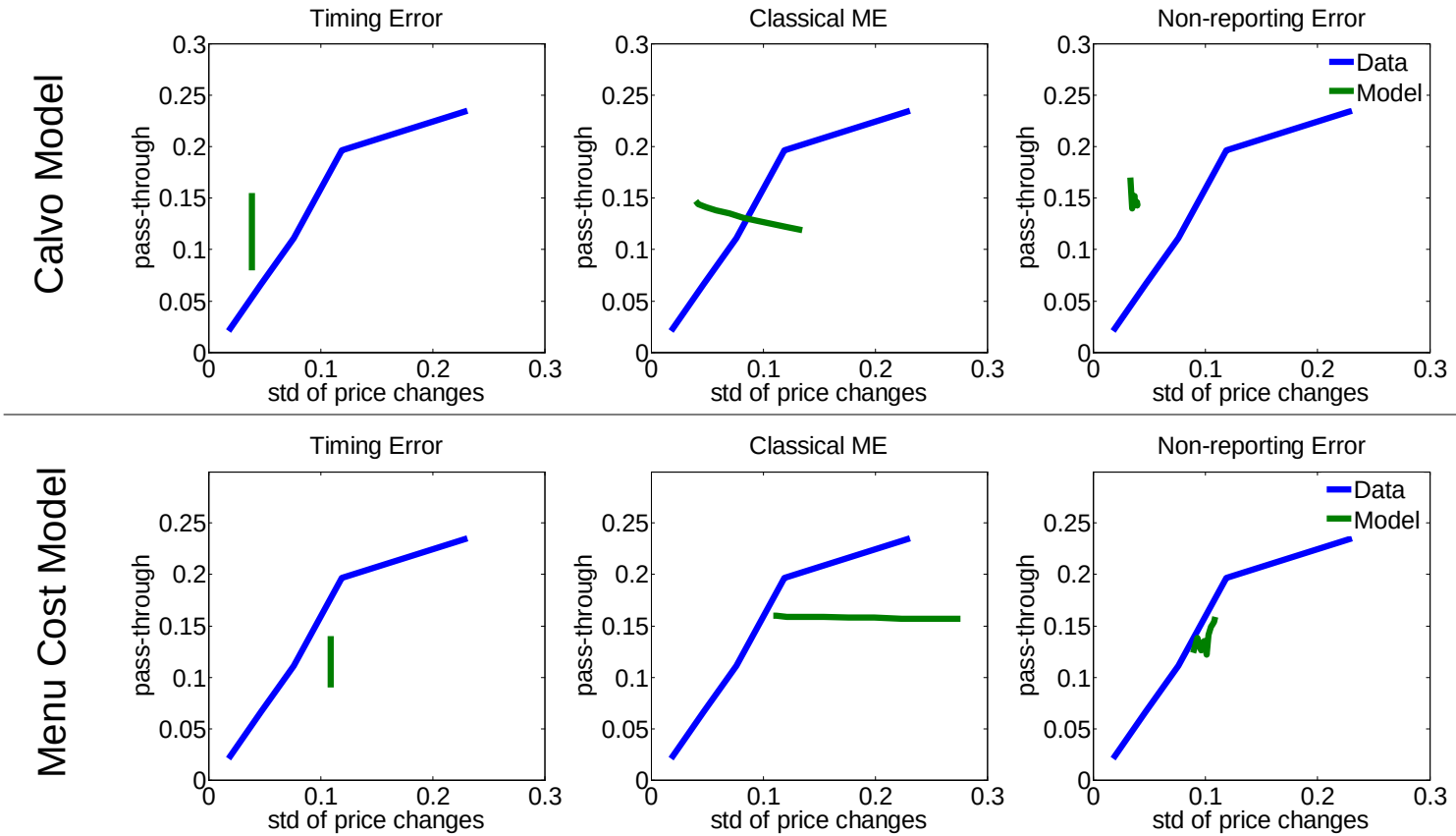
Measurement Error?

Various Forms of Measurement Error in Data

- Various forms of measurement and sampling error might affect both measured pass-through and dispersion:
  - Sampling Error
  - Size of price changes reported incorrectly
  - Inertia so not all price changes reported
  - Shipping lags
- Simulate these things in model to try to assess importance

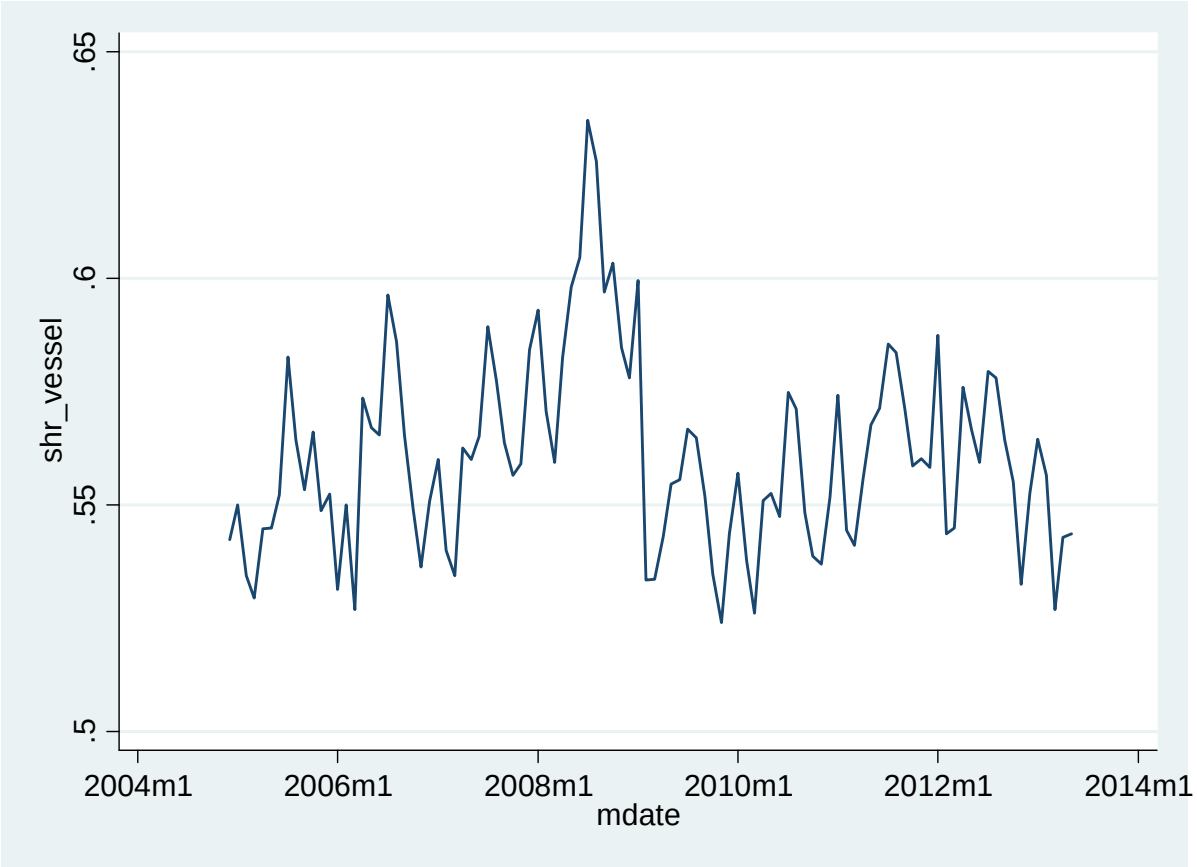
Modeling Measurement Error

- Modeling sampling error:
  - We already sample simulated data in previous experiments in same way as BLS, so all our results account for this
- Modeling errors in price change size:
  - Assume that $\Delta p_{reported} = \Delta p_{true} + \epsilon$
- Missing price changes
  - Assume that $\Delta p_{reported} = I_{report} \times \Delta p_{true}$ where I_{report} is a random variable that takes value 0 and 1
- Shipping lags:
  - $\Delta p_{reported,t} = \Delta p_{true,t-L}$ with $L \sim U[0, X]$



- Even really big measurement or non-reporting error don't affect measured passthrough much
- Time-varying shipping lags might be more important but even there would need big variation and would need to be correlated with something affecting volatility

- Can try to proxy for errors induced by shipping lags indirectly in data since more likely important for goods imported by boat:



- Items shipped by boat more likely to have long lags, attenuation bias and thus understated passthrough
  - But there is a positive correlation (0.13) between fraction of trade shipped by boat and IQR
  - So would work against our result
  - Have also controlled directly for shipping composition to the extent possible in both month-level and item-level results
- Other reason shipping lags have a hard time explaining our result:
  - Our results are strongest for firms with highest frequency of adjustment
  - Timing can be off by at most one month if prices adjust every month

Other Exchange Rate Passthrough Specifications

- May still have concerns about MRPT, measurement error, timing etc and prefer LRPT
  - Can't use LRPT since fixed for each item across time
    - But can do fixed horizon PT regressions. Theory⇒Same relationships
    - Instead of life-long, do 1-month, 3-month, 6-month, 12-month, 24-month PT. All results go through
  - One price change not enough to reflect full passthrough
    - Prices respond to exchange rate movements before previous price change
    - Theory: If item more responsive, should also be more responsive to lagged changes
    - Redo all regressions interacting passthrough of current and lagged exchange rate movement with dispersion
    - Find same result

More Structure and Additional Controls

$$
\begin{aligned}
\Delta p_{i,t} \quad = \quad & \beta^{ave} \Delta_c e_{i,t} \\
& + \beta^{Vol} \left(Vol_i \times \Delta_c e_{i,t} \right) + \delta Vol_i \\
& + \beta^{IQR} IQR_t \times \Delta_c e_{i,t} + \lambda IQR_t \\
& + \beta^{other} Other_t \times \Delta_c e_{i,t} + \chi Other_t \\
& + Z'_{i,t} \gamma + \epsilon_{i,t}
\end{aligned}
$$

DI Results with Item-Level Controls

	Ave PT β^{avg}	Volatility β^{Vol}	Frequency β^{freq}
All countries, all items ex petroleum			
- Cross-sectional std	0.14	0.05***	
	0.14	0.05***	0.02*
OECD countries, all items ex petroleum			
- Cross-sectional std	0.18	0.09***	
	0.19	0.08***	0.07***
All countries, all manufacturing items			
- Cross-sectional std	0.14	0.06***	
	0.13	0.06***	0.03***

DM Results with Controls

	Ave PT β^{avg}	Volatility β^{Vol}	Frequency/Subs β^{freq}
- Time trend + Month	.135***	.058***	
- Frequency	.14***	.063***	.011
- Product subs	.143***	.062***	.0004
- Time tr + Mth + Freq	.122***	.057***	.012
- Time tr + Mth + Prd sub	.134***	.058***	-.006

DM vs DI

	Ave PT β^{avg}	DI Effects β^{XSD}	DM Effects β^{IQR}
All countries, all items ex petroleum			
- No additional controls	.141***	.043***	.060***
- Item level frequency	.139***	.041***	.060***
- Aggregate frequency	.137***	.041***	.060***
- Time trend + Month	.137***	.042***	.055***
- All above controls	.125***	.042***	.055***

▸ Return

Additional Robustness Results

	Average PT β^{avg}	Volatility β^{Vol}	Freq β^{freq}
At least 3 price changes	0.15***	0.05***	
	0.15***	0.05***	0.01
Using trade-weighted broad xrate	0.41***	0.26***	
	0.44***	0.21***	0.27***
Using trade-weighted major country xrate	0.28***	0.21***	
	0.29***	0.18***	0.15***
Placebo num changes	0.15***	0.00	
	0.15***	-0.00	0.02*
Placebo num obs	0.15***	-0.00	
	0.15***	-0.00	0.02*
Median regression	0.16***	0.07***	
	0.16***	0.07***	0.01***

▸ Return