Quality of Goods and Price Setting

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Price Stickiness: Background

- Significant price rigidity in brick-and-mortar stores

  Klenow and Kryvtsov (2008, QJE), Nakamura and Steinsson (2008, QJE)

- Prices are more flexible on online market than in brick-and-mortar stores but the difference is quantitative rather than qualitative

  Gorodnichenko, Sheremirov and Talavera (2018, JEEA)

- Negative rigidity more marked than positive rigidity

  Alvarez et al. (2006, JEEA)

- Disaggregated prices appear sticky in response to macroeconomic and monetary disturbances, but flexible in response to sector-specific shocks

  Boivin, Giannoni and Mihov (2009, RES)

- Nominal rigidities take the form of inertia in reference prices and costs

  Eichenbaum, Jaimovich, Rebelo (2011, AER)

Potential Sources of Price Stickiness

- Search costs

  Burdett & Judd (1983), Benabou (1988)

- Costs of nominal price adjustment

  Sheshinski and Weiss (1977), Reinsdorf (1994)

- Transportation and delivery costs

  Betancourt and Gautschi (1993)

- Managerial costs such as costs of collecting information, decision-making, and communication

  Zbaracki et al. (2004)

Our Approach

We introduce quality of products into price setting

- Lack of precise quality measures in previous works
- Quality is often omitted in rigidity models
- Producers and sellers pay more to advertise new generations and higher quality products
- Search effort is likely to be larger for high-quality products

Quality: Background

- 2/3 of the price increases in the US should be treated as quality increases
  Bils (2009, QJE)

- Less than 1/3 of the price increases in Canada should be attributed to quality growth and the quality bias is not an important source of potential mismeasurement of CPI inflation in Canada (Kryvtsov, 2016, CanJE)

- Quality bias in price indices (adjusting for quality)
  Works of Erwin Diewert, Shiratsuka (1999), Byrne et al. (2018), Aizcorbe et al. (2019)

- Product replacement in CPI (ONS)

- Difficulties in quality measurement, the case of Bordeaux wine
  Combris et al. (1997)

This Study

We study

- The impact of quality on price-setting behaviour
- The effect of new generations of products on price setting
- CPU quality-adjusted price indexes

Our data

- Nearly 4 years of data collected online
- Multiple sellers (necessary for price dispersion)
- Unique manufacturing product number
- Exact quality measure for each product

Main Results

1. Higher quality products could have
   - Higher frequency of price changes
   - Smaller size of price changes
   - Lower price dispersion
2. Entries of products could increase frequency of price adjustments of existing products
   - However, if the number of low-quality products is large enough to upgrade an existing product to a higher quality quartile, that existing product would decrease the frequency of price changes.
3. Deflation in CPU market

Why Online Markets?

In order to document the impact of quality, we look at markets, where the price frictions are smaller

Online markets have unique characteristics

- Lower search costs
- Lower costs of price changes
- Lower costs of monitoring competitors' prices
- Low transportation costs

Are Online Prices Different from Offline Prices? Yes

- Online sales are increasing dramatically but still less than 10% of retail sales in most countries (Statista, 2019)

- Several studies, which use online prices of retailers that participate in PCWs, find that
  - Online retailers tend to have different pricing behaviours
  - Online prices tend to be more flexible and have smaller price changes than offline prices

Brynjolfsson et al. (2009), Lunnemann and Wintr (2011), Ellison et al. (2015), Gorodnichenko and Talavera (2017, AER)

Are Online Prices Different from Offline Prices? No

Most large multi-channel retailers price similarly online and offline (Cavallo, 2017, AER)

- Price levels are identical about 72% of the time
- Similar frequencies and average sizes
- No price discrimination based on location of customers
- No price discrimination based on persistent-browsing habits: prices were always the same

Online prices are a representative source of retail prices, even if most transactions still take place offline

Online Prices – Advantages and Disadvantages (Alberto Cavallo)

Advantages

- Online prices are easier and cheaper to collect
- Uncensored price spells
- Can be collected on a high-frequency basis without delays
- Detail information for all goods sold by each seller
- Better for studying the pricing dynamics and pricing strategies of seller
- Free from common sources of measurement error, such as time averages and imputation methods that can affect traditional micro-price data sets (Cavallo, 2018, REStat)

Disadvantages

- Limited sector coverage
- Smaller set of retailers
- Lack of information on quantities (Cavallo and Rigobon, 2016, JEP)

How Can We Measure Quality?

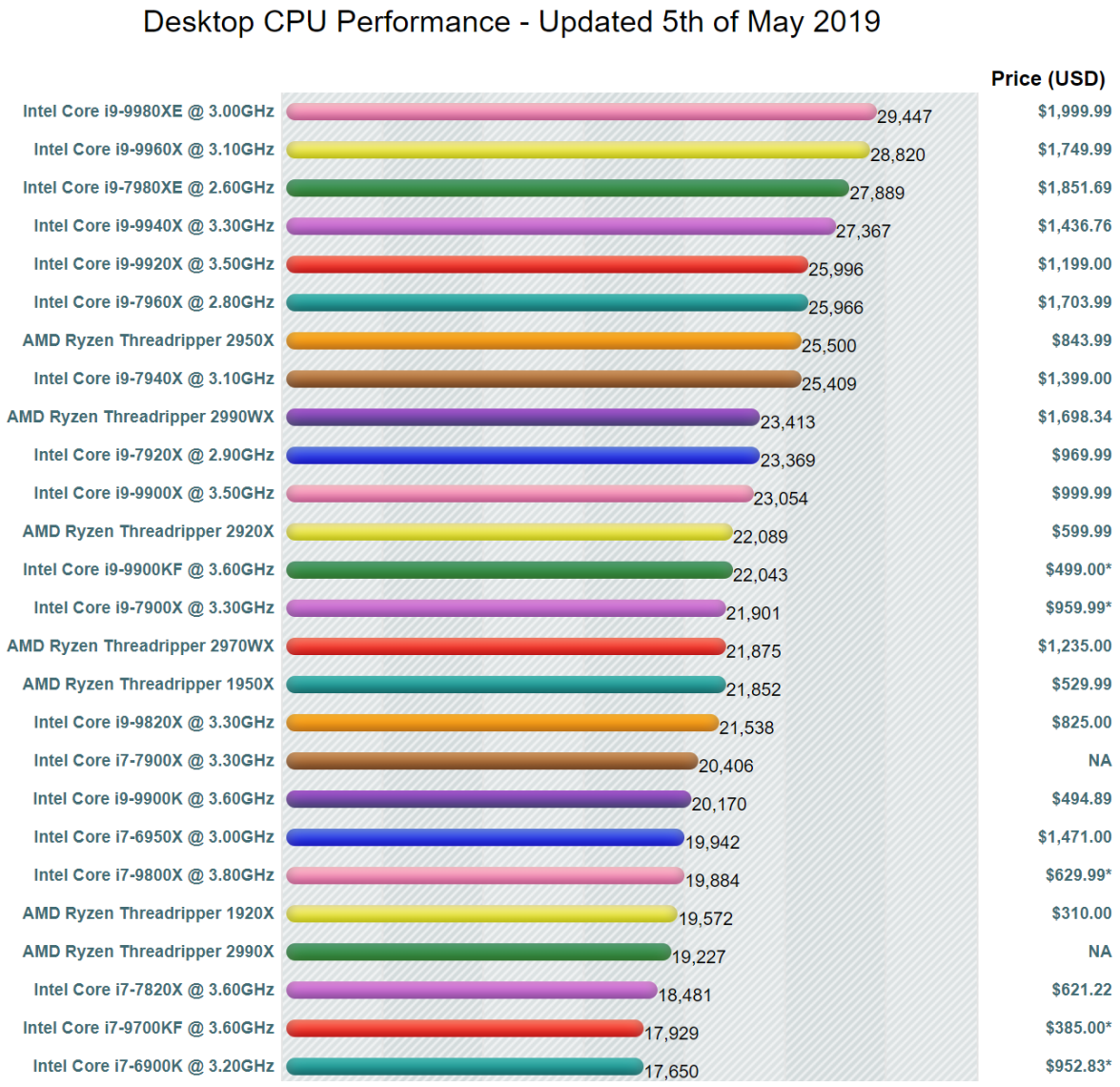
Can Quality be Measured? No

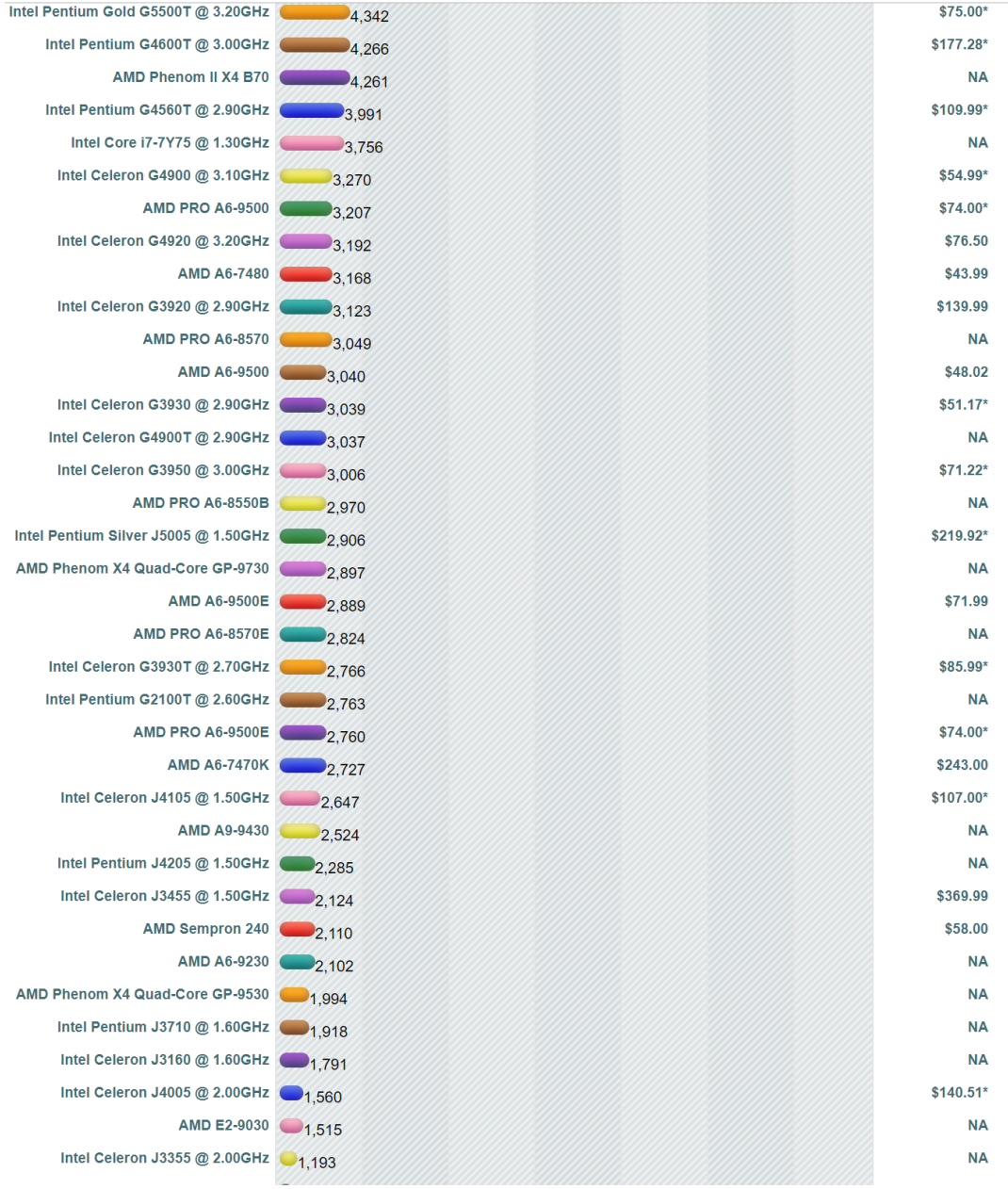
- https://allthatsinteresting.com/history-of-womens-swimwear
- Original idea by Diana Coyle (Cambridge)

Can Quality be Measured? Maybe

Audi 1990 vs Audi 2019

Can Quality be Measured? Yes





Do We Care About CPUs?

Weight in the UK CPI as a part per 1000 by hedonic item

Year	PCs	Laptops	Digital Cameras	Mobile Phones	Smart-phones	PC tablets	TOTAL
2003	5.39						5.39
2004	4.38		1.00				5.38
2005	2.10	2.20	3.28	0.92			8.50
2006	2.15	2.35	2.50	0.96			7.96
2007	3.01	3.36	2.76	0.92			10.05
2008	2.15	2.35	2.88	0.88			8.26
2009	2.00	2.30	2.76	0.88			7.94
2010	2.20	2.64	2.25	1.20			8.29
2011	2.24	2.94	3.50	0.72	0.46		9.86
2012	1.50	2.52	2.56	0.52	0.26	0.24	7.60
2013	1.05	2.31	1.89	0.29	0.29	1.47	7.30

Source: Office for National Statistics

What if quality of products is not taken into account?

Aizcorbe, Byrne, and Sichel (2019) developed new quality-adjusted price indexes for smartphones

- Their index falls at an average annual rate of 17 percent during 2010-2018 (the average prices over this period is relatively flat)
- The decline rate of the new index is about 4 percentage points slower than
  - The rate in Byrne and Corrado (2015)
  - The index currently being used by the Bureau of Economic Analysis since the Comprehensive Revision of the GDP accounts in the summer of 2018.
- New generation product is sold at a lower quality-adjusted price than old model
- CPU characteristics have significant impact on prices of smartphones
  - However, they only control for processor clockspeed but not other characteristics that affect to the real performance of CPU (such as turbo speed, number of cores, thermal design power)

History of CPU Performance

Mid-1980s – early 2000s:

- CPU performance increased quickly
  - New generation of CPU technology allowed for an increase in the number of basic calculations performed per second (clock speed) for a given chip design

Mid-2000s – Now:

- CPU performance increased quicker…
  - Because the heat dissipation problem, CPU producers shifted away from increases in clock speed
  - They place multiple copies of the core architecture on each chip (a change enabled by smaller feature size and by improving the design of those cores)

History of CPU Prices

Mid-1980s – early 2000s:

- CPU prices declined rapidly
  - Semiconductor prices dropped dramatically due to semiconductor technology improvement

Mid-2000s – Now:

- CPU prices have barely been falling
  - Semiconductor prices stop decrease
  - Cost of achieving engineering advances has risen so much as to leave constant-quality CPU prices about unchanged
- CPU prices became much stickier (Byrne, 2018)
  - The changes in pricing behaviour of Intel – the dominant producer of CPUs

Quality Adjusted Price Indexes for CPUs

Aizcorbe, Byrne, and Sichel (2018) developed new quality-adjusted price indexes for CPUs

- Before 2004, estimated indexes and PPI are similar
  - All indexes could capture the downward trend in quality-adjusted prices
- After 2004, their indexes and PPI diverge due to mismeasurement in PPI
  - The decline in PPI sharply slowed
  - Hedonic price index indicate the quality-adjusted price have continued drop rapidly

Data

Online-prices data (prices and other relevant information are gathered from a leading PCW)

- From April 2009 to December 2012
- Monthly frequency
- Data at product – seller – month level
- United States (.com domain)
  - 218 sellers – 861 CPUs
  - 110,120 observations
- Canada (.ca domain) from Gorodnichenko and Talavera (2017)
  - 30 sellers – 428 CPUs
  - 23,155 observations
- **Amended with Performance score** for each CPU

Price Comparison Website

- PCWs often charge per click or per listing

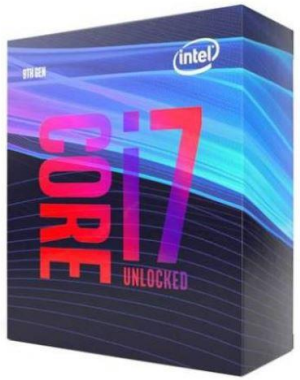
Thus, sellers have incentives to keep updating their best prices on PCWs. If their prices are not up to date, they will not gain sales and waste their money.

- Prices listed on PCW are likely close to transaction prices
  - Transaction prices are heavily concentrated in the competitive (bottom) part of the price distribution (Baye et al., 2009; Chevalier and Kashyap, 2011)

- The quality of price data from the PCW is high (Gorodnichenko et al., 2017)
  - The price quotes from PCWs and seller's websites are highly correlated ($\rho = 0.98$)
  - Price data from PCW is consistent with BLS data and updated rapidly in response to the aggregated shock.

A Typical Price Comparison Website

Computing > Components > CPUs



Intel Core i7-9700K 3.6GHz, Box

★★★★★ 4.8 (159 reviews)

3.6 GHz 8, Socket 1151

From **£345.42** to **£629** Alert price

Sponsored by **£409.98**

✓ Free shipping ✓ In stock

To store

Compare all Intel CPUs

Retailers (21) International (0)

Availability

TECHTRIAL	Intel Core i7-9700K processor 3.6 GHz Box 12 MB Smart Cache	In stock	£381.7 Free shipping	Go to store
egenisys	Intel Core i7-9700K processor 3.6 GHz Box 12 MB Smart Cache	In stock	£408.41 £403.42 excl. shipping	Go to store
ebuyer.com	Intel Core i7 9700K 3.6 GHz Processor	In stock	£409.98 Free shipping	Go to store

A Little Bit of History of CPU market over last 10 years

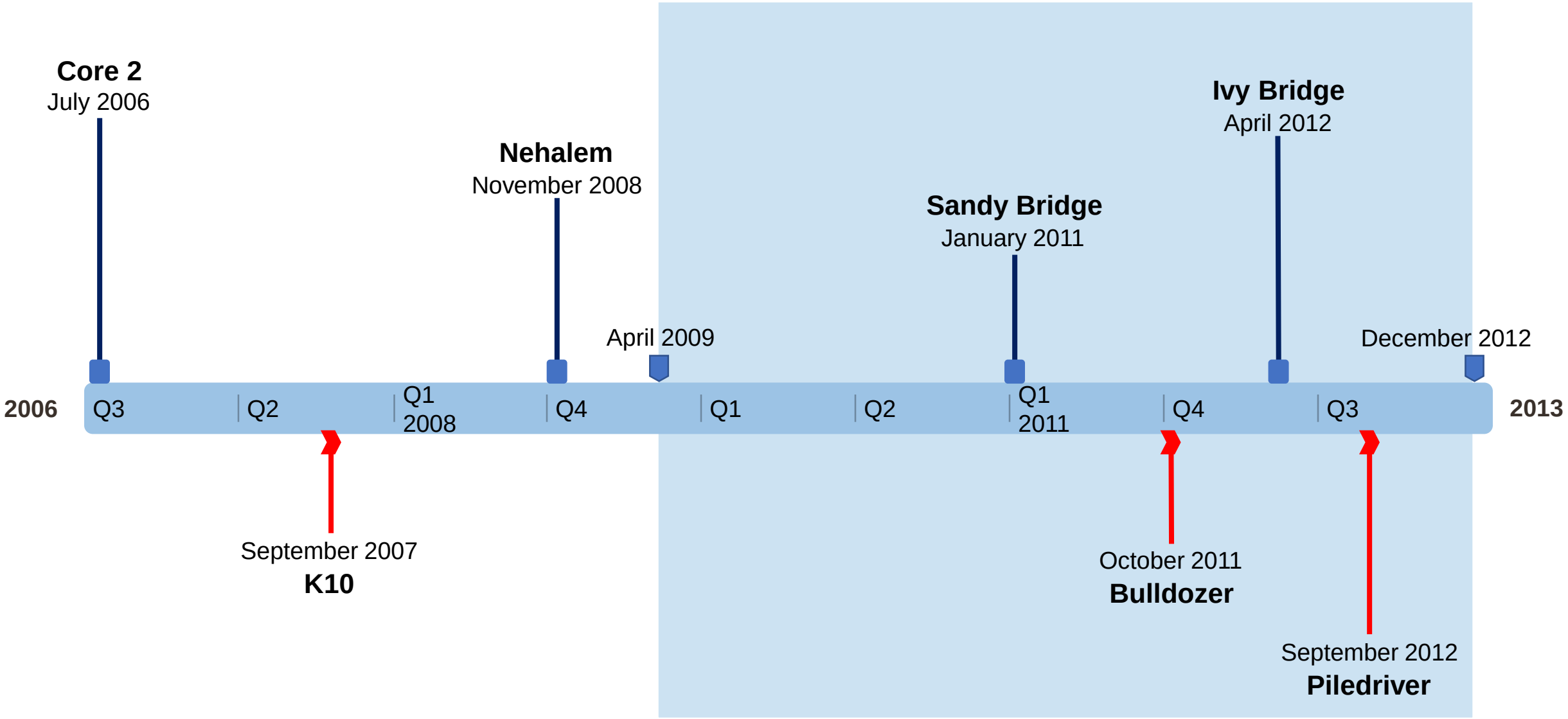
Intel:

1. 64-bit Core microarchitecture - Intel Core 2: 65/45 nm technology
2. Nehalem microarchitecture (1st generation): 45 nm technology
3. Sandy Bridge microarchitecture (2nd generation): 32 nm technology
4. Ivy Bridge microarchitecture (3rd generation): 22 nm technology

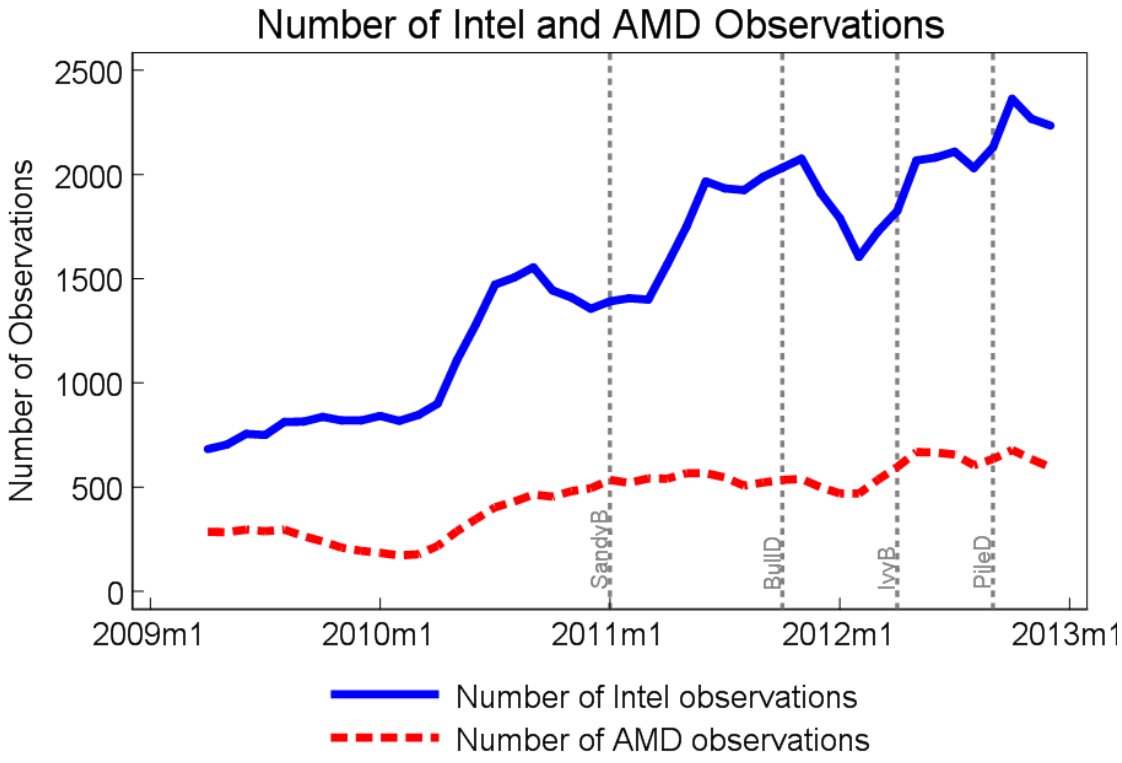
AMD:

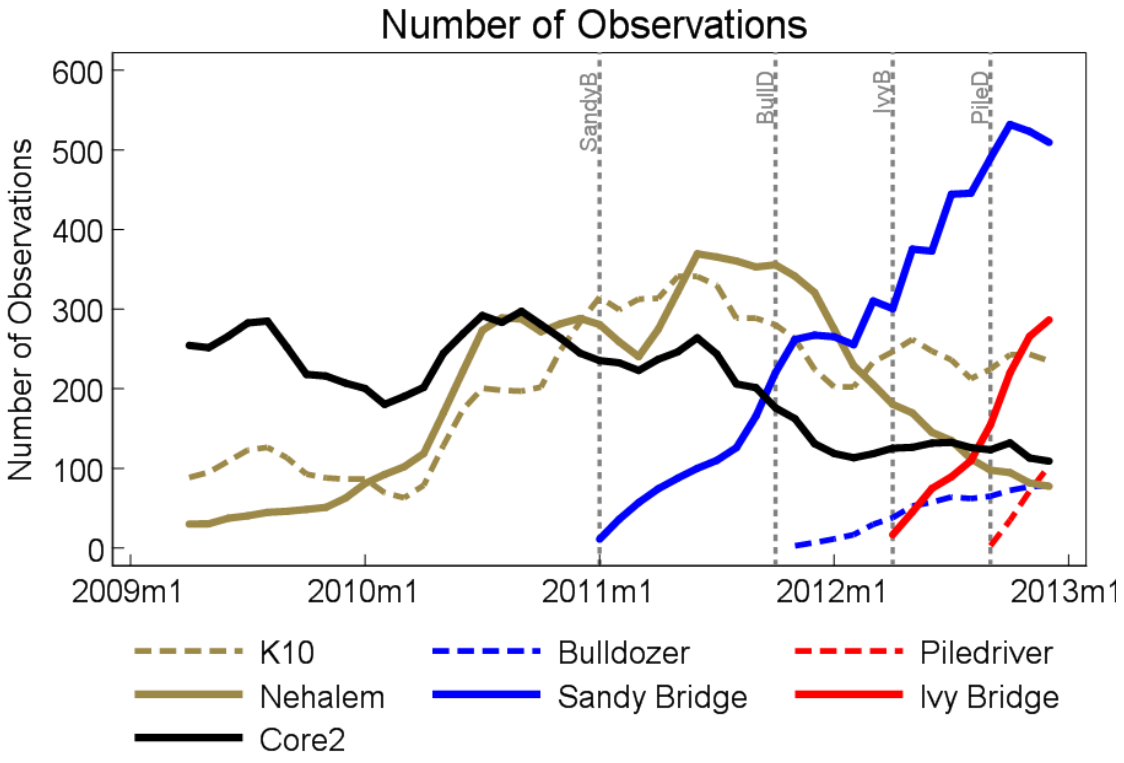
1. AMD Family 10h, or K10: 65/45/32 nm technology
2. AMD Bulldozer Family 15h (1st generation): 32 nm technology
3. AMD Piledriver Family 15h (2nd generation): 32 nm technology

Technology Innovation



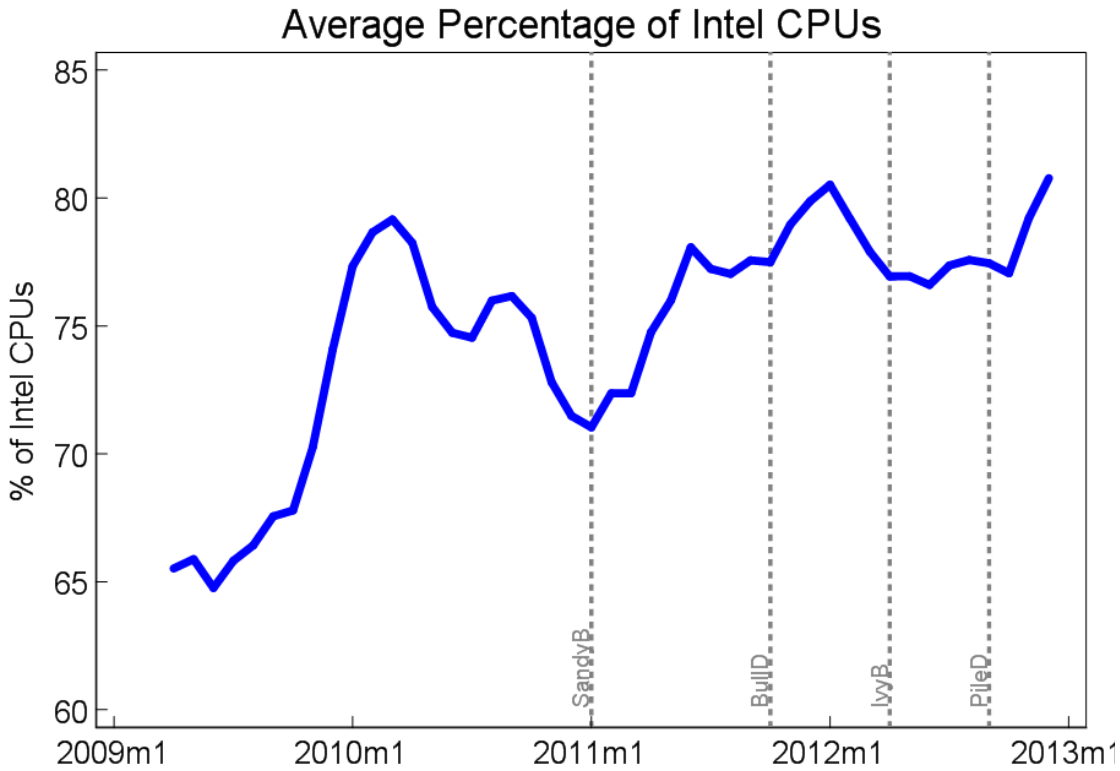
CPU Market Composition

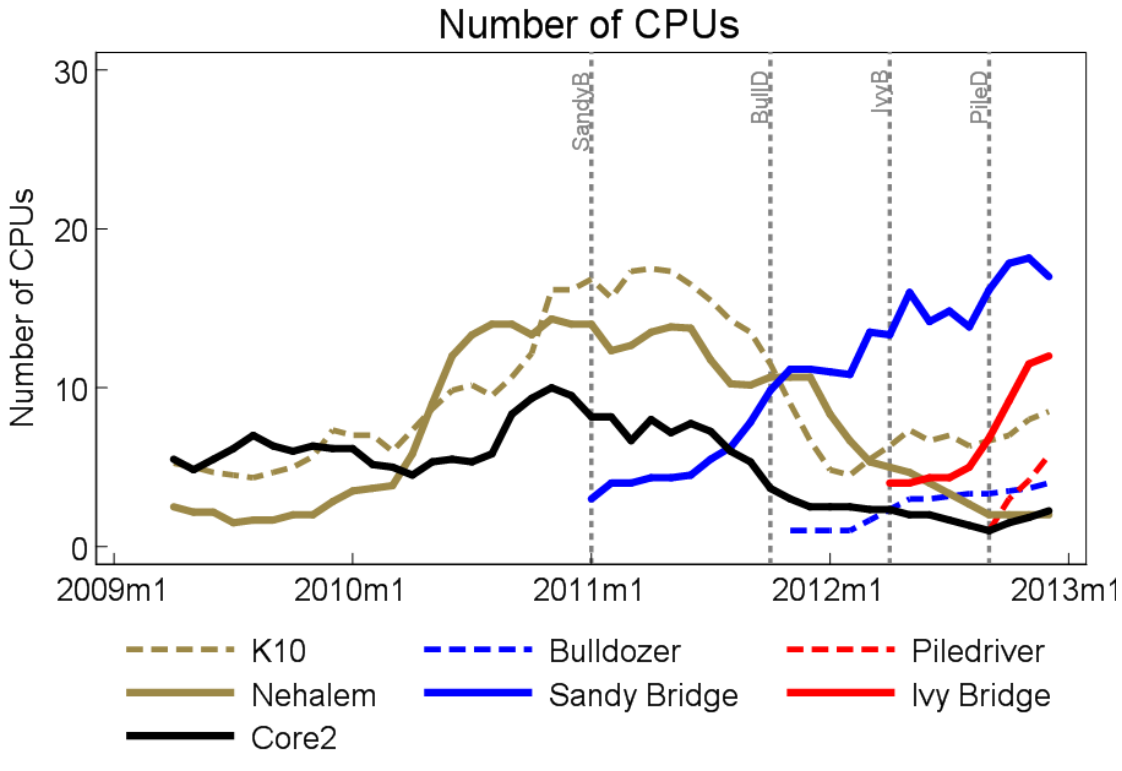




- Intel is the dominant producer of CPUs
- New technology is introduced fast

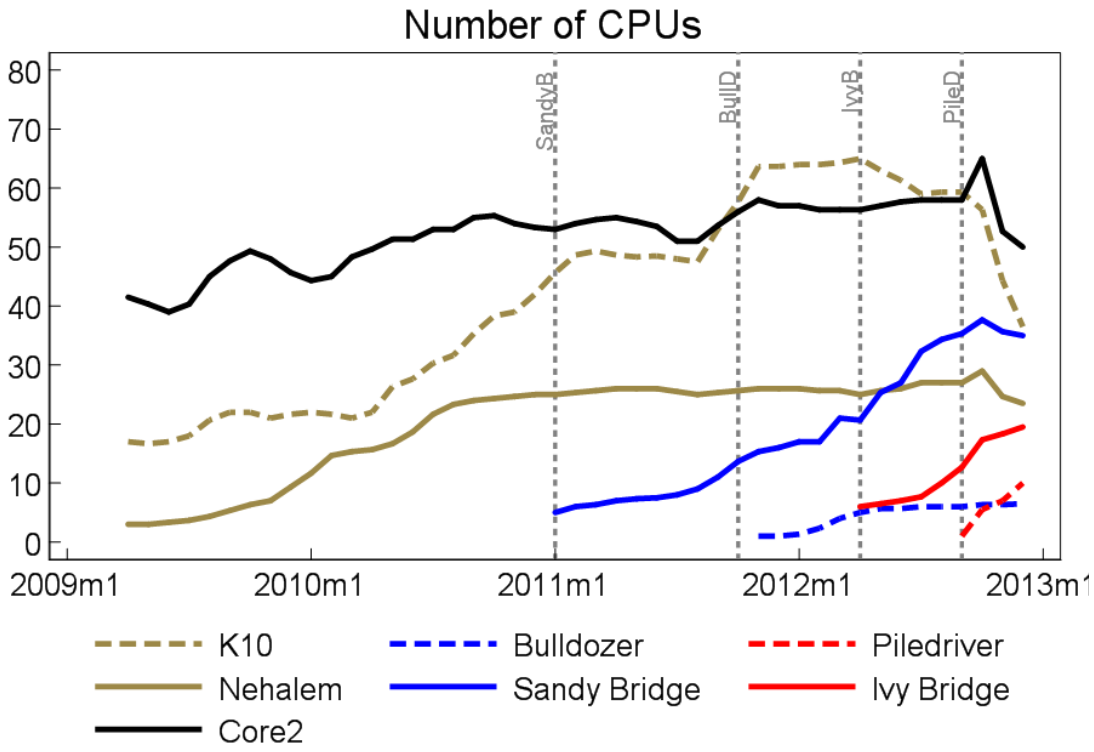
CPU Market Composition per Seller

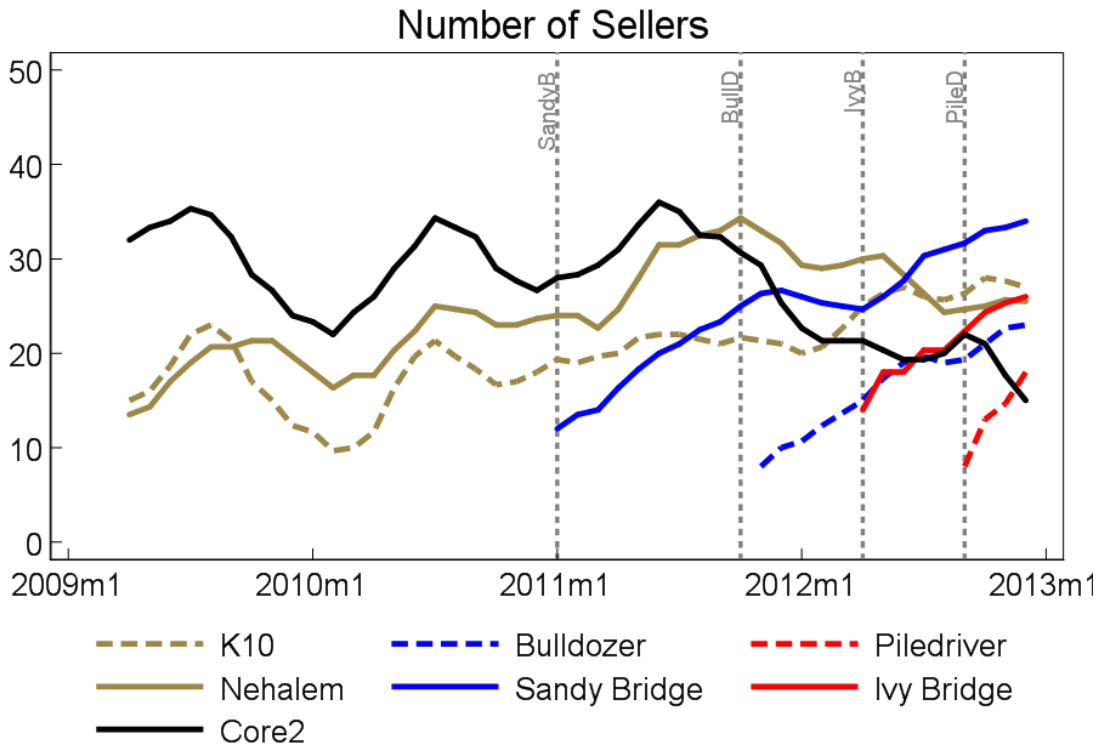




- Intel dominates AMD within each seller
- Number of CPUs per seller increases after new technology introduction

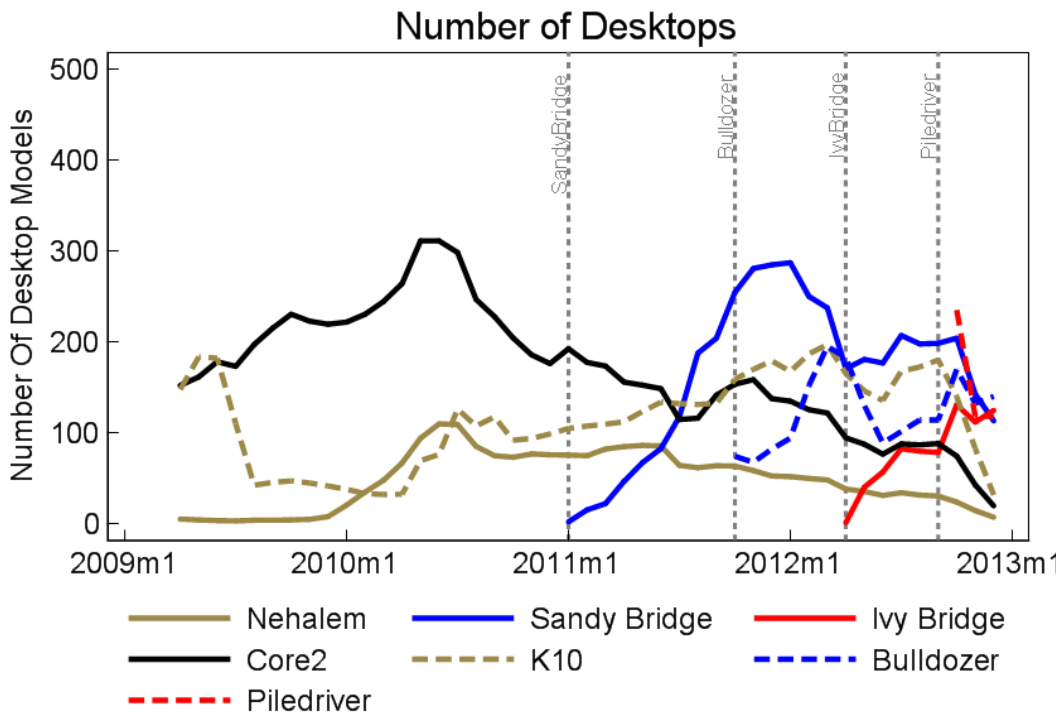
CPU Market Composition

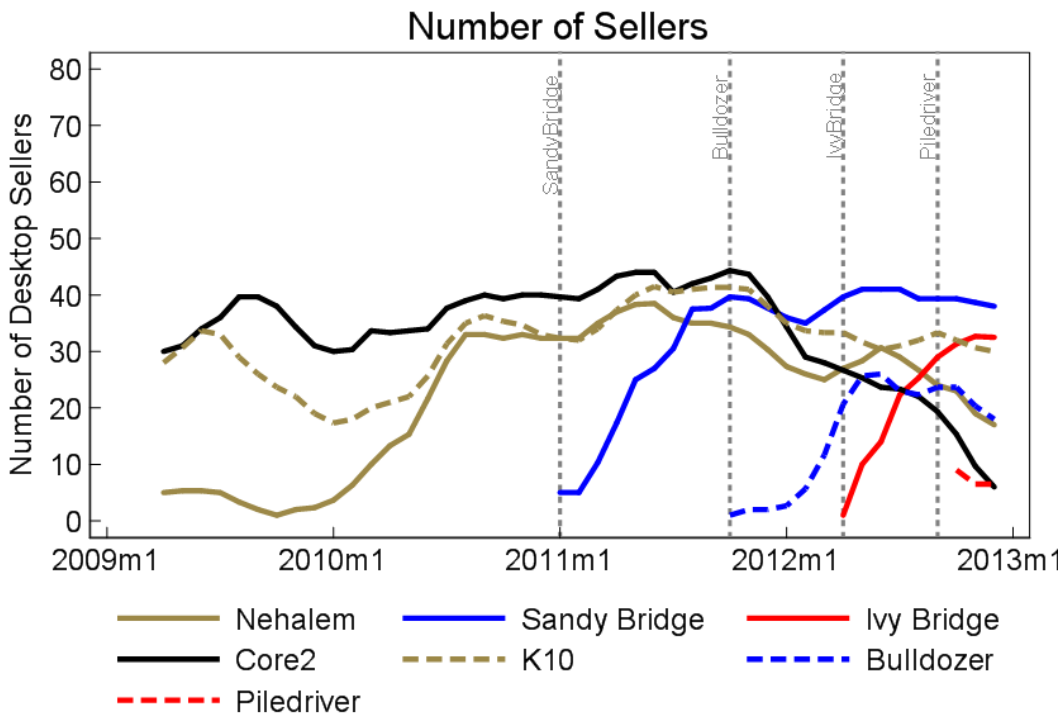




- Number of CPUs within generation increases after introduction of technology
- Number of sellers increases as well
- For the oldest technology, number of seller decreases

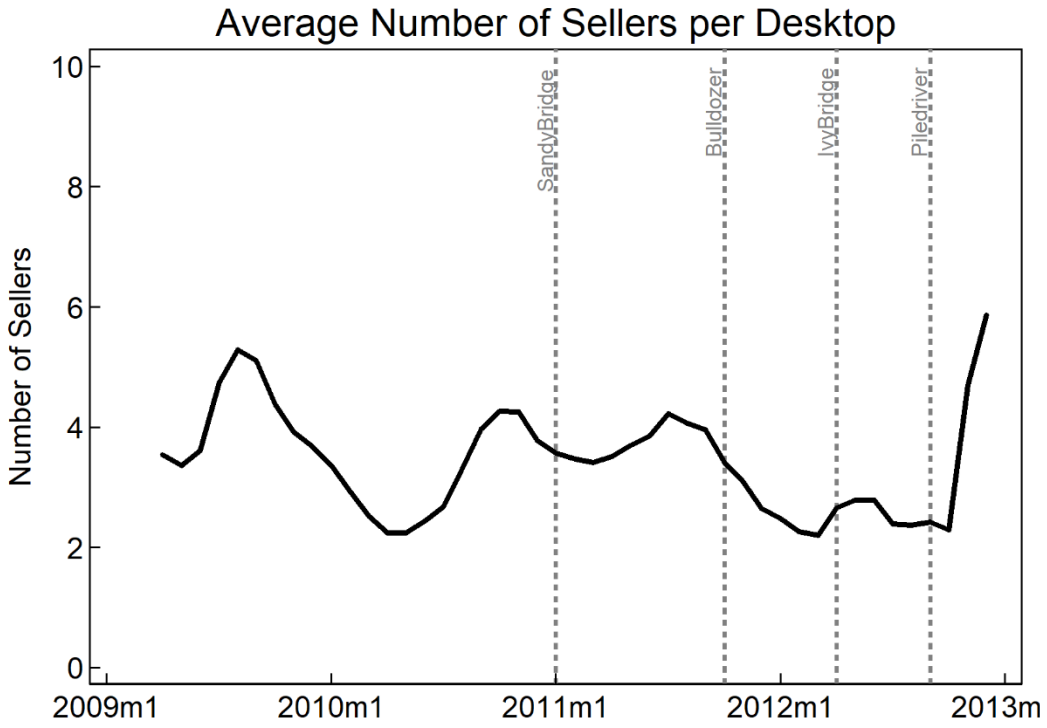
Desktop Market Composition

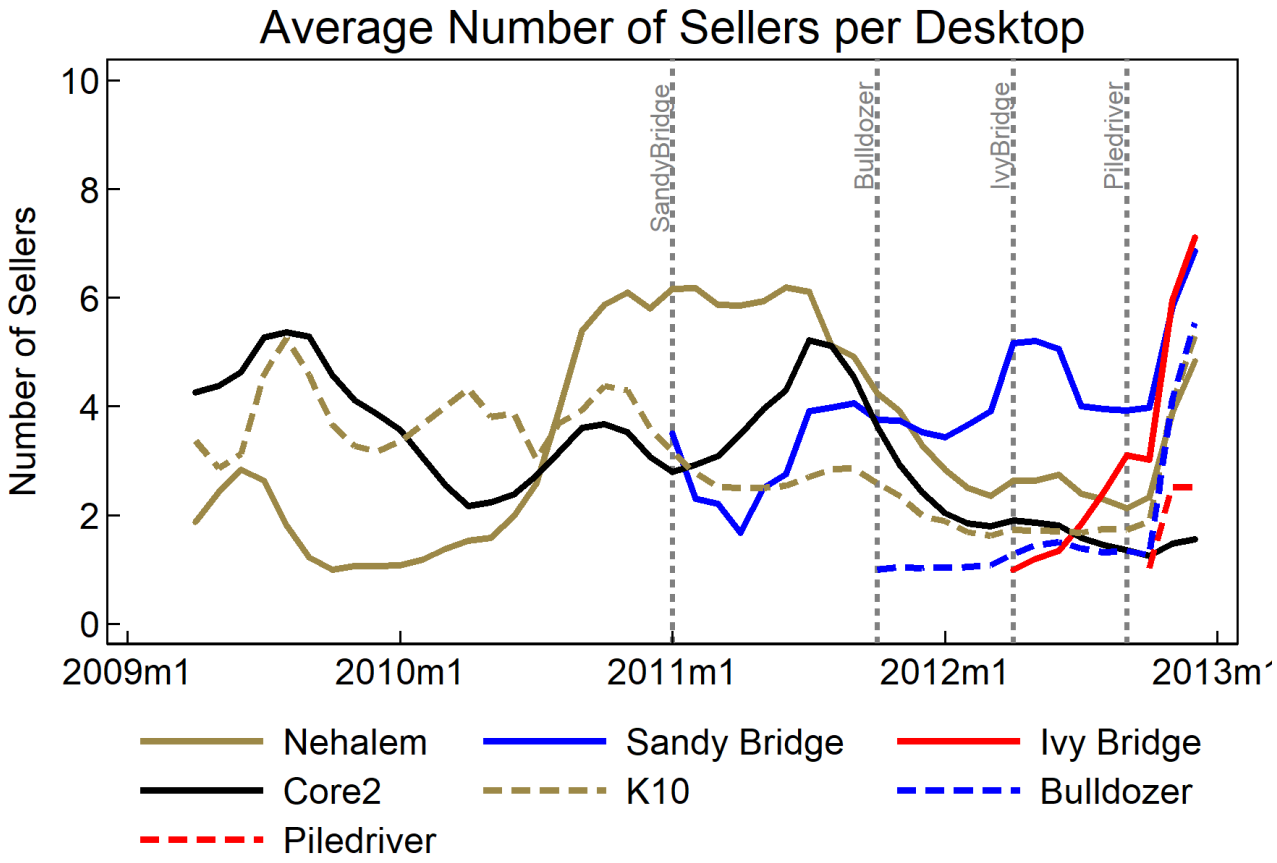




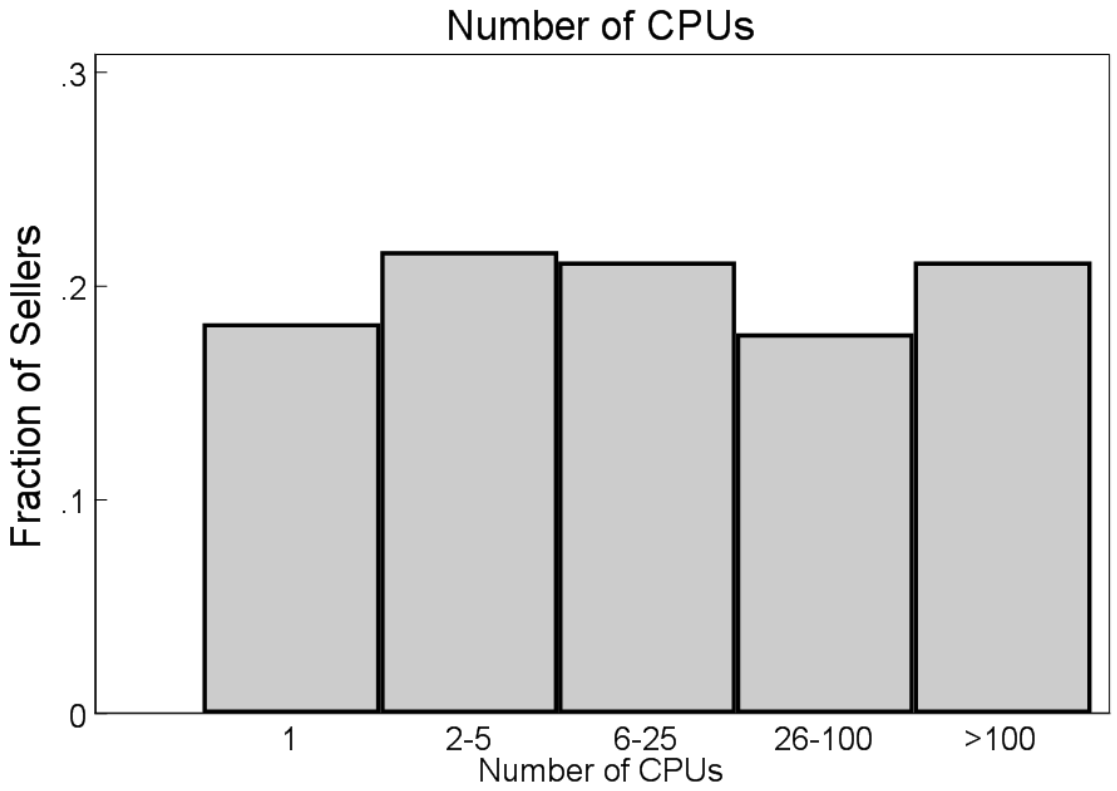
- Very fast adoption of new generation CPUs
- Following the same trend in CPU market, desktops that using the oldest technology CPUs has the number of seller decreases rapidly

Desktop Market Composition





CPU Sellers



Top 10 Sellers

Top	Seller	# of Products	% of Obs
1	Memory4Less.com	553	4.50
2	PC Connection	445	5.23
3	Compuvest	426	3.01
4	NextWarehouse.com	405	4.70
5	TheNerds.net	395	4.46
6	Buy.com	379	3.91
7	SeaBoom.com	373	4.98
8	CostCentral.com	316	4.11
9	LACC.com	314	2.24
10	PROVANTAGE	312	4.01

Introducing Quality into Price Setting Measures

Approaches:

- Quality adjusted price (per unit of performance)
- Quality weighted
  - Frequency and size of sales
  - Frequency and size of price changes

- The frequency of price increases covaries strongly with inflation, whereas the frequency of price decreases and the size of price increases and price decreases do not (Nakamura and Steinsson, 2008, QJE)
- Inflation is not correlated with the overall frequency (size) of price changes but rather with the relative frequency (size) of price increases over decreases (Cavallo, 2018, RES)

Quality Adjusted Prices

$$p_q = \frac{p * \mu_q}{q}$$

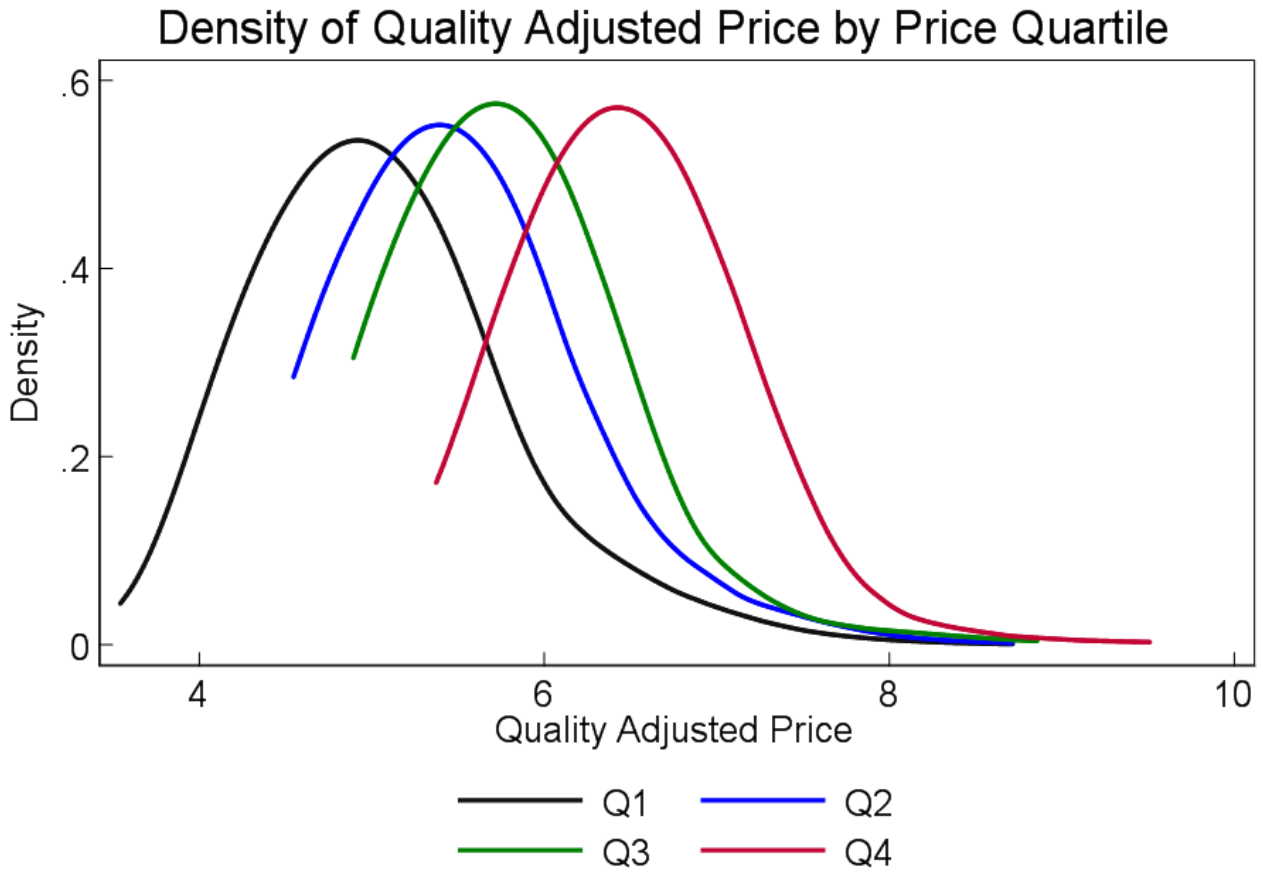
Where:

p_q: Quality Adjusted Price

p: Price

q: Performance Score

μ_q: Average Performance Score



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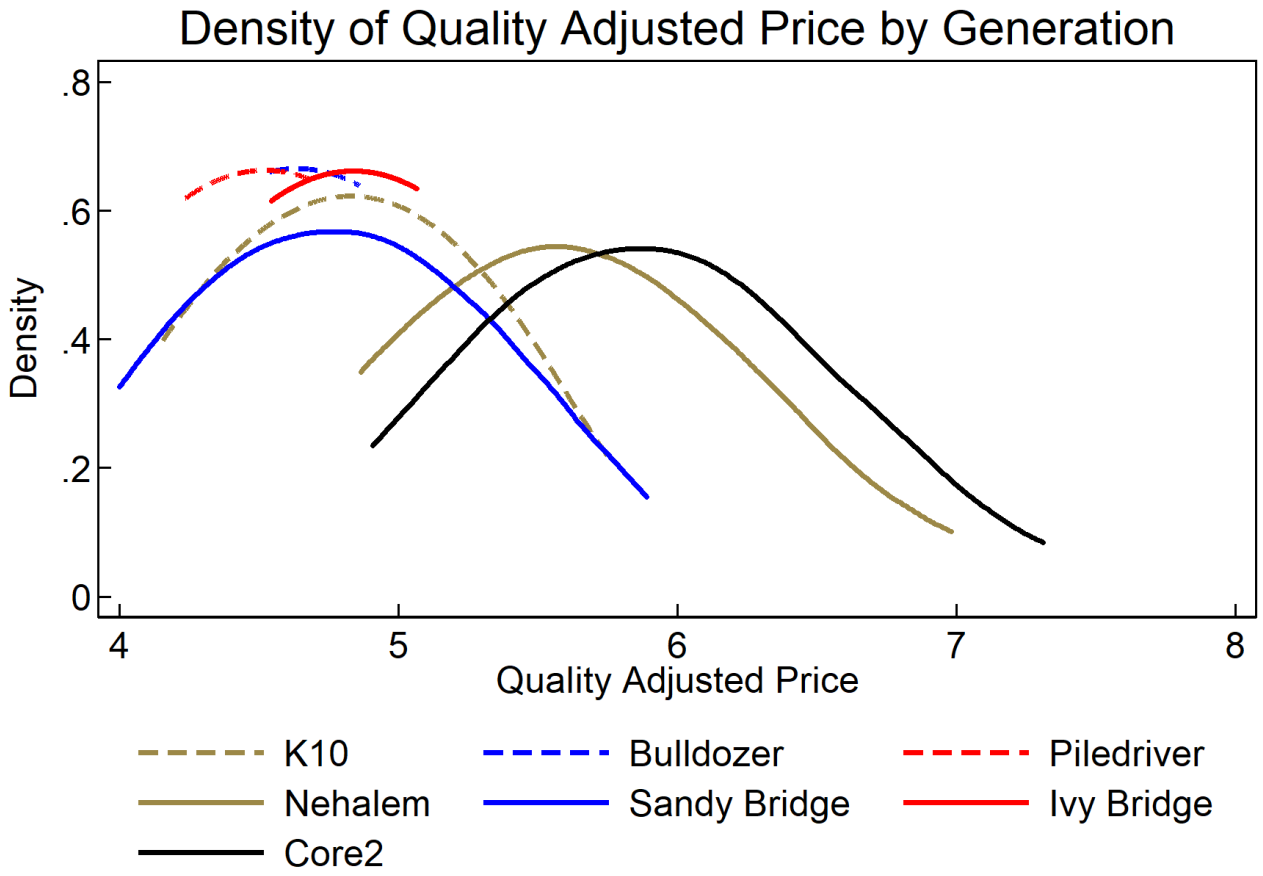
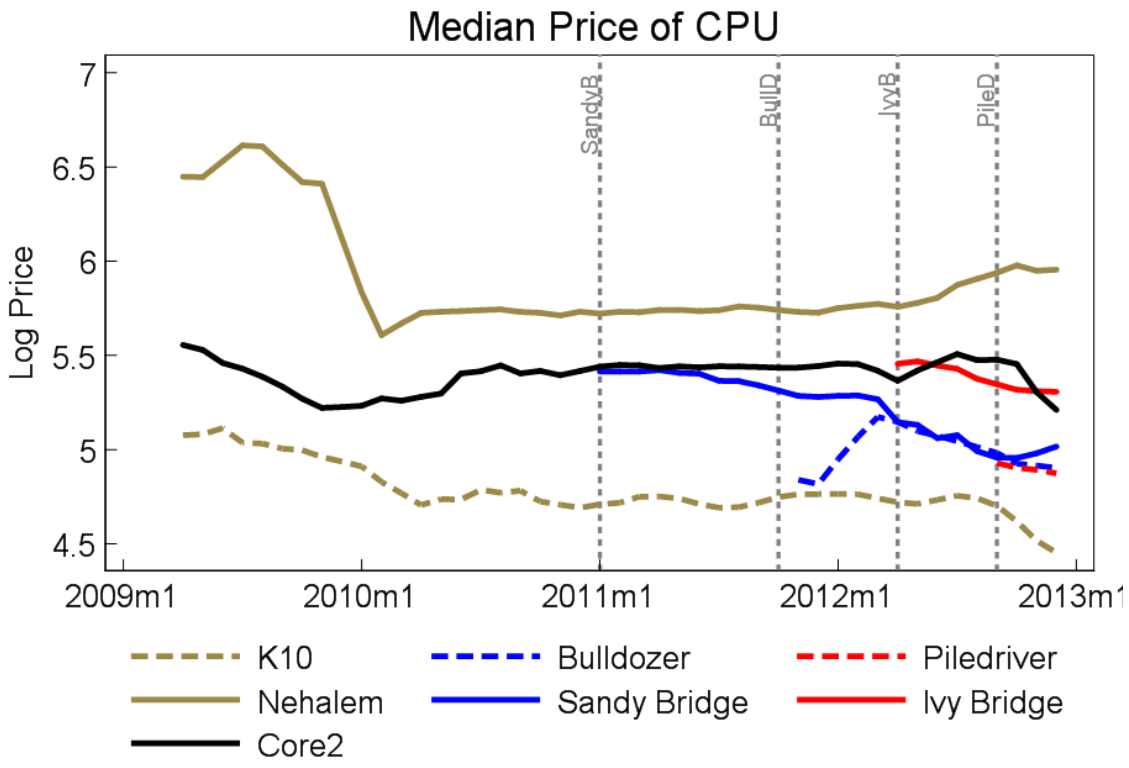
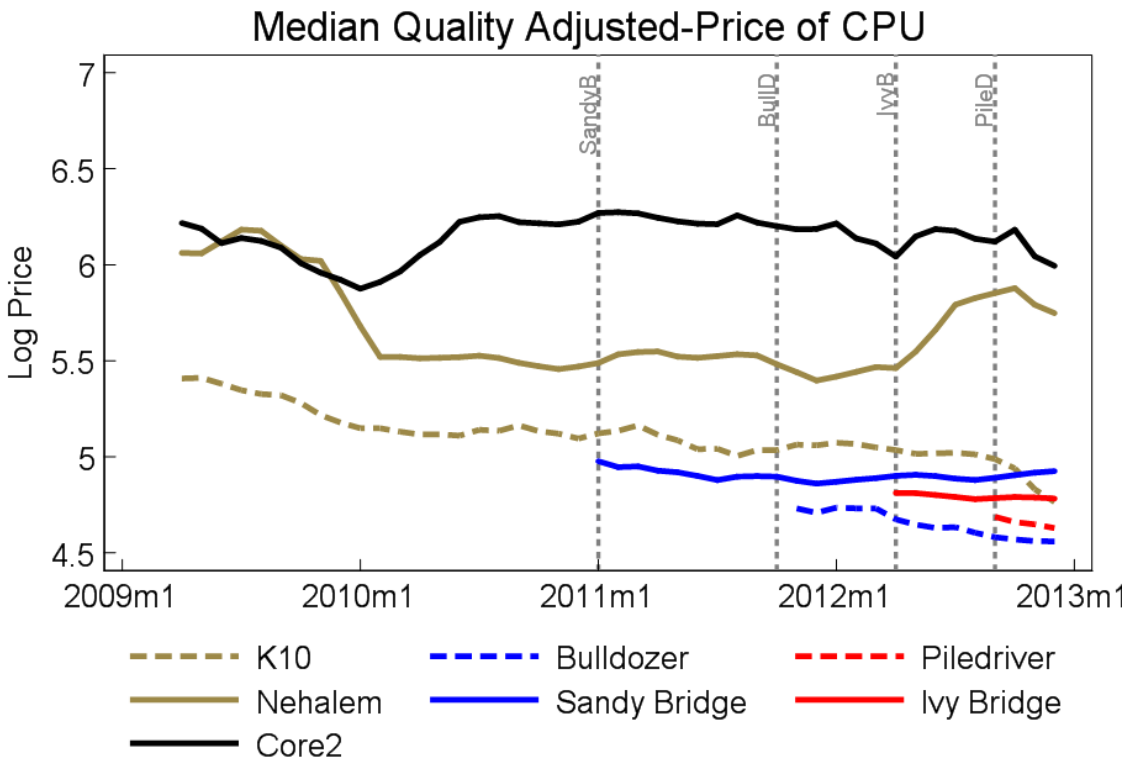


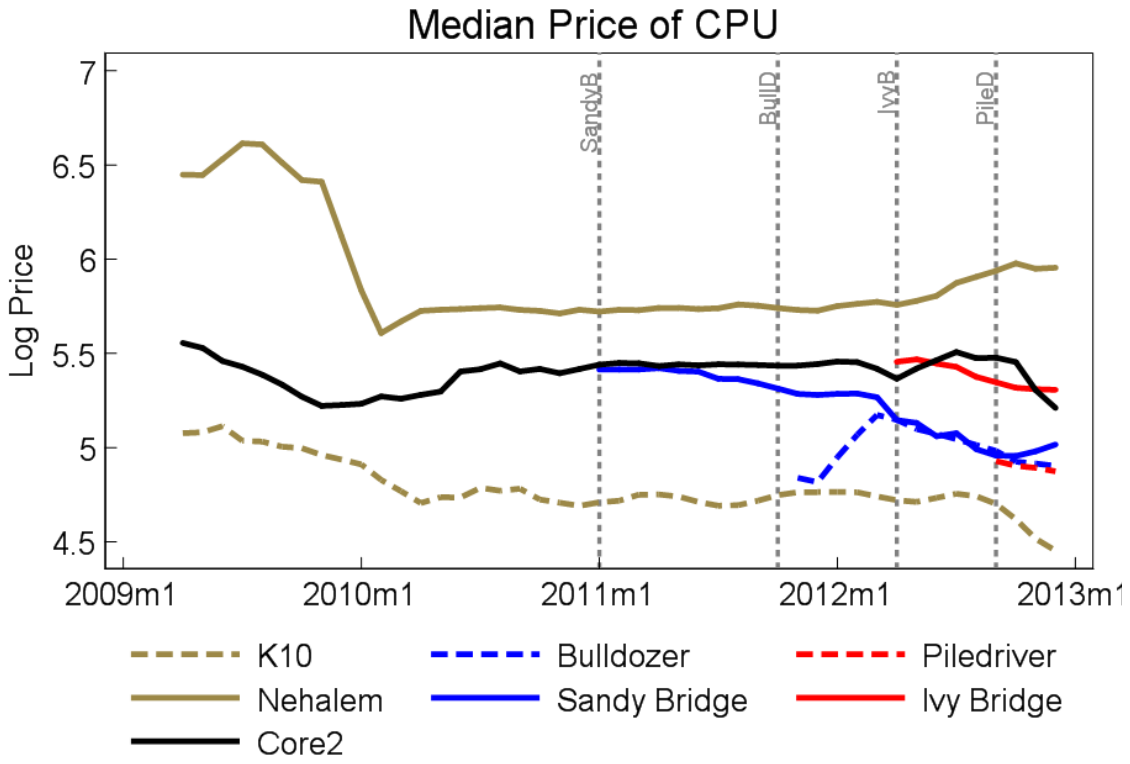
Dynamics of CPU Prices

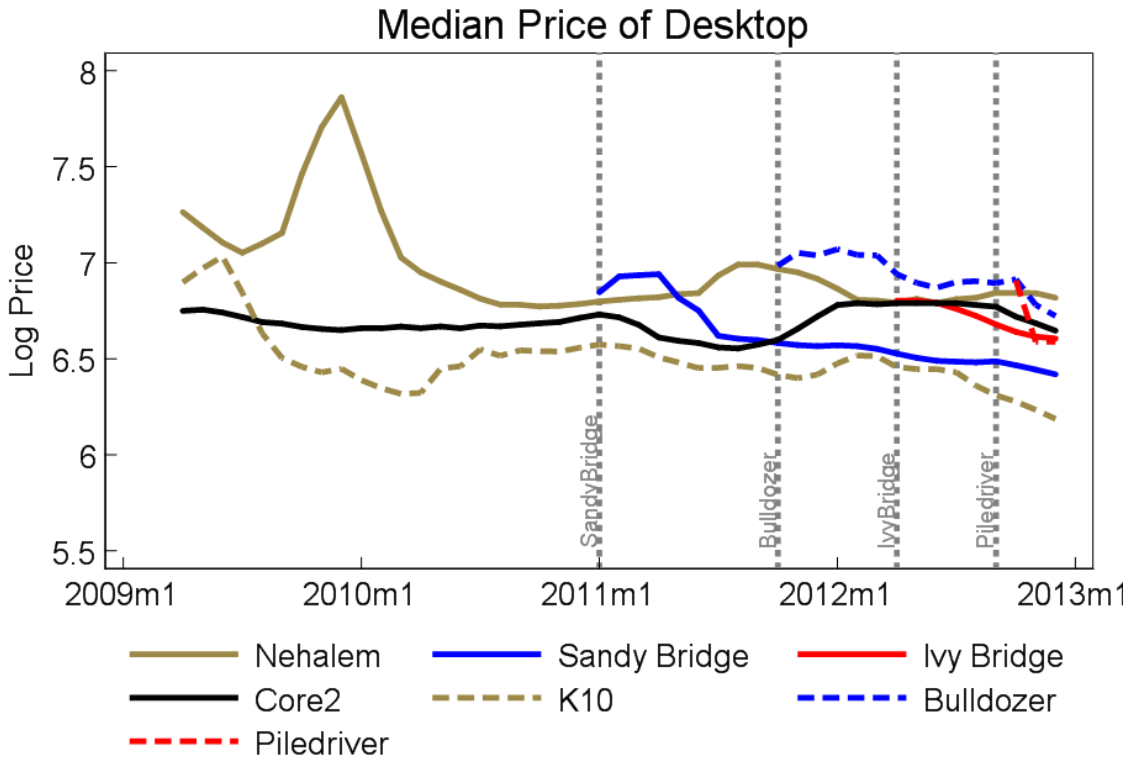




- AMD CPUs are often cheaper than Intel CPUs
- Actual prices may reflect incorrectly the expensiveness of product
- The price of the old model does not fall enough to equilibrate to the price-performance ratio of the new model (in line with Aizcorbe, Byrne, and Sichel, 2019)

Dynamics of Desktop and CPU Prices





The price range of desktop market is more compressed

Desktop price changes are similar to CPU price changes

Price Distribution

	Mean Log Price		Mean Price, Percentile					N
	Mean	SD	5%	25%	50%	75%	95%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No Weights	5.24	0.89	53.07	99.77	195.62	353.33	1107.77	814
Performance Weighted	5.78	0.89	84.20	186.45	301.67	628.88	1557.09	814
Quality Adjusted Price	5.76	0.83	89.91	162.94	314.24	584.63	1325.25	814

- High-quality products have higher prices than low-quality products
- In general, price per unit of performance is higher for high-quality products
  - Although technology innovation could decrease the price per unit of performance, this impact is dominated by the expensive quality premium of high-class CPU

Price Distribution (Canada)

Data for Canada from Gorodnichenko and Talavera (2017)

	Mean Log Price		Mean Price, Percentile					N
	Mean	SD	5%	25%	50%	75%	95%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No Weights	5.45	0.87	66.56	112.30	227.74	389.01	1291.33	338
Performance Weighted	5.79	0.88	83.67	184.99	304.04	619.32	1585.19	338
Quality Adjusted Price	5.76	0.91	99.18	163.14	272.97	531.70	1817.94	338

- It is similar in Canada

Posted Prices and Regular Prices

- Lots of price changes last for a limited period of time
  (Nakamura and Steinsson, 2008; Eichenbaum, Jaimovich, and Rebelo, 2011)

- The median frequency of non-sale price change is roughly half of what it is including sales
  (Nakamura and Steinsson, 2008)

- Sales do not affect monetary non-neutrality (Kehoe and Midrigan, 2015)
  may interact with regular prices (Sheremirov, 2015)
  are part of "sticky plans" (Anderson et al., 2017)

- Posted prices: Prices observed in the data
- Regular prices: Prices excluding temporary changes

Frequency and Size of Sales

Determining a temporary price change: V-shape in price changes

(Nakamura et al., 2008; Chahrour, 2011; Kehoe and Midrigan, 2015)

Monthly Frequency and Size of Sales

	One-month Two-sided Sales Filter			
	Mean Frequency	SD Frequency	Median Size	N
	(1)	(2)	(4)	(5)
No Weights	1.82	3.59	2.28	535
Performance Weighted	2.23	3.36	1.96	535

Frequency and Size of Sales (Canada)

Determining a temporary price change: V-shape in price changes

(Nakamura et al., 2008; Chahrour, 2011; Kehoe and Midrigan, 2015)

Monthly Frequency and Size of Sales (Data for Canada from Gorodnichenko and Talavera, 2017)

	One-month Two-sided Sales Filter			
	Mean Frequency	SD Frequency	Median Size	N
	(1)	(2)	(4)	(5)
No Weights	1.65	3.32	2.41	249
Performance Weighted	1.85	3.63	2.41	249

Frequency and Size of CPU Price Changes

Weights:	Whole US Sample		**Core-2 CPUs**		Nehalem CPUs		K10 CPUs	
	No	Yes	**No**	**Yes**	No	Yes	No	Yes
	(1)	(2)	**(3)**	**(4)**	(5)	(6)	(5)	(6)
Posted Price								
Median Frequency, %	40.48	44.56	**31.30**	**40.48**	50.32	47.78	53.72	55.68
Implied Duration, Months	1.93	1.70	**2.66**	**1.93**	1.43	1.54	1.30	1.23
Median Absolute Size, Log Points	7.97	5.12	**11.44**	**9.15**	5.33	5.33	7.58	7.59
Regular Price								
Median Frequency, %	36.77	39.75	**30.89**	**33.47**	45.22	43.45	43.67	48.19
Implied Duration, Months	2.18	1.97	**2.71**	**2.45**	1.66	1.75	1.74	1.52
Median Absolute Size, Log Points	8.20	5.35	**11.96**	**9.02**	5.60	5.68	7.69	7.76

For the whole sample and every generation, the impact of quality on price setting is similar (except for Intel Nehalem CPUs)

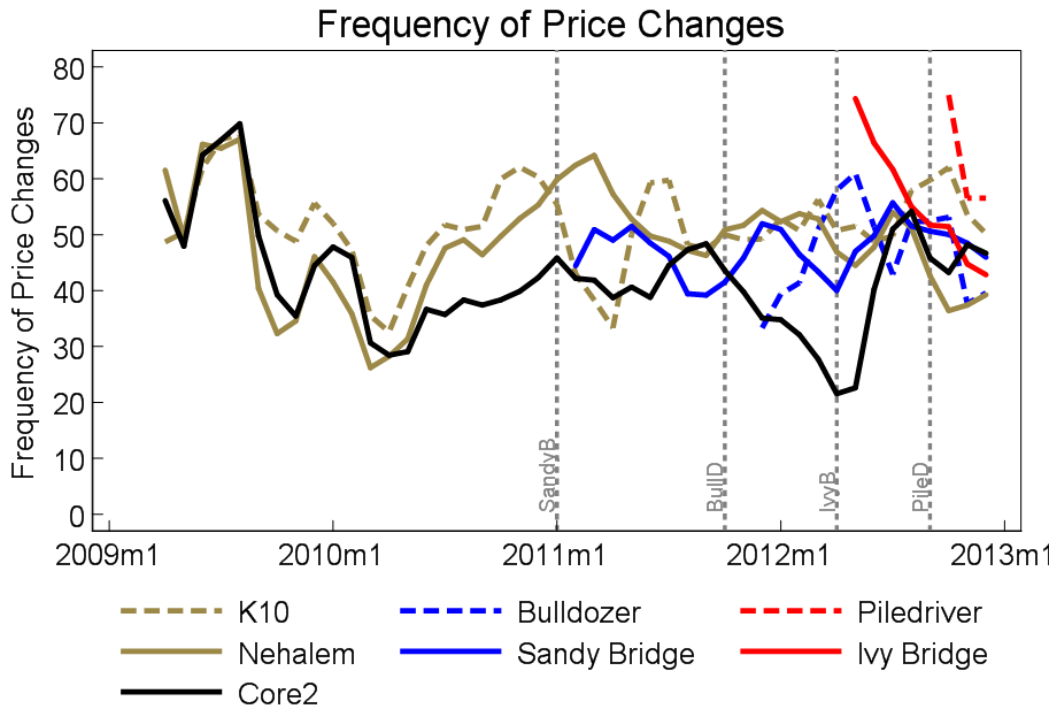
Frequency and Size of CPU Price Changes

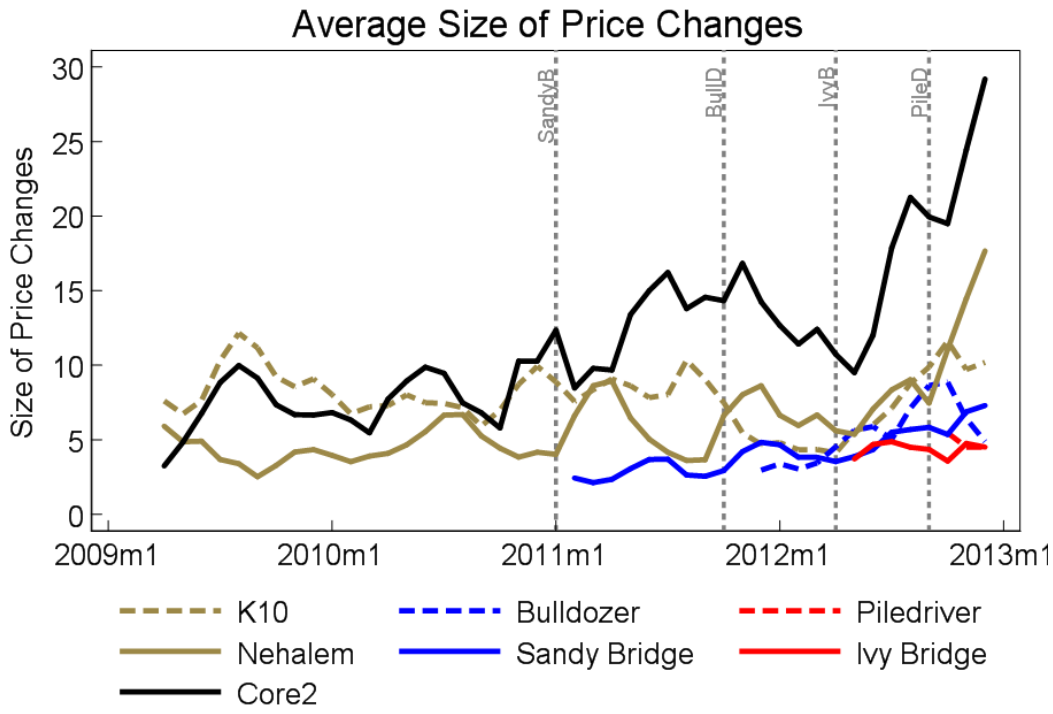
Weights:	Whole US Sample		Whole Canada Sample		US Online Market
	No	Yes	No	Yes	
	(1)	(2)	(3)	(4)	(5)
Posted Price					
Median Frequency, %	40.48	44.56	77.68	77.03	14.0
Implied Duration, Months	1.93	1.70	0.67	0.68	6.6
Median Absolute Size, Log Points	7.97	5.12	4.05	3.72	11.0
Regular Price					
Median Frequency, %	36.77	39.75	74.08	74.17	8.8
Implied Duration, Months	2.18	1.97	0.74	0.74	10.9
Median Absolute Size, Log Points	8.20	5.35	4.24	3.86	10.9

Column (5) shows the corresponding statistics from Gorodnichenko et al. (2018) for the United States online market

The results are weekly and without imputation and weights

Frequency and Size of CPU Price Changes

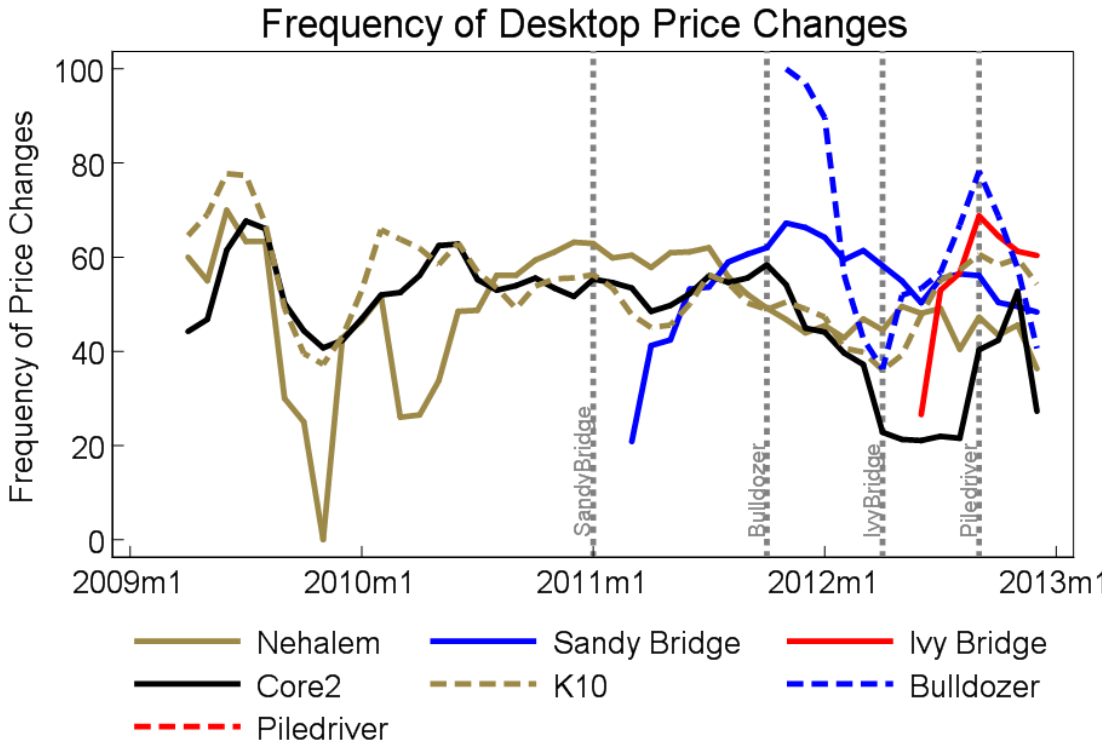


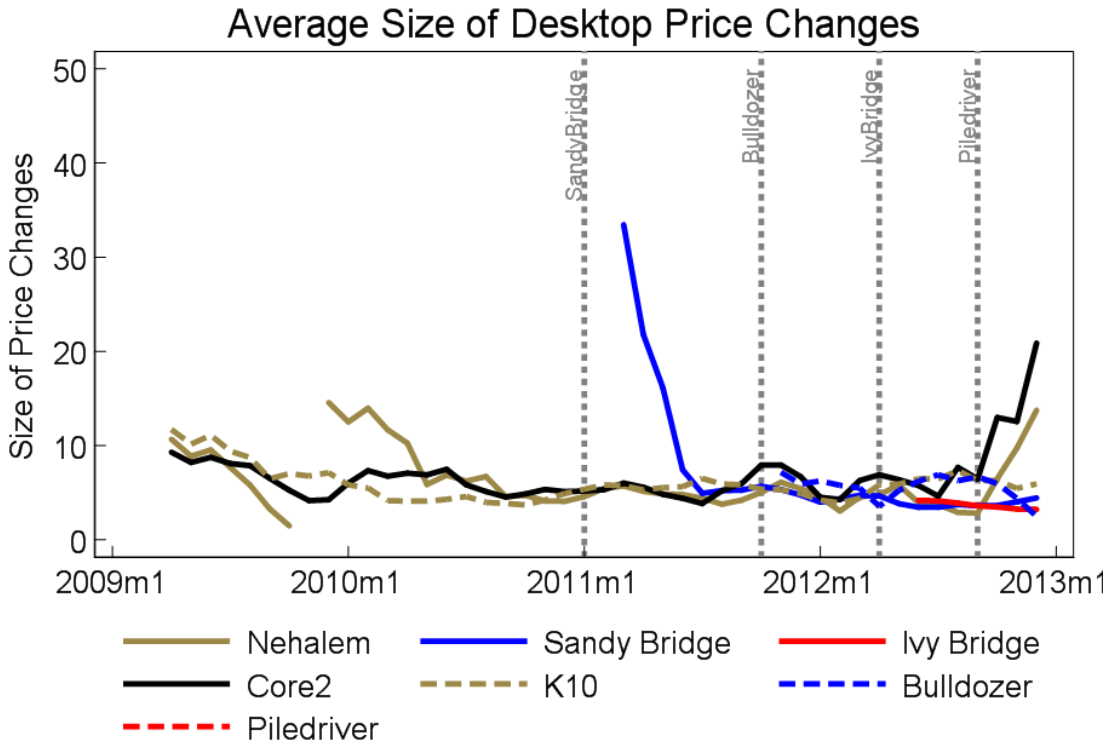


At introduction, new technology products often have high frequency and small size of price adjustments

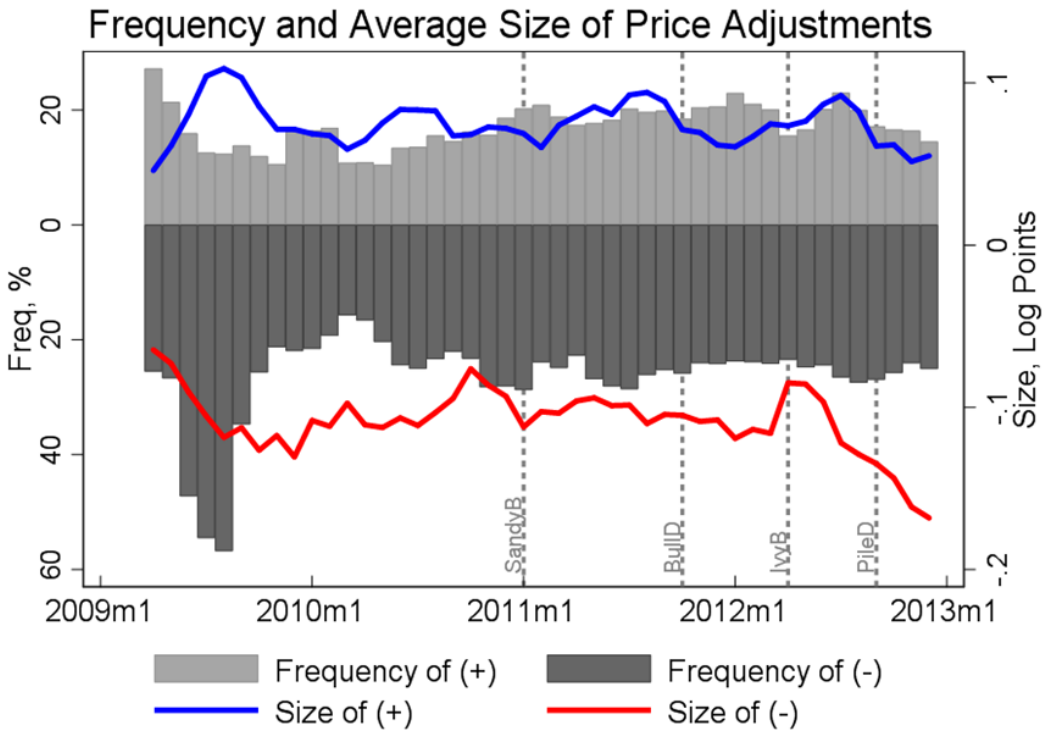
After the release of Intel Ivy Bridge, sellers started the clearance sales on Intel Core-2 CPUs

Frequency and Size of Desktop Price Changes

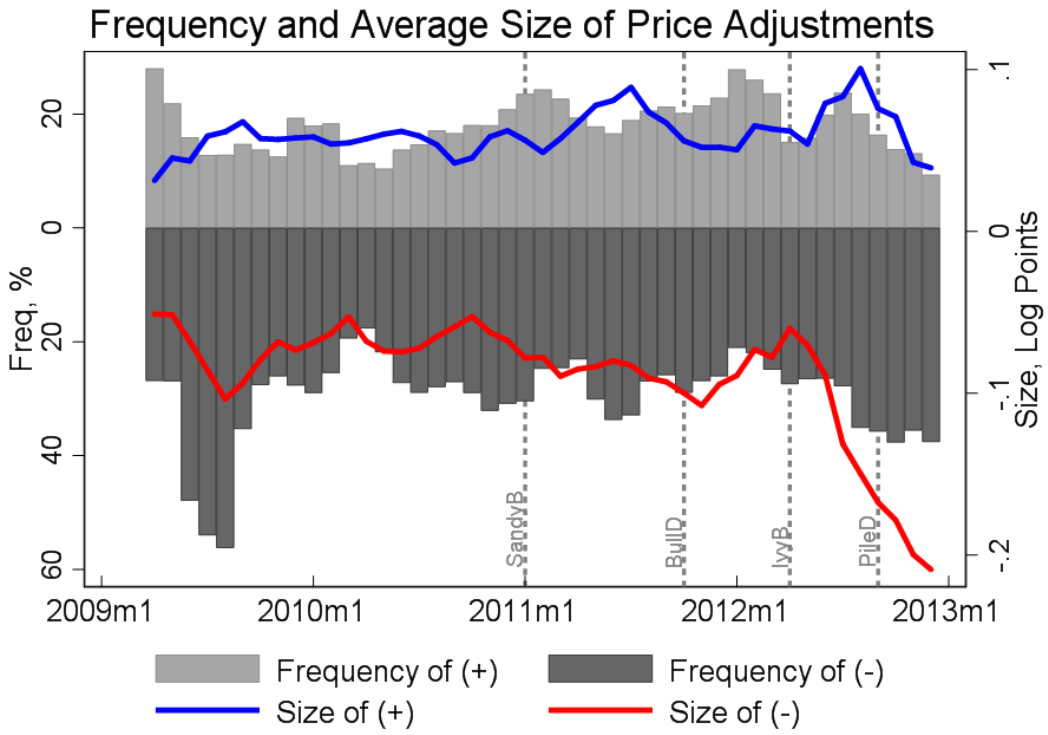




Frequency and Size of CPU Price Changes



Whole sample

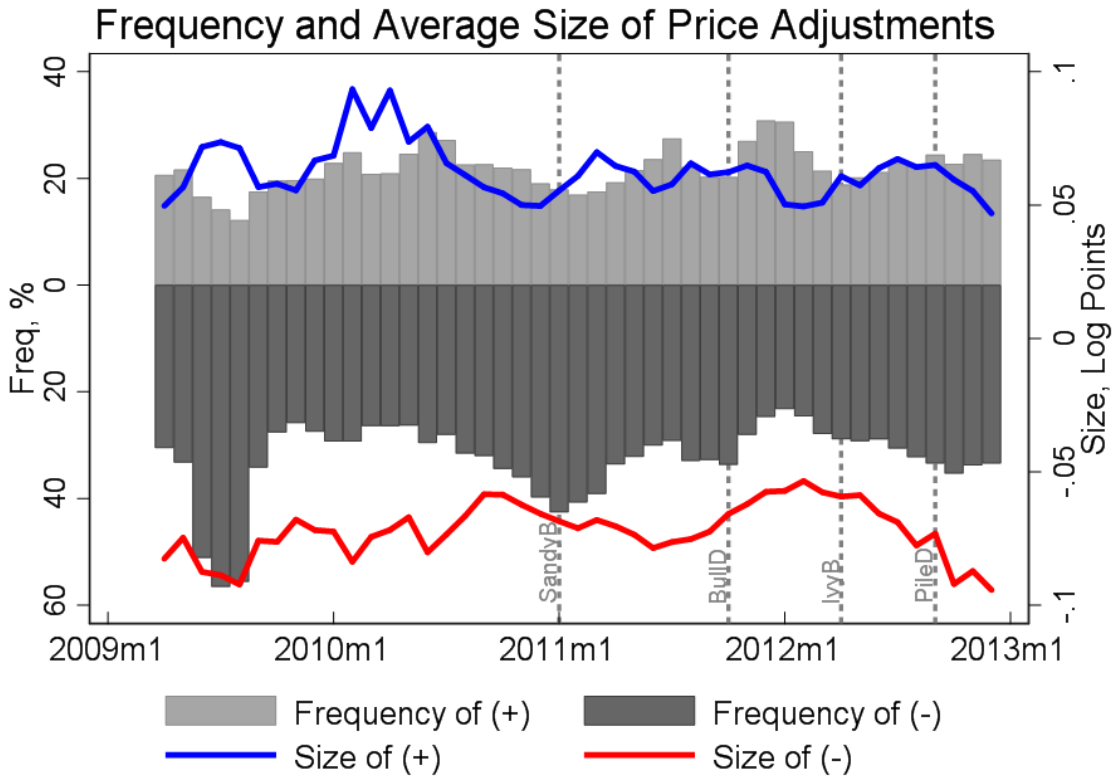


Core2/K-10/Nehalem

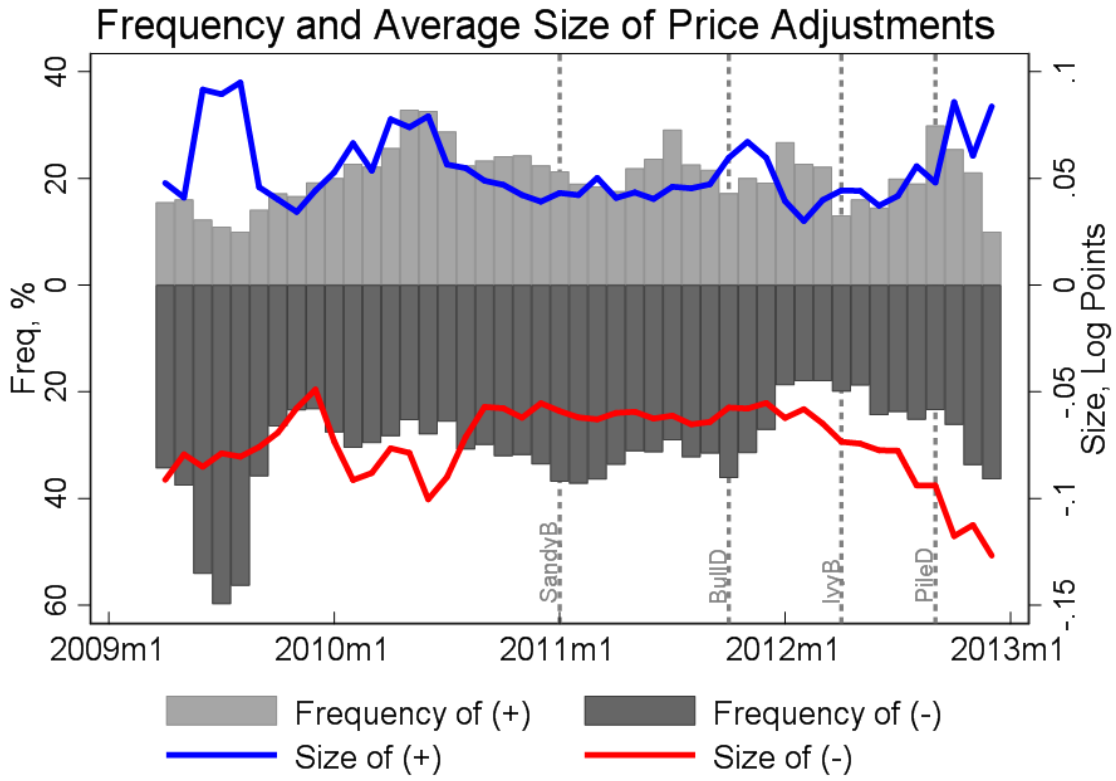
Negative price changes are more often and have bigger size than positive changes

Technology shocks seems to increase size of negative adjustments

Frequency and Size of Desktops Price Changes



Whole sample



Core2/K-10/Nehalem

Predictors of Price Stickiness

$$f_i = log\, S_i\, \beta_1 + log\, Q_i \beta_2 + \overline{logP_i}\beta_3 + \overline{logP_i}^2 \beta_4 + SPP_i \beta_5 + Stab_i \beta_6 + Intel_i \beta_7 + \gamma_t + \varepsilon_i$$

Where:

f_i is the frequency, frequency of (+), frequency of (-) or size of price change for product i

S_i is the # of sellers that offer product i

Q_i is the performance score of product i

$\overline{logP_i}$ is the log of the median price of product i

SPP_i (share of price points) is the percentage of price that end at 95-99 cents of product i

$Stab_i$ is the stability of the # of sellers that offering product i (1 quarter base)

$Intel_i$ = 1 if the brand of product is Intel

γ_t is the time fixed effect

Predictors of Regular-Price Stickiness (US)

Predictors	Frequency of Price Changes, % (1)	Frequency of Positive Changes, % (2)	Frequency of Negative Changes, % (3)	Absolute Size of Price Changes, Log Points (4)
Log # of Sellers	-0.029**	-0.004	-0.025**	-0.046***
	(0.013)	(0.007)	(0.010)	(0.008)
Log Performance Scores	0.035***	-0.003	0.038***	-0.026***
	(0.012)	(0.006)	(0.009)	(0.007)
Log Median Price	0.178**	0.039	0.139**	0.148***
	(0.070)	(0.038)	(0.056)	(0.045)
Log Median Price Squared	-0.018***	-0.004	-0.015***	-0.012***
	(0.006)	(0.003)	(0.005)	(0.004)
Share of Price Points	-0.080***	-0.059***	-0.021	0.032
	(0.030)	(0.016)	(0.024)	(0.021)
Stability of Sellers	-0.760***	-0.294***	-0.466***	0.048
	(0.100)	(0.053)	(0.079)	(0.062)
Intel CPU	0.050***	0.023***	0.027**	-0.005
	(0.016)	(0.008)	(0.013)	(0.010)
R^2	0.447	0.406	0.354	0.397
N	608	608	608	582

Predictors of Regular-Price Stickiness (US – Data from Gorodnichenko and Talavera, 2017)

Predictors	Frequency of Price Changes, % (1)	Frequency of Positive Changes, % (2)	Frequency of Negative Changes, % (3)	Absolute Size of Price Changes, Log Points (4)
Log # of Sellers	0.006	0.014	-0.007	-0.041**
	(0.036)	(0.021)	(0.028)	(0.018)
Log Performance Scores	0.178***	0.055***	0.123***	-0.084***
	(0.031)	(0.017)	(0.024)	(0.017)
Log Median Price	-0.062	0.101	-0.163	0.089
	(0.146)	(0.083)	(0.113)	(0.075)
Log Median Price Squared	-0.005	-0.012*	0.008	-0.004
	(0.013)	(0.007)	(0.010)	(0.006)
Share of Price Points	-0.019	-0.016	-0.003	-0.030
	(0.056)	(0.032)	(0.043)	(0.033)
Stability of Sellers	-0.482***	-0.242**	-0.240*	0.159*
	(0.182)	(0.104)	(0.141)	(0.091)
Intel CPU	-0.014	0.026	-0.040	-0.006
	(0.033)	(0.019)	(0.026)	(0.018)
R^2	0.411	0.343	0.387	0.526
N	282	282	282	264

Predictors of Regular-Price Stickiness (Canada – Data from Gorodnichenko and Talavera, 2017)

Predictors	Frequency of Price Changes, % (1)	Frequency of Positive Changes, % (2)	Frequency of Negative Changes, % (3)	Absolute Size of Price Changes, Log Points (4)
Log # of Sellers	0.053	0.007	0.046*	-0.024**
	(0.034)	(0.021)	(0.024)	(0.010)
Log Performance Scores	0.054**	0.026*	0.028*	0.016**
	(0.022)	(0.014)	(0.016)	(0.007)
Log Median Price	0.477***	0.087	0.391***	-0.147***
	(0.136)	(0.086)	(0.096)	(0.042)
Log Median Price Squared	-0.043***	-0.007	-0.036***	0.011***
	(0.012)	(0.007)	(0.008)	(0.004)
Share of Price Points	-0.285***	-0.125***	-0.160***	-0.013
	(0.054)	(0.034)	(0.038)	(0.017)
Stability of Sellers	-0.260	0.035	-0.295**	0.012
	(0.172)	(0.108)	(0.121)	(0.052)
Intel CPU	0.050*	0.056***	-0.006	-0.039***
	(0.029)	(0.018)	(0.020)	(0.009)
R^2	0.565	0.512	0.469	0.385
N	338	338	338	333

Predictors of Price Stickiness

$$f_{it} = log\, S_{it}\, \beta_1 + \overline{logP_{it}}\beta_2 + \overline{logP_{it}}^2\beta_3 + SPP_{it}\beta_4 + Stab_{it}\beta_5 +$$
$$+ \boldsymbol{HP\_Entry_{it}\beta_6} + \boldsymbol{HP\_Exit_{it}\beta_7} + \boldsymbol{LP\_Entry_{it}\beta_8} + \boldsymbol{LP\_Exit_{it}\beta_9} + \alpha_i + \gamma_t + \varepsilon_{it}$$

$$f_{it} = log\, S_{it}\, \beta_1 + \overline{logP_{it}}\beta_2 + \overline{logP_{it}}^2\beta_3 + SPP_{it}\beta_4 + Stab_{it}\beta_5 +$$
$$+ \boldsymbol{Upgrading_{it}\beta_6} + \boldsymbol{Downgrading_{it}\beta_7} + \alpha_i + \gamma_t + \varepsilon_{it}$$

Predictors of Regular-Price Stickiness

Predictors	Frequency of Price Changes, % (1)	Frequency of Positive Changes, % (2)	Frequency of Negative Changes, % (3)	Absolute Size of Price Changes, Log Points (4)
Log # of Sellers	-0.001	0.013***	-0.014***	-0.031***
	(0.005)	(0.004)	(0.005)	(0.003)
Log Median Price	0.445***	0.260***	0.186***	-0.067*
	(0.058)	(0.043)	(0.051)	(0.038)
Log Median Price Squared	-0.051***	-0.018***	-0.032***	-0.000
	(0.006)	(0.004)	(0.005)	(0.004)
Share of Price Points	-0.101***	-0.055***	-0.046***	0.021***
	(0.011)	(0.008)	(0.009)	(0.008)
Stability of Sellers	-0.078***	-0.086***	0.009	0.029***
	(0.014)	(0.011)	(0.013)	(0.010)
Log # of Higher CPU Enter	0.034***	0.018**	0.016**	-0.004
	(0.009)	(0.007)	(0.008)	(0.005)
Log # of Lower CPU Enter	0.024***	-0.001	0.024***	-0.007
	(0.008)	(0.006)	(0.007)	(0.006)
Log # of Higher CPU Exit	0.003	-0.006	0.009	0.016***
	(0.009)	(0.007)	(0.008)	(0.005)
Log # of Lower CPU Exit	-0.013	-0.012*	-0.001	0.015**
	(0.009)	(0.007)	(0.008)	(0.006)
R^2	0.348	0.200	0.283	0.335
N	14428	14428	14428	8463

Predictors of Regular-Price Stickiness

Predictors	Frequency of Price Changes, % (1)	Frequency of Positive Changes, % (2)	Frequency of Negative Changes, % (3)	Absolute Size of Price Changes, Log Points (4)
Log # of Sellers	0.000	0.014***	-0.014***	-0.031***
	(0.005)	(0.004)	(0.005)	(0.003)
Log Median Price	0.459***	0.264***	0.195***	-0.067*
	(0.058)	(0.043)	(0.051)	(0.038)
Log Median Price Squared	-0.052***	-0.019***	-0.033***	-0.000
	(0.006)	(0.004)	(0.005)	(0.004)
Share of Price Points	-0.103***	-0.055***	-0.047***	0.020**
	(0.011)	(0.008)	(0.009)	(0.008)
Stability of Sellers	-0.075***	-0.085***	0.011	0.027***
	(0.014)	(0.011)	(0.013)	(0.010)
Upgrading	-0.063***	-0.041***	-0.022	0.004
	(0.021)	(0.016)	(0.019)	(0.014)
Downgrading	0.010	0.004	0.007	-0.000
	(0.015)	(0.011)	(0.014)	(0.009)
R^2	0.348	0.200	0.283	0.334
N	14428	14428	14428	8463

Results

- Better quality products could have
  - Higher frequency of price changes
  - Smaller size of price changes
- Markets with more sellers could have higher frequency of negative price changes
  - More competition could lead to better prices
- Price flexibility increases in the median price for low- and moderate-price goods (nearly 75% of goods in our sample)
  - Consistent with the view that increased returns to search could make prices more flexible
- The bigger is the share of price points, the stickier are prices
  - Bounded rationality may play some role in price rigidity
- The more stable is the number of sellers, the stickier are prices
  - Markets that are more difficult for sellers to enter would have higher level of price stickiness

Is There More Price Convergence for High Quality Goods?

Intra-Month Dispersion Across Sellers

Average Dispersion of Posted Price Across Sellers

	CV $std(P)/\bar{P}$	*Std(log P)*	VI $\bar{P}$ - P_{min}	IQR $P_{75\%} - P_{25\%}$	Range $P_{max} - P_{min}$	Gap $P_{min1} - P_{min2}$	Std(ε)	N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No Weights	24.22	25.15	26.48	35.73	50.10	25.21	21.49	675
Performance Weighted	16.51	16.44	17.81	21.75	39.54	13.01	13.84	675

Seller fixed effects control for: delivery, return, sellers' reputation, seller-customer relationship, customer experience, and so on

$$logP_{ist} = \alpha_i + \delta_s + \varepsilon_{ist}$$

Seller fixed effects account for 11.3% - 16.2% of price dispersion across sellers, depending on weights

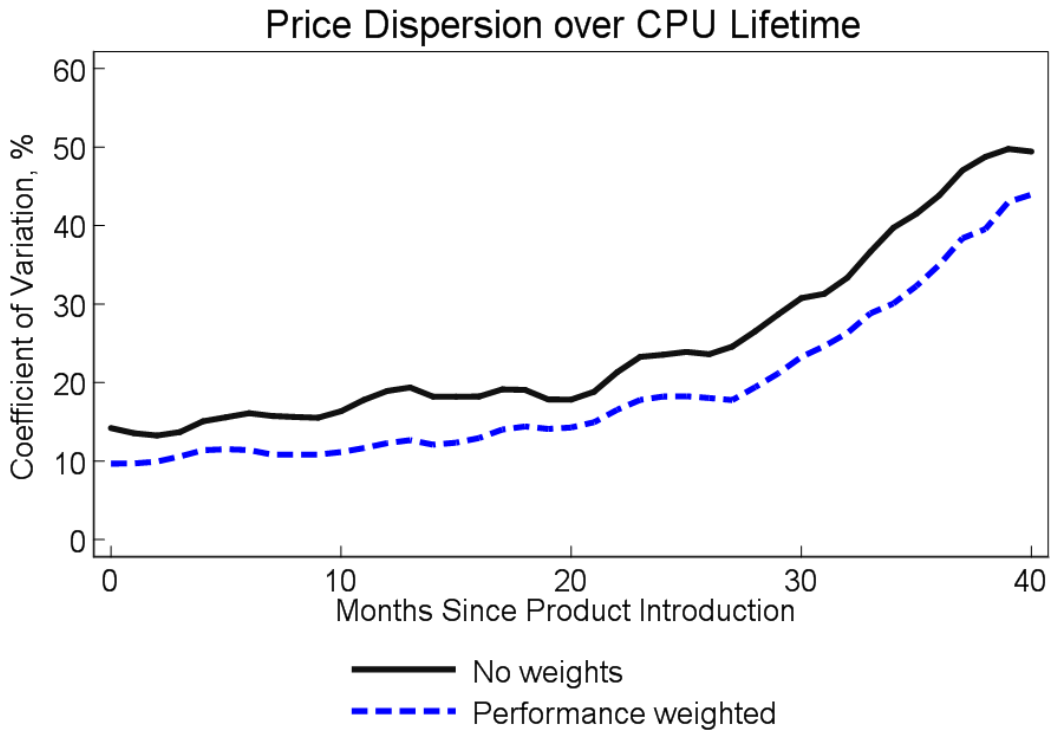
Intra-Month Dispersion Across Sellers (Canada)

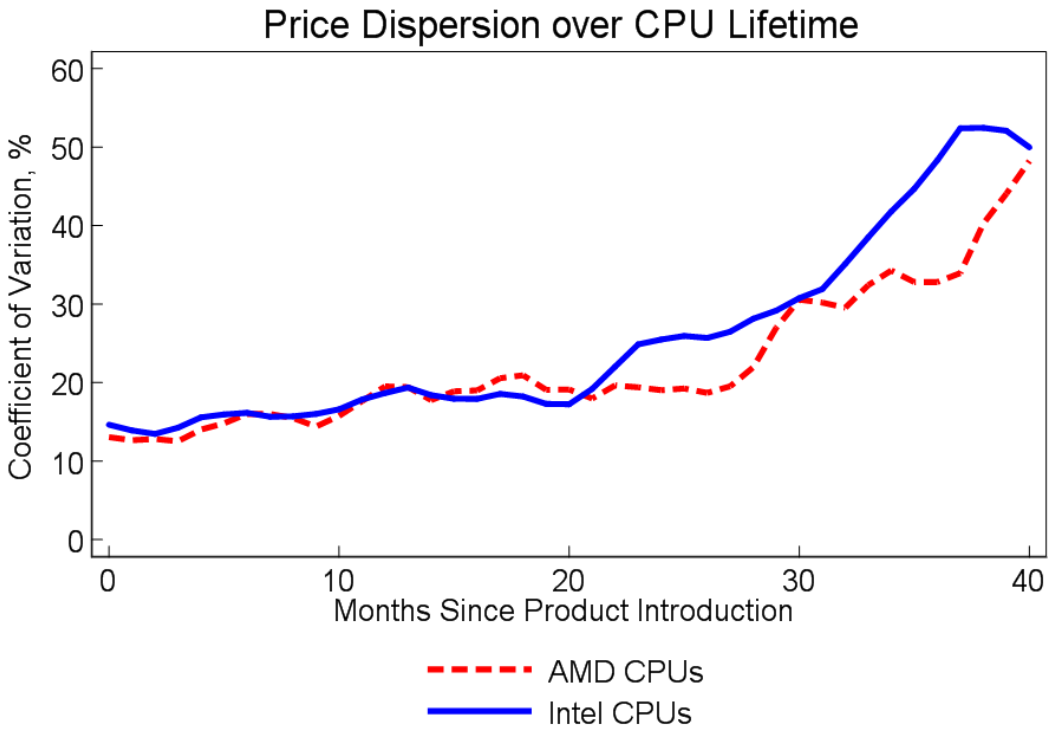
Average Dispersion of Posted Price Across Sellers

	CV $std(P)/\bar{P}$	*Std(log P)*	VI $\bar{P}$ - P_{min}	IQR $P_{75\%} - P_{25\%}$	Range $P_{max} - P_{min}$	Gap $P_{min1} - P_{min2}$	Std(ε)	N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No Weights	8.82	8.77	8.82	12.52	17.85	7.90	8.24	257
Performance Weighted	8.10	8.02	7.81	11.22	16.12	7.25	7.97	257

- The impact of goods quality on price dispersion is similar in Canada but with smaller magnitude
- Canada seems to have lower price dispersion level in CPU online market

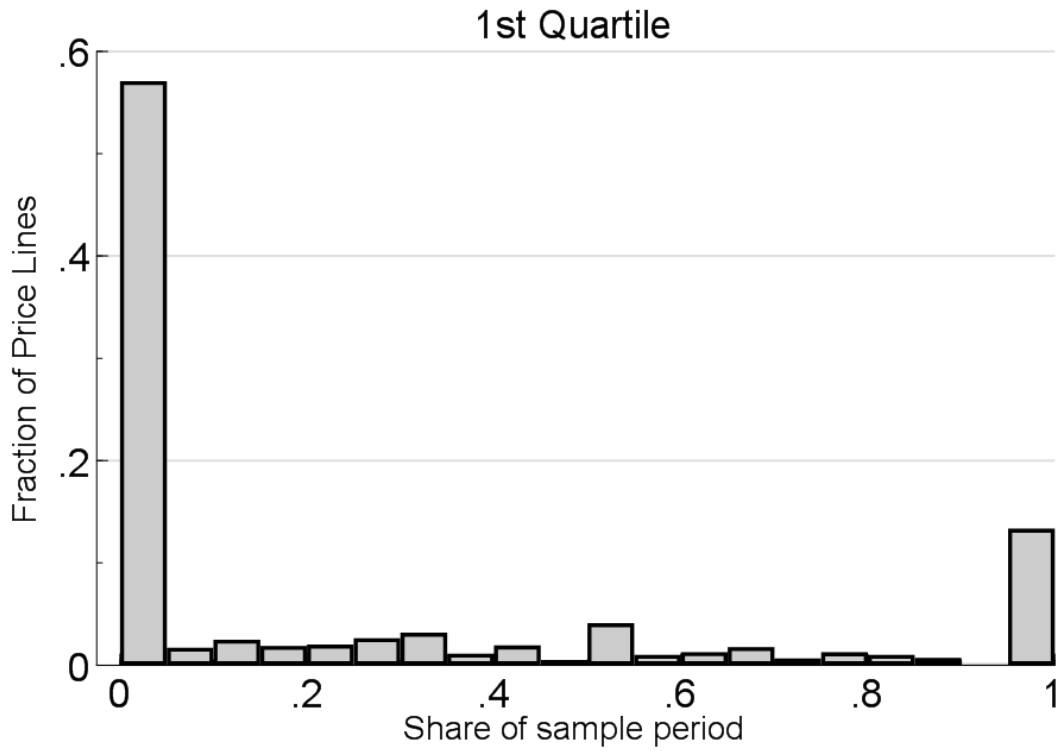
Price Dispersion Since Product Introduction

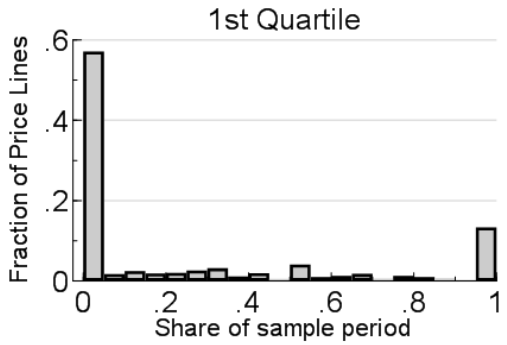


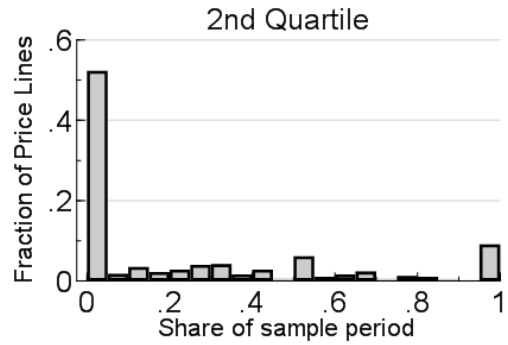


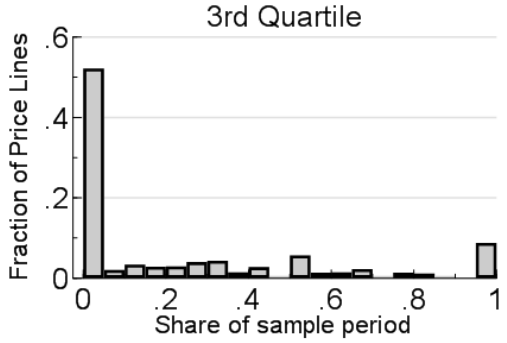
- Price dispersion increases over the lifetime of product
- Higher quality products have less price dispersion than lower quality products
- 20 first weeks since product introduction, Intel and AMD CPUs has similar price dispersion level
- After 20 weeks, Intel CPU's price dispersion is often higher than AMD's

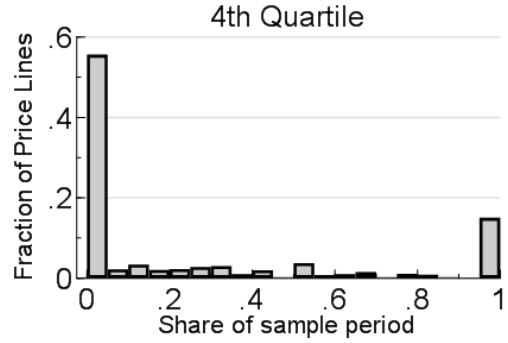
Spatial vs Temporal Price Dispersion











Predictors of Price Dispersion

$$f_i = log\, S_i\, \beta_1 + log\, Q_i \beta_2 + \overline{log P_i} \beta_3 + SPP_i \beta_4 + FreqRP_i \beta_5 + SizeRP_i \beta_6 +$$
$$+ Sync_i \beta_7 + Stab_i \beta_8 + \gamma_t + \varepsilon_i$$

Where:

f_i is the measure of price dispersion for product i

$\mathrm{FreqRP_i}$ is the frequency of regular price changes of product i

$\mathrm{SizeRP_i}$ is the absolute size of regular price changes of product i

$\mathrm{Sync_i}$ is the synchronisation rate of posted price changes across seller within product i

γ_t is the time fixed effect

Predictors of Price Dispersion

Predictors	Standard Deviation of Log Price (1)	Net of seller fixed effects (2)
Log # of Sellers	-0.011	0.011
	(0.016)	(0.012)
Log Performance Scores	-0.091***	-0.085***
	(0.019)	(0.014)
Log Median Price	0.045***	0.052***
	(0.015)	(0.011)
Share of Price Points	0.056	0.009
	(0.056)	(0.041)
Frequency of Regular Price Changes, %	0.288***	0.208***
	(0.079)	(0.058)
Size of Regular Price Changes, Log Points	0.010***	0.008***
	(0.001)	(0.001)
Synchronization of Posted Price Changes	-0.075	-0.078*
	(0.061)	(0.045)
Seller Stability	0.323**	0.094
	(0.128)	(0.094)
Intel CPU	0.012	-0.004
	(0.020)	(0.015)
R^2	0.534	0.586
N	482	482

CPU Quality-Adjusted Price Indexes

Specification of Hedonic Regression

$$\overline{logP_{it}} = D_2\beta_1 + logQ_i\beta_2 + \varepsilon_{it}$$

Where:

$\overline{\text{logP}_{it}}$ is the log of the median price across sellers of product i at time t

D_2 is dummy variable = 1 if price observation is in the 2nd year of the 2-year overlapping period

Q_i is the performance score of product i

CPU Index

Regression results for 2009 – 2012

	2009-2010	2010-2011	2011-2012
Year Dummy	-0.146***	-0.139***	-0.068***
	(0.020)	(0.016)	(0.015)
Ln Performance	0.788***	0.785***	0.714***
	(0.011)	(0.010)	(0.009)
R^2	0.516	0.477	0.427
N	4649	7285	8370

Specification of Hedonic Regression

$$\overline{logP_{it}} = D_2\beta_1 + logQ_i\beta_2 + log\,S_{it}\,\beta_3 + SPP_{it}\beta_4 + Stab_{it}\beta_5 + Intel_i\beta_6 + \varepsilon_{it}$$

Where:

$\overline{\text{logP}_{it}}$ is the log of the median price across sellers of product i at time t

D_2 is dummy variable = 1 if price observation is in the 2nd year of the 2-year overlapping period

Q_i is the performance score of product i

S_i is the # of sellers that offer product i at time t

SPP_{it} (share of price points) is the percentage of price that end at 95-99 cents of product i at time t

$Stab_{it}$ is the stability of the # of sellers that offering product i (1 quarter base) at time t

$Intel_i = 1$ if the brand of product is Intel

CPU Index

Regression results for 2009 – 2012

	2009-2010	2010-2011	2011-2012
Year Dummy	-0.043**	-0.091***	-0.022*
	(0.018)	(0.014)	(0.011)
Log Performance Scores	0.772***	0.776***	0.668***
	(0.009)	(0.008)	(0.008)
Log # of Sellers	-0.142***	-0.140***	-0.125***
	(0.011)	(0.008)	(0.008)
Share of Price Points	-0.127***	-0.036*	-0.096***
	(0.025)	(0.020)	(0.021)
Stability of Sellers	0.234***	0.301***	0.224***
	(0.039)	(0.034)	(0.034)
Intel	0.494***	0.472***	0.407***
	(0.019)	(0.015)	(0.034)
R^2	0.610	0.599	0.499
N	5549	8183	9787

Conclusion

1. The quality of goods indeed does affect price setting behaviours on online market

   Better quality products could have

   - Higher frequency of price changes
   - Smaller size of price changes
   - Lower price dispersion

2. Entries of products could increase frequency of price adjustments of existing products

   - However, if the number of low-quality products is large enough to upgrade an existing product to a higher quality quartile, that existing product would decrease the frequency of price changes.

3. Deflation in CPU market