Offshoring and Price Measurement in the Semiconductor Industry

David Byrne
Federal Reserve Board

Brian K. Kovak
University of Michigan

Ryan Michaels
University of Michigan

Measurement Issues Arising from the Growth of Globalization
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Research Question

How do shifting international sourcing patterns affect measures of semiconductor input prices?

Why Semiconductors?

- Critical input to high-end domestic manufacturing and productivity growth
- Large, continuing movement to offshore production
- Recent shifts to China
- Discrete technological advance – allows quality adjustment
- Unique data on input prices by country and detailed product characteristics

Preview of Results and Conclusions

Results

- Baseline quality adjusted price decline for processed semiconductor wafers: 12.6% per year

- Shifting sourcing toward low-cost countries' suppliers contributes additional decline up to 0.8% per year
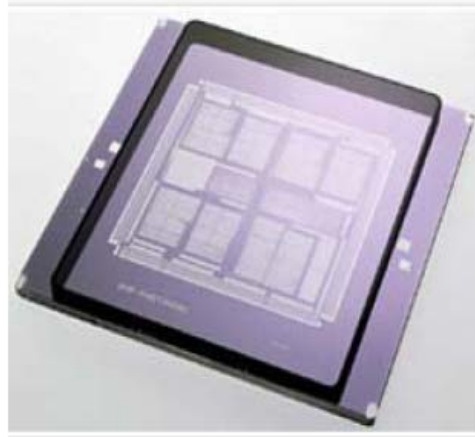
Conclusions

- Quality measurement remains the primary challenge

- Shifting sourcing patterns can result in important biases in input price measurement

- Particulars of semiconductor fabrication industry make equilibrium price dispersion plausible

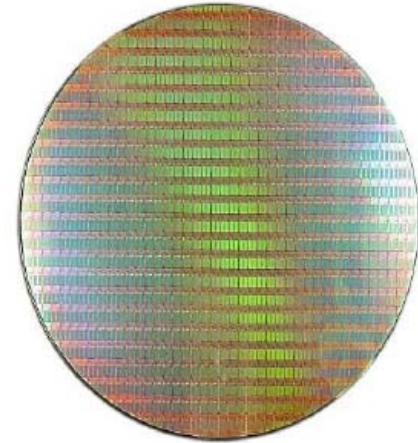# Semiconductor Production
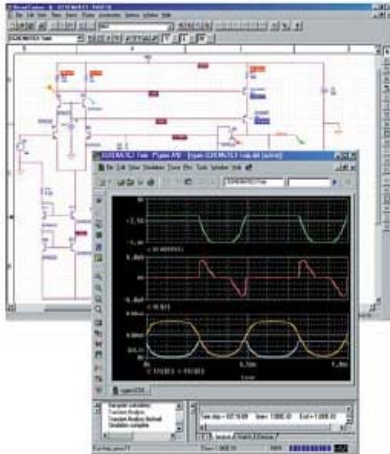
Design / Intellectual Property
(fileextensions.com)

Mask
(dnpamerica.com)

Wafer Fabrication
(hardwarezone.com)

Test
(visionxinc.com)
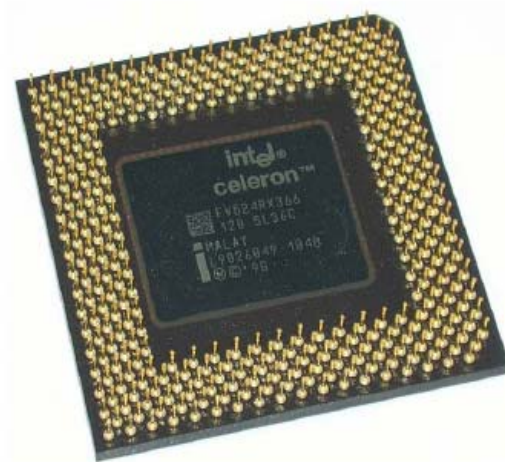
Package
(cpu-world.com)

Final Goods
(hisandherscreative.com)

Semiconductor Production

Critical Technological Characteristics

- Wafer Size
  - Current diameters: 150mm, 200mm, 300mm
  - Savings ≈ 30% per chip (Kumar 2007)

- Line Width – size of each transistor
  - Current widths: 500nm – 32nm
  - Savings ≈ 40% per chip (Kumar 2007)

Semiconductor Production

Moore's Law - Increasing Transistors per Chip

Sources: http://www.intel.com/technology/timeline.pdf
http://www.intel.com/pressroom/kits/quickreffam.htm

Semiconductor Production

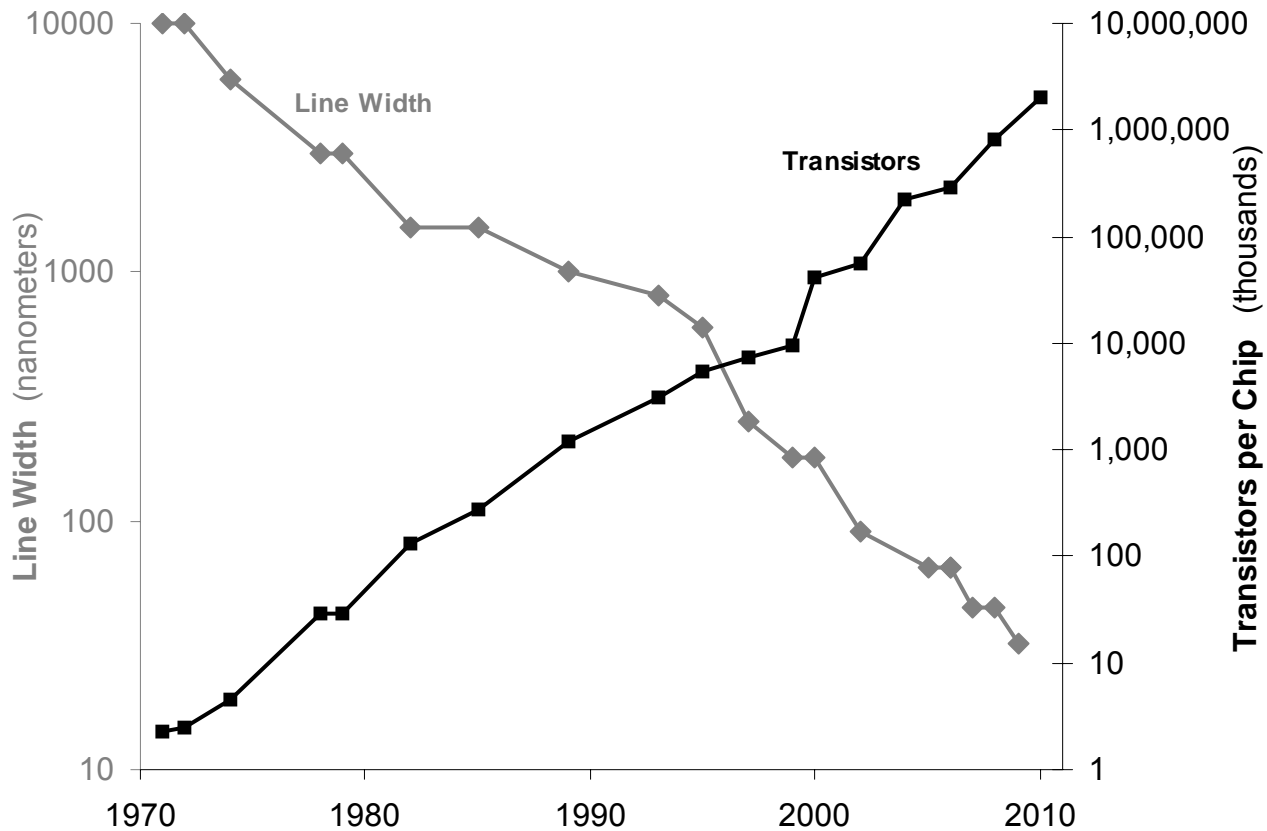TSMC Technology Cycle
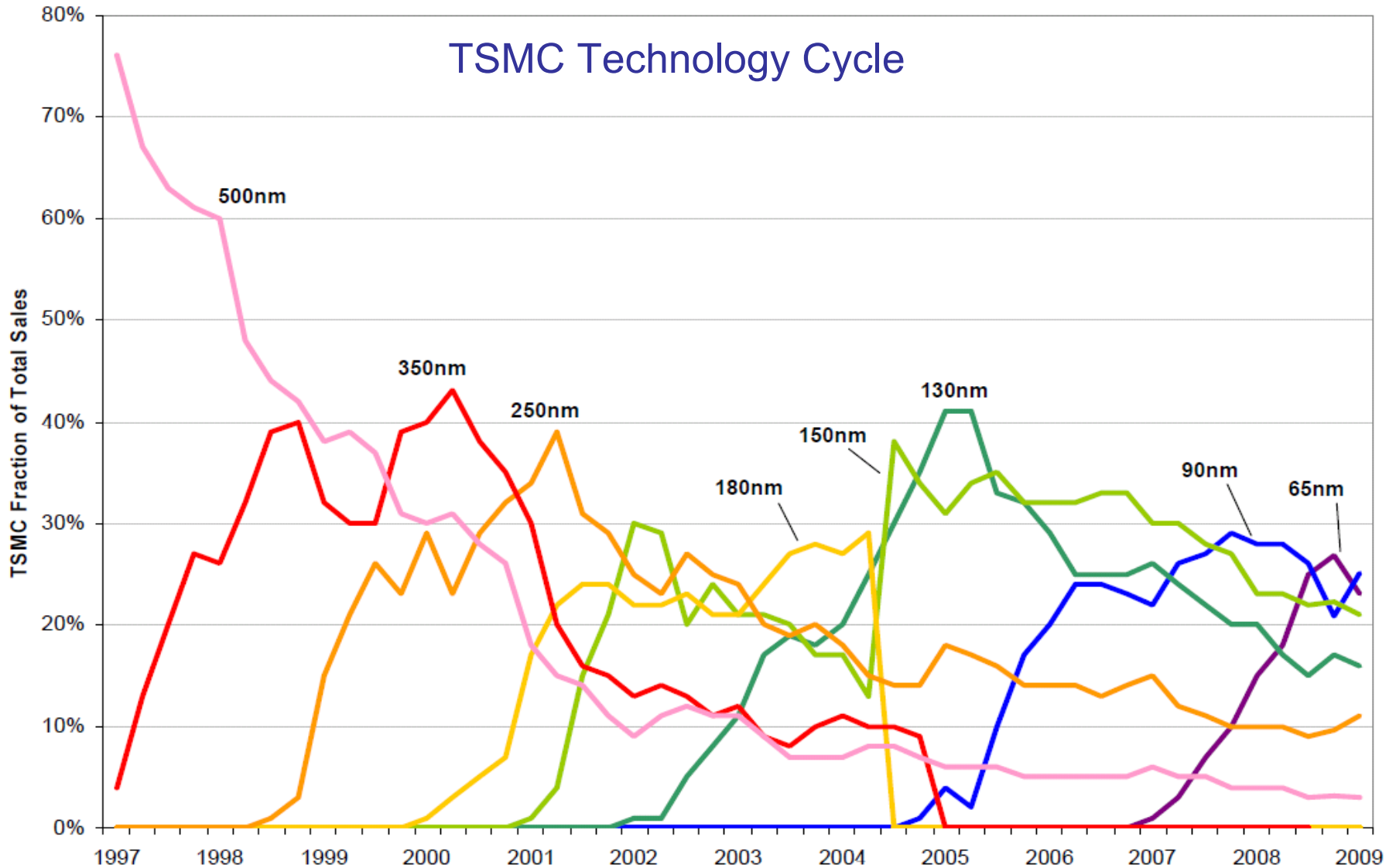
Source: TSMC quarterly reports

Semiconductor Production

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- Logic Family
- Number of Layers
  - Chip complexity
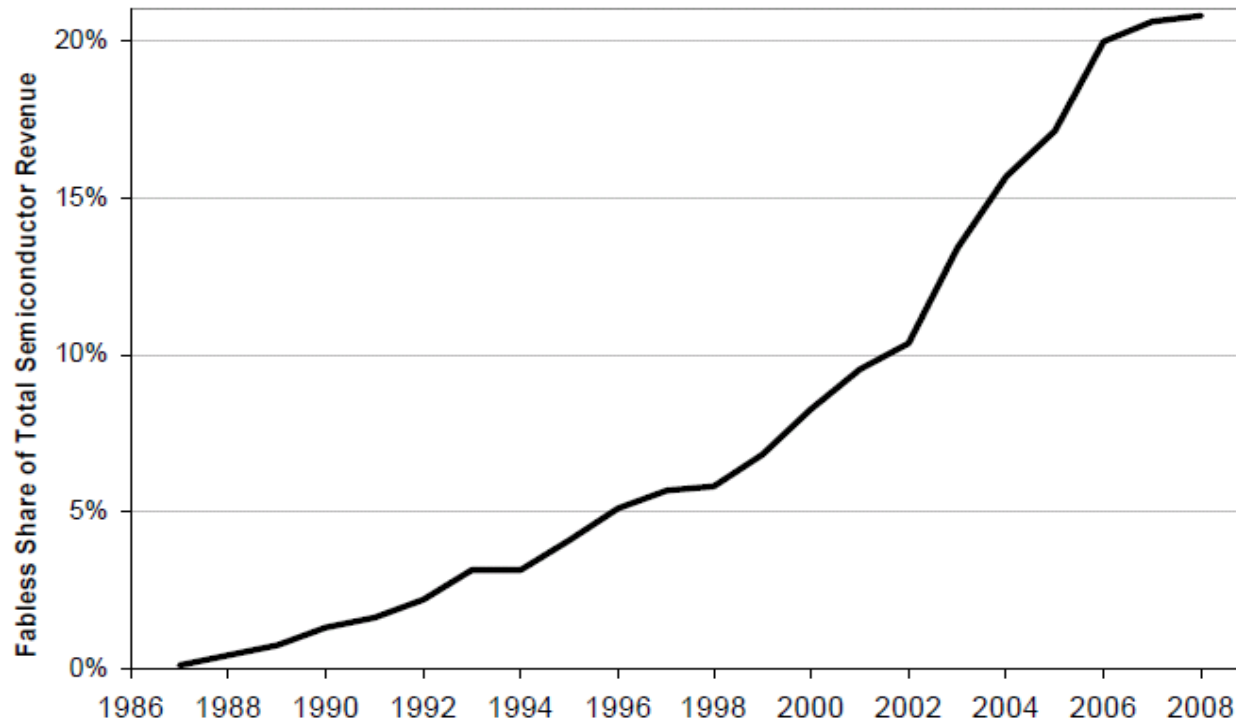 - More masks, materials, production time

Semiconductor Production

Changing Market Structure

- Most packaging and assembly in Asia since 1970's
- Recently, wafer fabrication moving to Asia
- Growth of "fabless" firms and foundry production model

Semiconductor Production

Growth of Fabless Business Model

Sources: Global Semiconductor Association (GSA) and Semiconductor Industry Association (SIA)

China
Korea
Japan
India
Taiwan
Hong Kong
Philippines
Thailand
Vietnam
Malaysia
Singapore

Foundry Capacity
fraction of world 200mm equivalent starts

	1997	2007
Americas	16.0%	0.5%
USA	16.0%	0.5%
Other Americas	0.0%	0.0%
Europe, Middle East, Africa	4.3%	2.2%
W. Europe	4.1%	0.6%
E. Europe	0.0%	0.0%
Middle East, Africa	0.2%	1.6%
Asia	79.6%	94.4%
China	8.4%	25.1%
Hong Kong	0.0%	0.0%
India	0.0%	0.0%
Japan	0.0%	1.9%
Malaysia	4.3%	3.3%
Philippines	0.0%	0.0%
S. Korea	4.3%	3.3%
Singapore	15.4%	13.3%
Taiwan	43.6%	47.6%
Thailand	3.4%	0.0%
Vietnam	0.0%	0.0%
Other Asia	0.2%	0.0%

Source: Gartner

Semiconductor Production

Implications for Price Measurement

- Use discrete technology nodes to control for quality
- Model: wafer size, line width, logic family
- Calculate price per layer

- Focus on foundry production (avoid transfer pricing)

Data

Wafer Prices

- Global Semiconductor Alliance *Wafer Fabrication & Back-End Pricing Survey*
- Quarterly 2004-08
- Observations represent individual contracts
- Technological features, foundry location (country), price

Quantities

- Foundry capacity by technology and country
- Constructed from multiple industry sources

Descriptive Statistics

	Mean	Std. Dev	Yearly Means				
			2004	2005	2006	2007	2008
Price Per Wafer ($)	1575.40	1145.54	1,576.58	1,609.53	1,502.86	1,545.03	1,655.18
Number of Wafers Contracted	2307	7514	1924	2357	1941	2710	2627
Number of Layers Per Wafer	25.74	7.57	23.25	24.64	25.79	26.64	27.93
Metal Layers	4.77	1.81	4.23	4.55	4.75	4.97	5.27
Wafer Size							
150 mm or less	0.14	0.35	0.17	0.17	0.15	0.12	0.10
200 mm	0.76	0.42	0.80	0.77	0.79	0.76	0.70
300 mm	0.10	0.30	0.03	0.06	0.06	0.12	0.20
Line Width							
65 nm	0.00	0.06	0.00	0.00	0.00	0.00	0.01
90 nm	0.03	0.16	0.00	0.08	0.01	0.03	0.07
130 nm	0.23	0.42	0.14	0.18	0.22	0.27	0.32
180 nm	0.25	0.43	0.26	0.27	0.26	0.26	0.22
250 nm	0.13	0.34	0.13	0.16	0.12	0.12	0.09
older vintage	0.36	0.48	0.45	0.38	0.38	0.31	0.28
CMOS process	0.92	0.28	0.92	0.92	0.92	0.91	0.91

5464 Observations

Source: Authors' calculations based on GSA Wafer Fabrication & Back-End Pricing Survey

Price Indexes

Fisher matched-model index

- Model: country, technology cells
- Implicit assumption: price level difference across countries for same technology reflects quality differences
- Average yearly price decline: 12.6%

Average price index

- Average prices across country within technology
  (follows Reinsdorf 1993)
- Implicit assumption: quality is identical across countries for a given technology
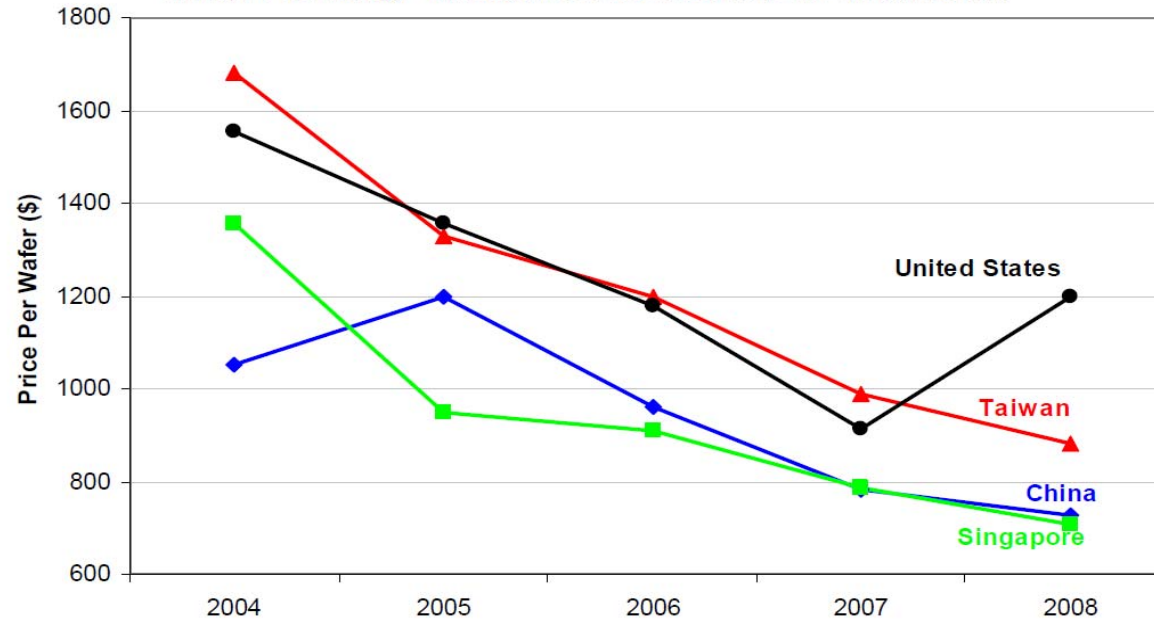- Average yearly price decline: 13.4%

Price Indexes

Cross-country price variation

- Large startup costs for a given chip on a particular production line
- Staggered product introduction across countries

Leading Edge Technology - CMOS, Wafer Size: 300mm, Line Width: 130nm
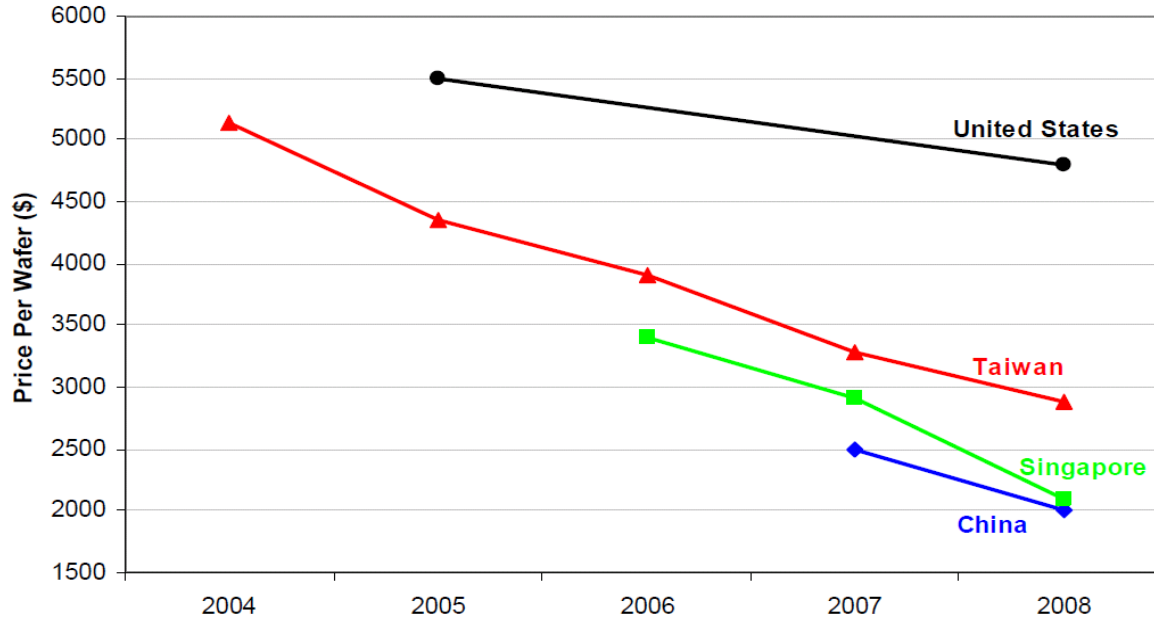
Mature Technology - CMOS, Wafer Size: 200mm, Line Width: 180nm

Price Indexes

Hedonic index

- Dependent variable: log price
- Independent variables: indicators for country, wafer size, line width, and quarter; layers per wafer, number of metal
- Very similar results with more flexible specifications
- Average yearly price decline: 10.8%

Official Semiconductor index

- BLS IPP for HS 8542 – electronic IC's
- Average yearly price decline: 2.9%

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			Fisher Matched-Model Indexes				Average	Hedonic	BLS IPP
Quarter	Overall	Taiwan	China	Singapore	USA	Europe	Price Index	Index	HS 8542
2004Q1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2004Q2	101.5	101.7	99.9	102.7	97.5	108.5	100.7	99.5	98.3
2004Q3	99.6	103.2	90.1	101.7	97.2	94.6	98.4	97.7	97.1
2004Q4	93.5	95.1	84.3	102.1	95.5	89.1	89.5	91.3	95.9
2005Q1	91.3	86.9	100.5	101.5	93.0	89.5	87.7	87.4	95.5
2005Q2	83.5	76.9	95.2	94.1	95.2	85.1	79.1	87.3	95.1
2005Q3	81.7	79.5	85.5	88.7	80.0	86.8	79.5	83.8	93.9
2005Q4	82.0	79.2	90.6	85.8	79.3	92.1	77.8	82.7	93.5
2006Q1	76.4	73.6	83.5	82.0	69.4	87.2	72.8	78.4	94.0
2006Q2	74.4	71.6	77.8	84.2	70.8	82.0	70.4	74.1	93.8
2006Q3	72.4	69.4	78.0	80.8	66.4	82.0	68.7	73.6	94.6
2006Q4	69.6	65.9	78.6	76.4	64.1	82.1	66.3	71.0	95.3
2007Q1	70.3	67.1	77.7	75.7	65.6	87.6	66.9	69.2	93.3
2007Q2	67.9	63.3	77.4	77.1	59.1	90.0	64.8	67.6	88.8
2007Q3	62.8	58.7	67.2	74.8	56.0	88.4	59.7	65.3	90.0
2007Q4	59.6	55.5	65.3	70.1	52.2	84.1	56.5	64.5	90.3
2008Q1	60.4	55.7	66.3	71.7	58.2	83.7	57.3	65.0	88.5
2008Q2	57.1	51.9	63.9	68.2	57.1	83.3	54.3	61.9	87.5
2008Q3	58.2	52.5	68.2	65.0	69.2	85.3	55.3	59.6	85.8
2008Q4	54.2	49.2	63.1	59.7	63.4	82.9	51.4	59.7	85.6
Year									
2004	98.6	100.0	93.6	101.6	97.6	98.1	97.2	97.1	97.8
2005	84.6	80.6	93.0	92.5	86.9	88.4	81.0	85.3	94.5
2006	73.2	70.1	79.5	80.9	67.7	83.3	69.5	74.3	94.4
2007	65.2	61.2	71.9	74.5	58.2	87.5	62.0	66.6	90.6
2008	57.5	52.3	65.4	66.2	62.0	83.8	54.6	61.6	86.9
Avg. Yearly Change '04-'08	-12.6%	-14.9%	-8.6%	-10.2%	-10.7%	-3.9%	-13.4%	-10.8%	-2.9%

Conclusions

Quality measurement remains the primary challenge

Shifting sourcing patterns can result in important biases in input price measurement

Particulars of semiconductor fabrication industry make equilibrium price dispersion plausible