Macro from Micro:
Estimates and Implications of Sector-Specific Technical Change

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Why should central banks care about disaggregated data?

- Central banks control a small number of policy instruments
  - Maybe just one
- Thus, a consensus that they can target only a few variables
- Generally these targets are some of the key macro aggregates
- Do central banks need to know about disaggregated data to target macro variables using aggregate instruments?

Yes, for at least one important example

- Central banks try to forecast and target *output gaps*
- With frictions like sticky prices/wages, technical change typically creates output gaps and also changes future *potential output*
- Suppose, however, that technical change is not uniform across *final-use sectors* (consumption, investment)
  - The price of TVs has fallen much faster than the price of hair cuts
- What if this were true over higher frequencies too?
- Aggregate Solow productivity residual gives a weighted average of TFP growth across all sectors—can be measured readily
- Is that good enough? If not what richer measures do we need?

Sectoral foundations of aggregate macro

Show that

1. The average is not a sufficient statistic for either output gaps or potential output
2. Central banks should care about sector-specific technical change, even if they only target macro aggregates
3. The most robust way to estimate sectoral technology is using disaggregated industry data

This talk draws on the following co-authored papers:

"Sector-specific technical change," with Fernald, Fisher and Kimball

"Technology Shocks in a Two-Sector DSGE Model," with Fernald and Liu

Macro Example: A 2-Sector Sticky-Price Model

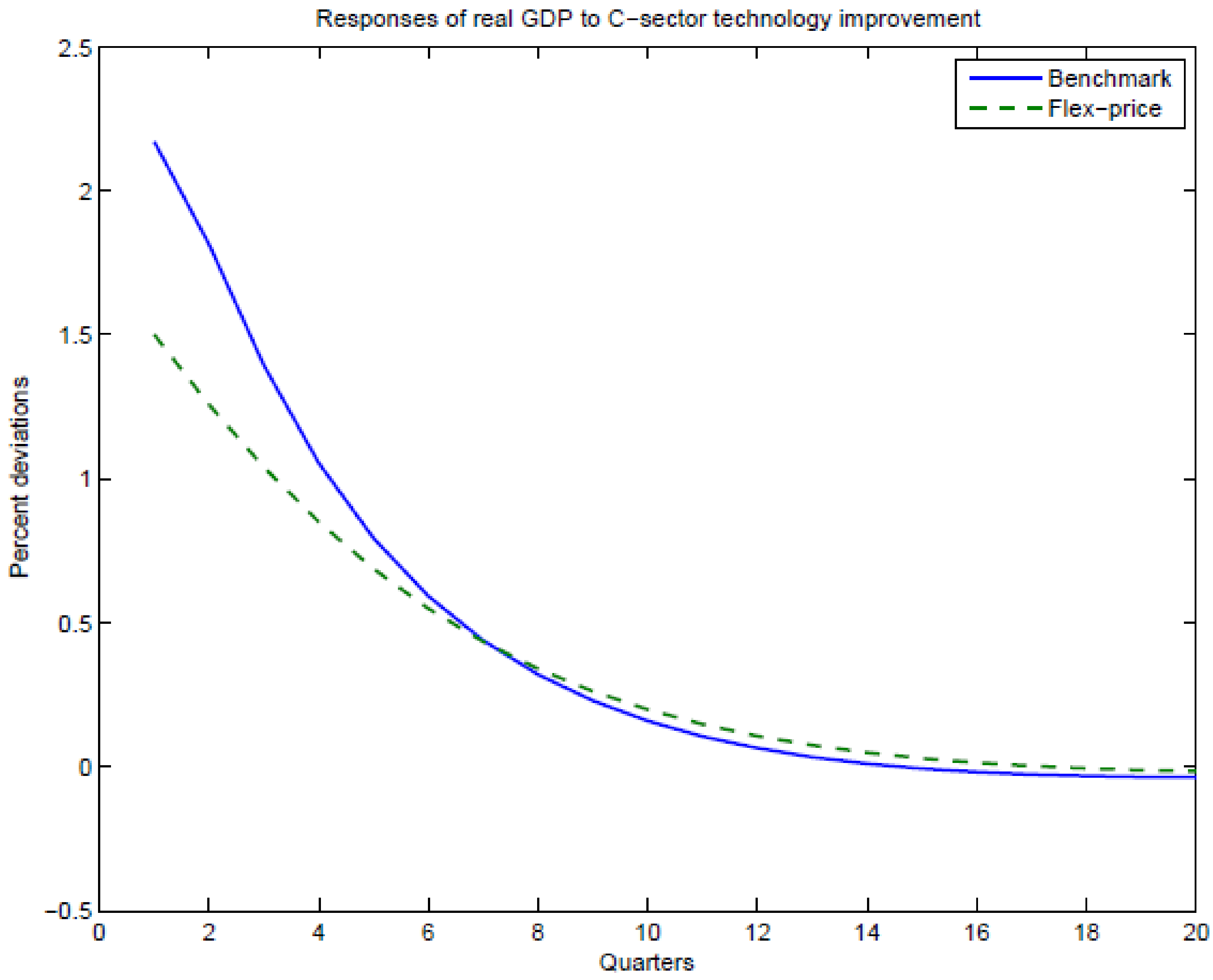
- Variant of CEE (2005) / Smets-Wouters (2007)
  - Sticky nominal prices & wages, habit formation, capital adjustment costs, variable capital utilization, KPR utility with IES < 1
- Novelty: Separate sectors for C and I goods; sticky prices for both
- Cobb-Douglas production functions for C and I

$$C = Z^C \cdot K_C^\alpha L_C^{1-\alpha} - \Phi$$

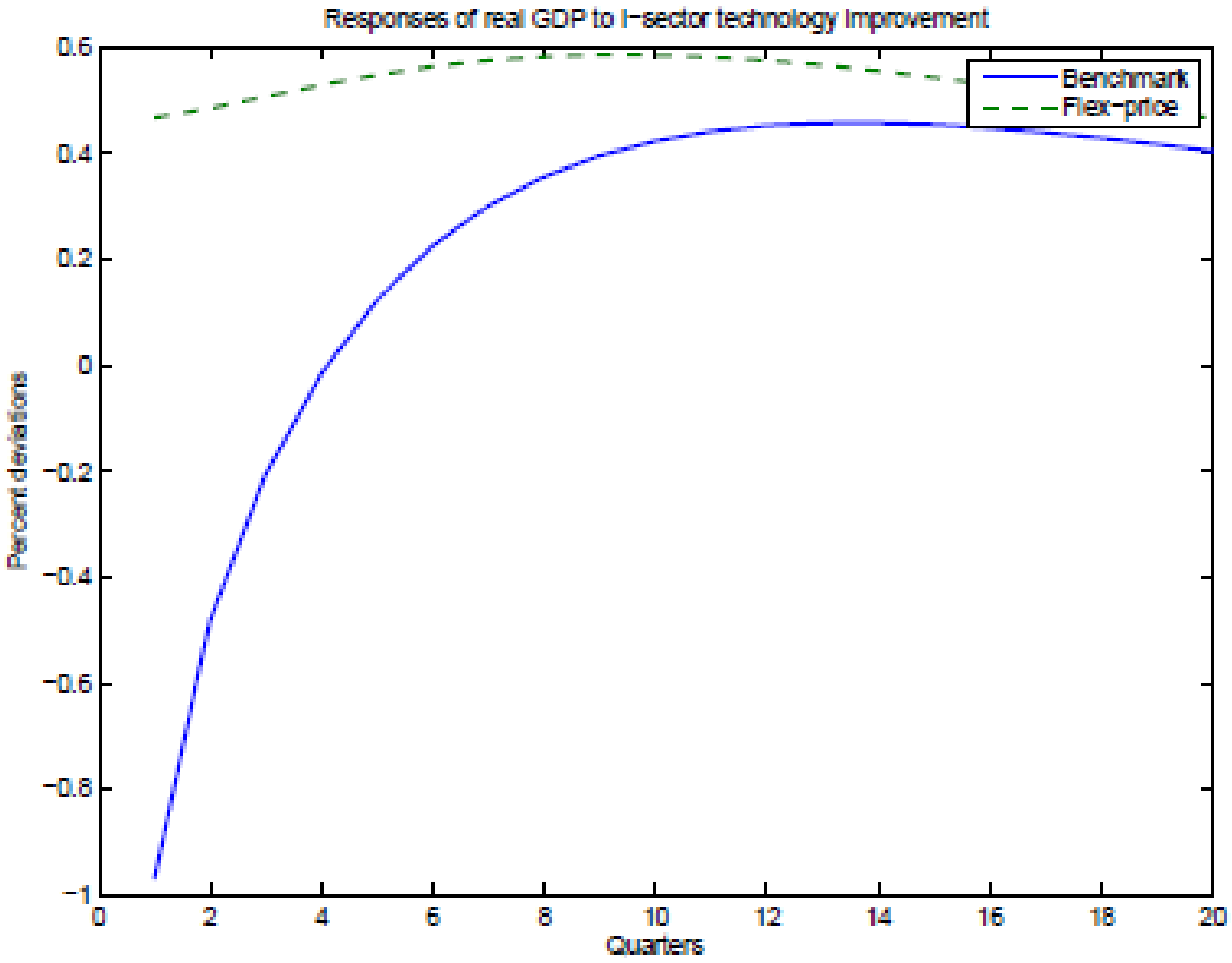
$$J = Z^J \cdot K_J^\alpha L_J^{1-\alpha} - \Phi$$

  - Same fixed cost of production (10 percent of st. st. output)
  - Same factor shares ($\alpha = 0.33$)
- Factors mobile across sectors
- Calvo-pricing : Probability $\theta_C = \theta_J = 0.75$ of keeping unchanged price
- Monetary policy follows Taylor rule, where Fed targets the "marginal cost gap" and consumer inflation

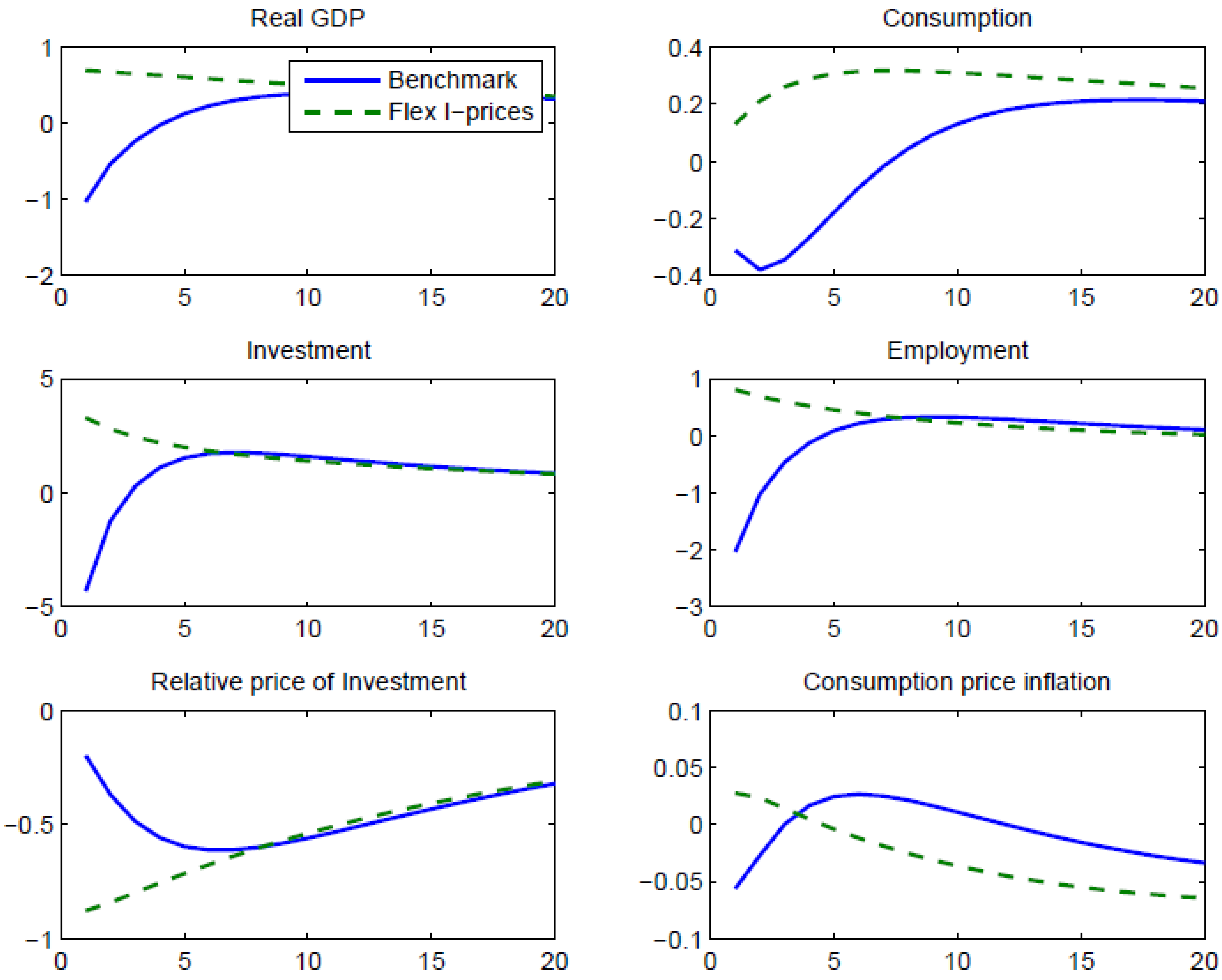
Response to consumption technology improvement



Response to investment technology improvement

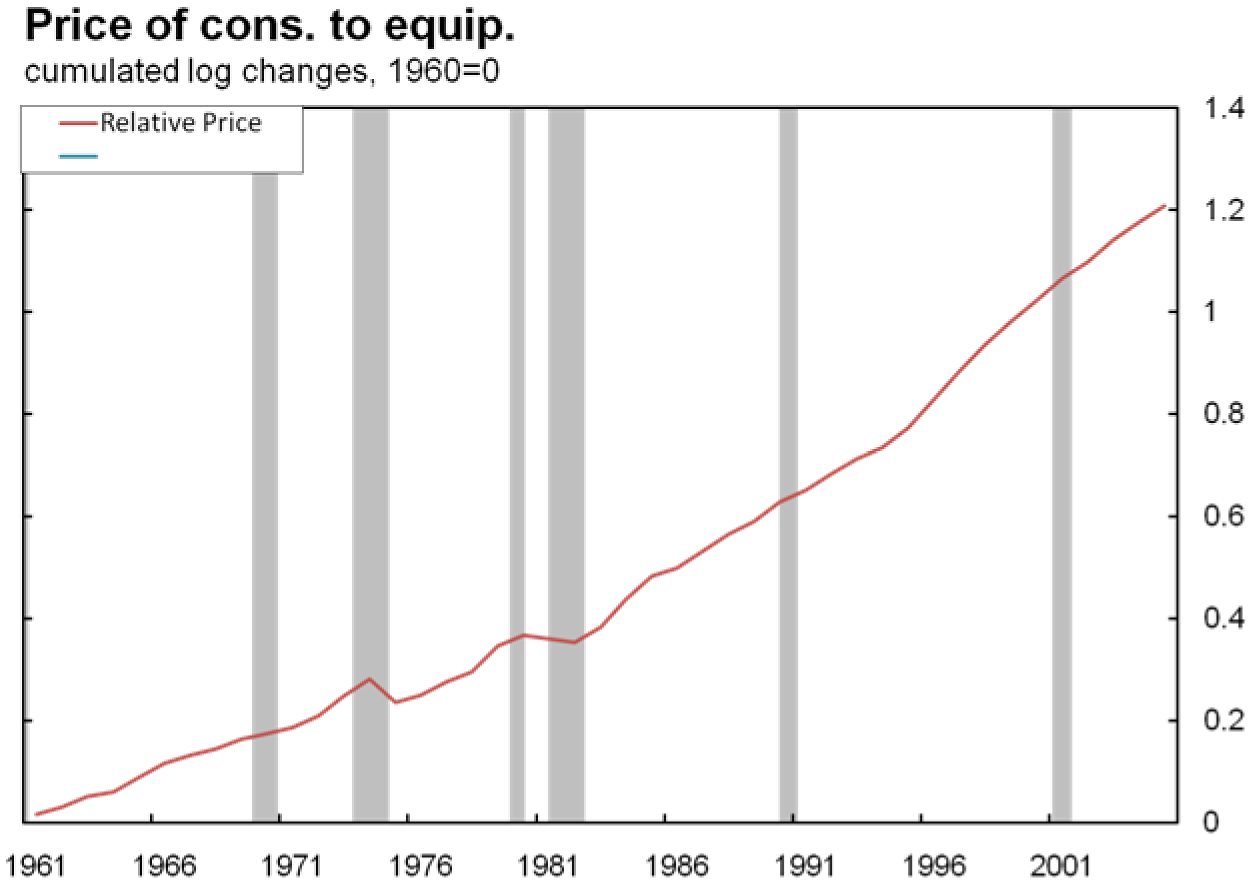


Why the contraction when Z^J improves?



How to measure Z^C and Z^J? Existing method pioneered by Greenwood, Hercowitz, and Krusell

- Use relative **price** of cons. to equip. to infer relative **technology** of equipment to consumption



Do relative final-goods prices reflect relative technologies?

- Producer sets $P_i^{\text{Producer}} \equiv \mu_i MC^i$, though purchaser pays $P_i = (1+\tau_i)\, P_i^{\text{Producer}}$:

$$\frac{P_C}{P_J} = \frac{(1+\tau_C)\mu_C MC^C}{(1+\tau_J)\mu_J MC^J} = \frac{(1+\tau_C)\mu_C\left(\frac{1}{Z_C}\right)\left[R_C{}^{\alpha_C} W_C{}^{(1-\alpha_C)}\right]}{(1+\tau_J)\mu_J\left(\frac{1}{Z_J}\right)\left[R_J{}^{\alpha_J} W_J{}^{(1-\alpha_J)}\right]}$$

- In log deviations,

$$\hat{P}_C - \hat{P}_J \simeq \left(\hat{Z}_J - \hat{Z}_C\right) + \left(\hat{\tau}_C - \hat{\tau}_J\right) + \left(\hat{\mu}_C - \hat{\mu}_J\right)$$
$$+\left[\alpha_C \hat{R}_C + (1-\alpha_C)\hat{W}_C\right] - \left[\alpha_J \hat{R}_J + (1-\alpha_J)\hat{W}_J\right]$$

- If identical production functions (especially factor shares)…
  …and identical factor price movements…
  …and identical time variation in markups and taxes …
- then relative price changes give relative technology change.
- Strong assumptions; would like to relax (and test)

Method: Estimate final-use technology "directly" (I)

- Problem: 2-sector production model is simple, but data are complicated and messy
- Many industries/types of goods in the world
- They sell intermediate goods to one another
- Some of their output is aggregated into final goods
  - Conceptually, consider stream of production leading to a final consumption or investment good, e.g., C_i
  - The technology for producing it depends on the technologies used in all the goods that are aggregated into that final good, and the technologies for all the intermediate goods used to produce those goods, …

Method: Estimate final-use technology "directly" (II)

- Use input-output table and estimates of the industry production functions to back out implied final-goods technology
- Proposed method is exactly correct if
  - All industries have Cobb-Douglas production functions
  - The aggregators for producing final goods (e.g., C and J) from industry output are also Cobb-Douglas
  - There is perfect competition and constant returns everywhere
- A closely-related aggregation procedure works with imperfect competition and increasing returns
  - Get qualitatively the same results with either set of assumptions

Using input-output tables to map disaggregated technology shocks into final-use technology

- Direct technology estimates from industry production functions
  - vector *dz* of (gross-output) technology shocks, $[dz_1, dz_2, \ldots]'$
- Implicit production function for delivering output to final consumption or investment. Intuition:
- Matrix *B* is (nominal) intermediate input shares
  - b_{ij} is share of commodity *j* in producing commodity *i*
- Technology for deliveries to final demand

$$\begin{bmatrix} dz_1^f \\ dz_2^f \\ \ldots \end{bmatrix} = \begin{bmatrix} dz_1 \\ dz_2 \\ \ldots \end{bmatrix} + B \begin{bmatrix} dz_1 \\ dz_2 \\ \ldots \end{bmatrix} + B^2 \begin{bmatrix} dz_1 \\ dz_2 \\ \ldots \end{bmatrix} + \ldots$$

$$dz^f = (I - B)^{-1} dz$$

Given TFP for final-use commodities, Z^C, Z^J, etc. easy

- With Cobb-Douglas aggregator, final-use technologies are:

$$dz_t^C = b_C[I-B]^{-1}dz_t$$

$$dz_t^J = b_J[I-B]^{-1}dz_t$$

$$dz_t^G = b_G[I-B]^{-1}dz_t$$

$$dz_t^{NX} = b_{NX}[I-B]^{-1}dz_t$$

- b's and B are data. Need to feed in vector of industry dz's for each period

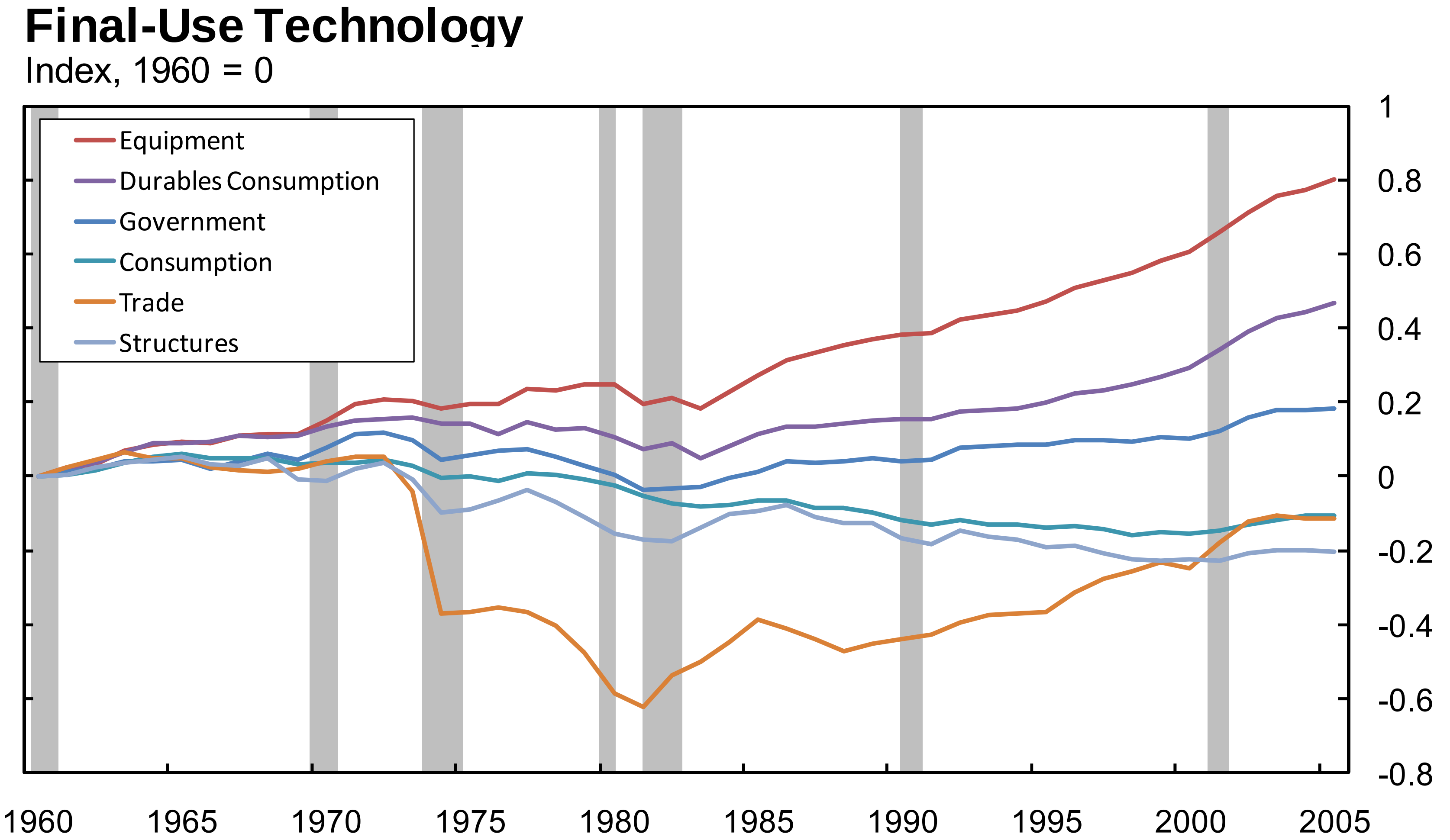
We estimate industry technology residuals dz_i following Basu-Fernald-Kimball (2006, AER)

- Regress industry output growth dy_i on input growth dx_i and hours-per worker growth dh_i:

$$dy_i = c_i + \gamma_i dx_i + \beta dh_i + \varepsilon_i$$

- Use updated Ramey-Hall instruments:
  - Hamilton-style oil-price increases,
  - government defense spending,
  - monetary innovations from an SVAR
- "Corrected" technology $dz_i = (c_i + \varepsilon_i)$ controls for factor utilization and non-constant RTS
  - For agriculture, mining, and govt enterprises, where BFK don't estimate residuals, we use uncorrected TFP
  - Also use an unadjusted terms of trade

Feeding industry BFK shocks through I-O tables: Equip and con. dur. technology rise fastest



Cumulated log change in final-use BFK technology

Relative sectoral technology diverges from typical macro proxy of relative prices

Correlation of growth in relative TFP, relative BFK technology, and relative output prices

	Relative TFP	Relative BFK Technology	Relative Final-goods prices
Relative TFP $(dz_{Equipment} - dz_{Consumption})$	1		
Relative BFK Technology $(dz_{BFK,\ Equipment} - dz_{BFK,\ Consumption})$	0.28	1	
Relative final-goods prices $(dp_{Consumption} - dp_{Equipment})$	0.76	0.23	1

- Relative price changes have correlation (in annual data) of only 0.23 with relative BFK technology

Investment technology and consumption technology have very different macroeconomic effects—just as model predicts

		Technology Shock								
		Equipment (lag)			Consumption (lag)			Net Exports (lag)		
	Var. (log-change)	dzje(0)	dzje(-1)	dzje(-2)	dzc(0)	dzc(-1)	dzc(-2)	dznx(0)	dznx(-1)	dznx(-2)
(1)	GDP	**-0.70**	**-0.28**	0.25	**0.73**	**0.66**	-0.28	-0.07	0.09	0.09
		(0.15)	***(0.09)***	*(0.18)*	***(0.20)***	***(0.26)***	*(0.19)*	*(0.11)*	*(0.05)*	*(0.10)*

- **Each row is a separate regression of log change in variable shown on current and lagged tech shocks**
- **Equip tech. includes con dur and govt equip. Cons. (Nondur) tech includes structures and nonequip. govt.**
- **Intrumental variables estimation. Instruments zero out terms of trade and industry shocks not estimated via BFK. Annual data 1961-2005.**

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(1) GDP				**0.73**	**0.66**	-0.28			
				(0.20)	***(0.26)***	*(0.19)*			
(2) Investment (equip.)				1.33	**2.14**	-1.16			
				(0.90)	***(0.85)***	*(0.89)*			
(3) Consumer durables				**1.98**	0.94	-0.59			
				(0.56)	*(0.73)*	*(0.42)*			
(4) Consumption (ND+serv)				**0.35**	**0.28**	0.15			
				(0.13)	***(0.14)***	*(0.16)*			
(5) Investment (nonres. Struct.				-0.64	**3.43**	0.34			
				(0.85)	***(0.92)***	*(0.88)*			
(6) Hours				0.00	**0.65**	-0.38			
				(0.30)	***(0.32)***	*(0.30)*			
(7) GDP deflator				0.07	0.16	-0.11			
				(0.28)	*(0.30)*	*(0.33)*			
(8) Fed Funds Rate				**-0.78**	-0.13	-0.41			
				(0.30)	*(0.23)*	*(0.37)*			

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		(0.15)	***(0.09)***	*(0.18)*	***(0.20)***	***(0.26)***	*(0.19)*			
(2)	Investment (equip.)	**-2.66**	**-1.91**	1.13	1.33	**2.14**	-1.16			
		(0.81)	***(0.61)***	*(0.58)*	*(0.90)*	***(0.85)***	*(0.89)*			
(3)	Consumer durables	**-1.48**	-0.33	0.61	**1.98**	0.94	-0.59			
		(0.27)	*(0.24)*	*(0.44)*	***(0.56)***	*(0.73)*	*(0.42)*			
(4)	Consumption (ND+serv)	**-0.30**	-0.05	-0.01	**0.35**	**0.28**	0.15			
		(0.12)	*(0.07)*	*(0.11)*	***(0.13)***	***(0.14)***	*(0.16)*			
(5)	Investment (nonres. Struct.	-1.27	**-2.07**	-0.16	-0.64	**3.43**	0.34			
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		(0.16)	*(0.18)*	*(0.21)*	*(0.28)*	*(0.30)*	*(0.33)*			
(8)	Fed Funds Rate	-0.15	**-0.59**	-0.40	**-0.78**	-0.13	-0.41			
		(0.27)	***(0.26)***	*(0.29)*	***(0.30)***	*(0.23)*	*(0.37)*			

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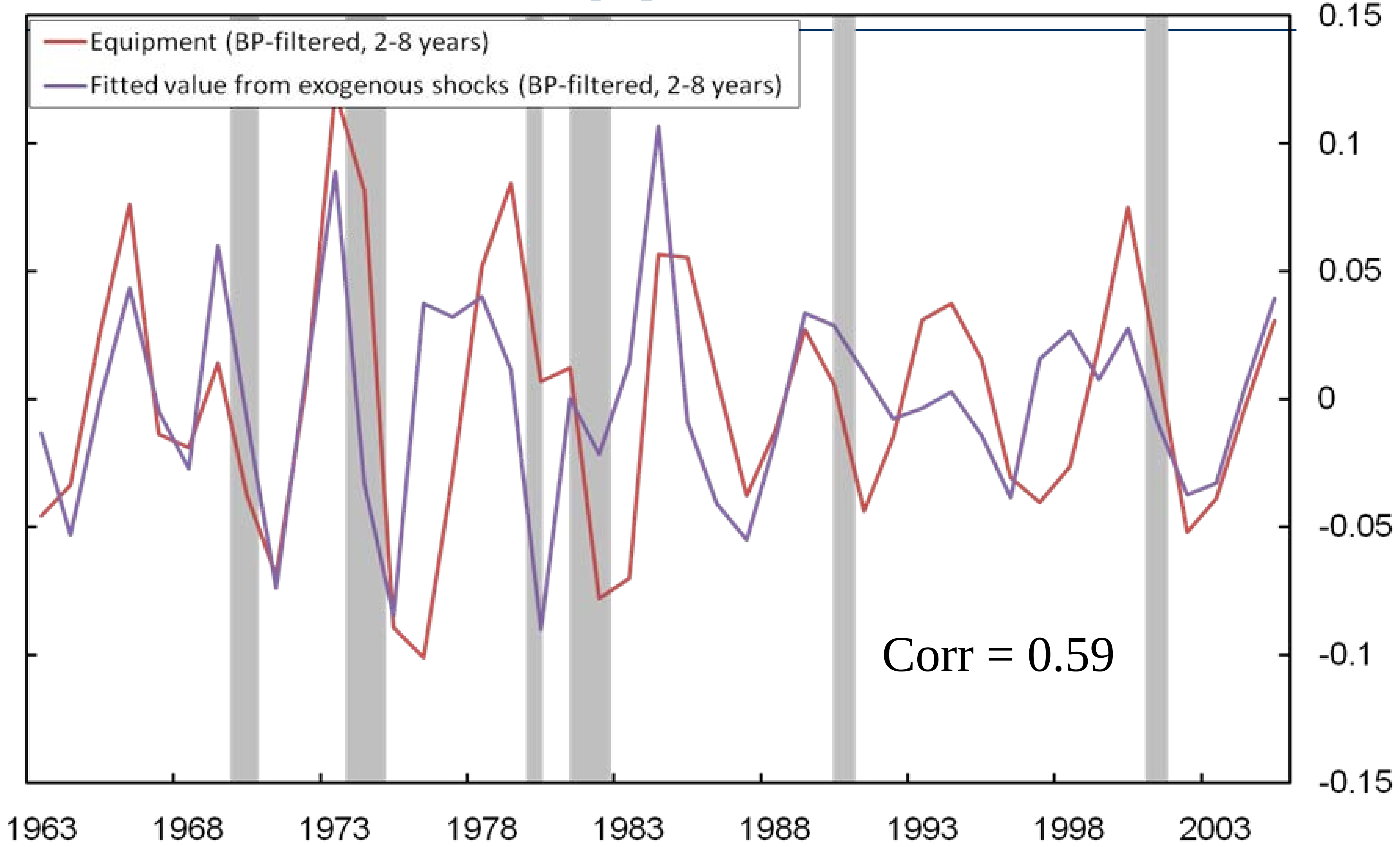
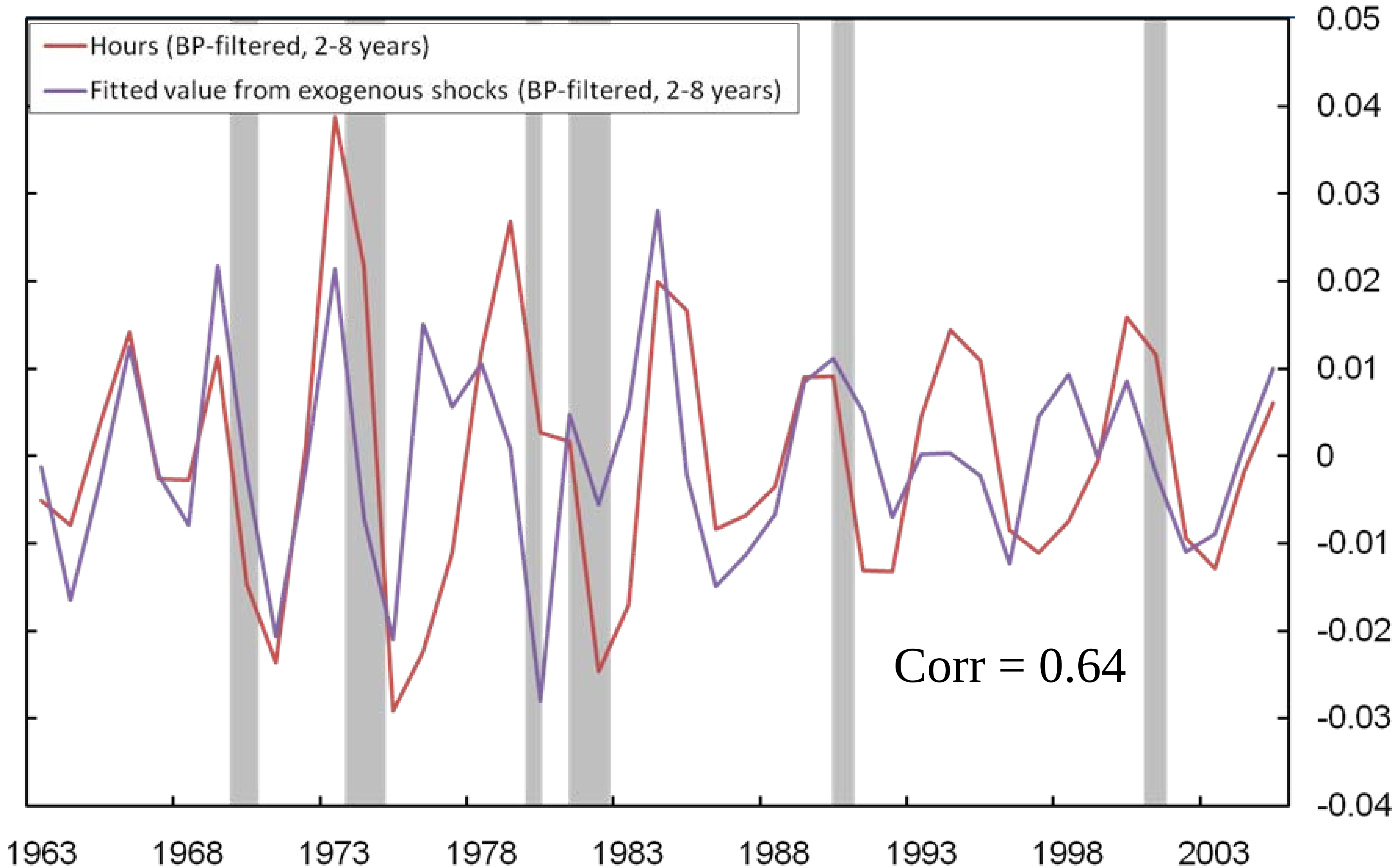
Technology shocks explain a lot of the variation in equipment…



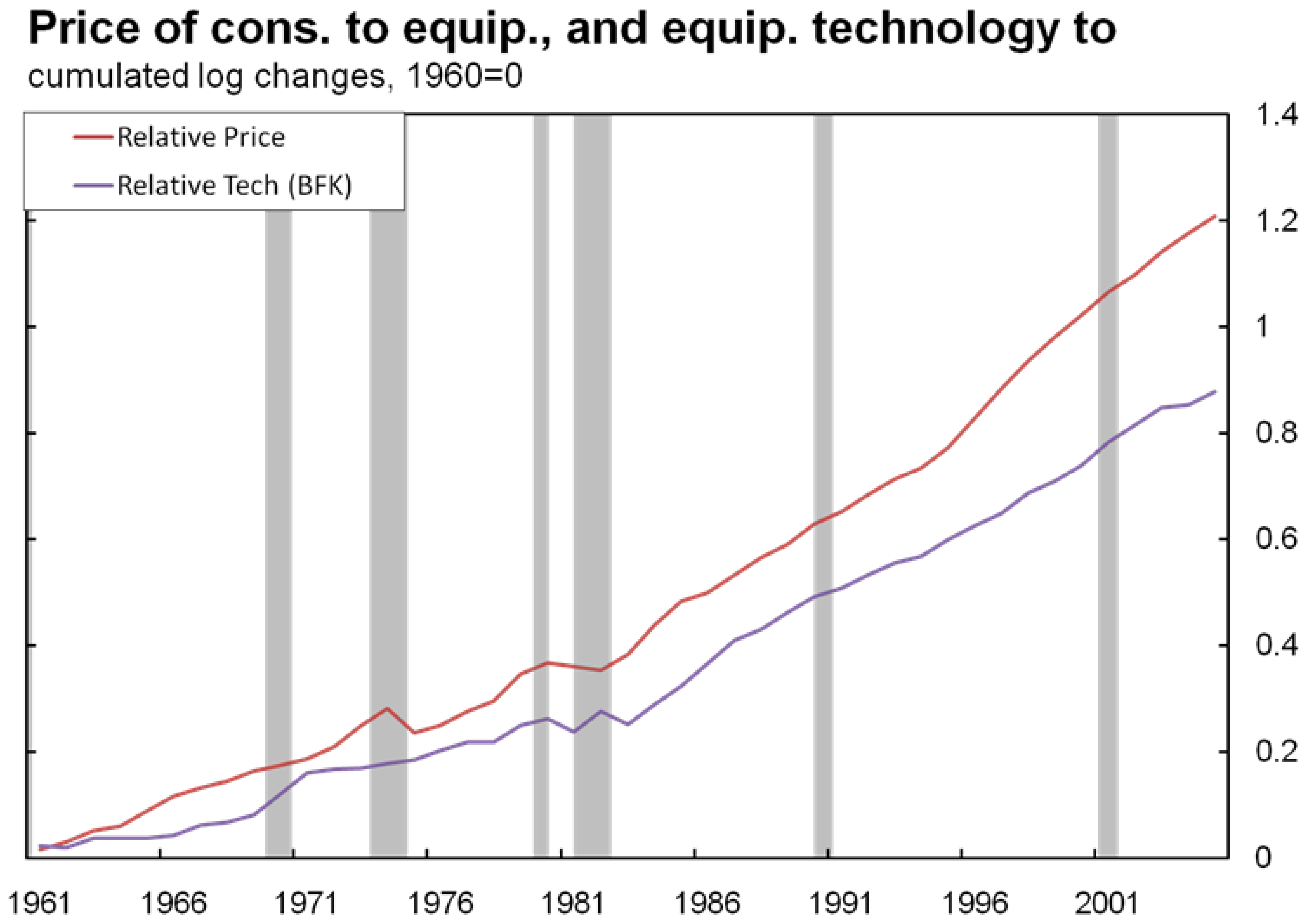
…as well as hours



Why are investment technology improvements contractionary—even for *investment*?

- Relative price of *I* drops very slowly in response to relative technology improvement
  - Creates strong incentive to delay purchases
  - Durable goods have high intertemporal elasticities of substitution
- Given the observed dynamics of the relative price, demand for durables *should* decline on impact when investment technology improves

In long run, relative prices (CNDS to equip/durables) move with relative TFP and relative technology



Relative prices respond to relative technology with long lags

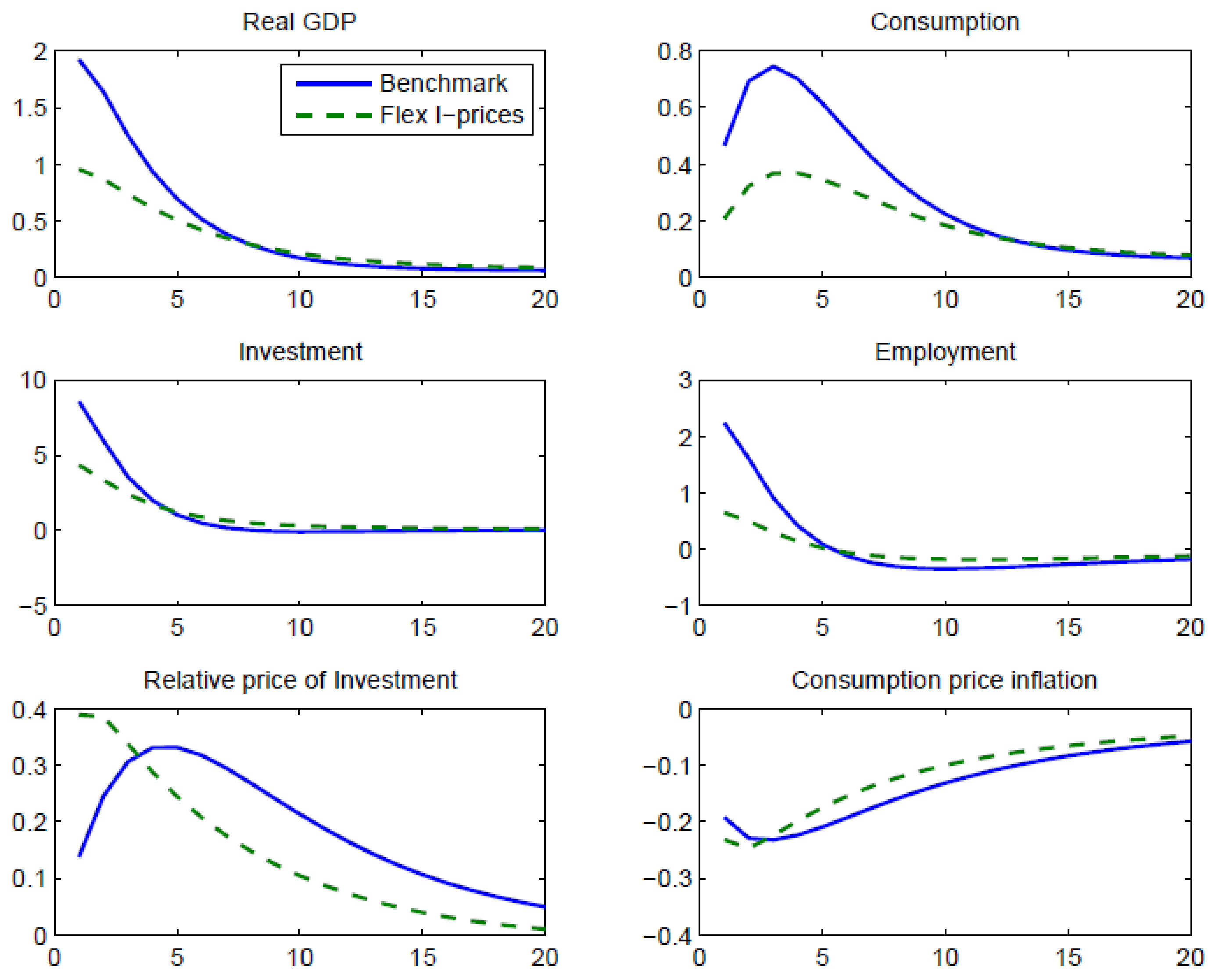
	d Relative Technology (Lag)				Cumulative effect
	0	1	2	3	
d Relative Price (cons to equip)	0.28	0.15	0.17	0.23	0.83
	(0.13)	*(0.20)*	*(0.14)*	*(0.19)*	*(0.31)*

- **Relative Price (LHS var): growth in price of consumption (ND and services) relative to price of equipment**
- **Rel. Technology (RHS var) : Growth in equipment technology relative to consumption (ND and services)**

Conclusions

- Theory and data show the importance of disaggregating technology change by "final use" sector
- Measure sectoral technical change using a new method that doesn't require relative prices—and gives different results
- Central banks need to think about the disaggregated sources of technical advance
- Problem: industry data and IO tables are only available at annual frequency and with a lag
- Suggested research: investigate state space methods to combine high-quality sectoral data with up-to-date price indicators

Response to consumption technology improvement



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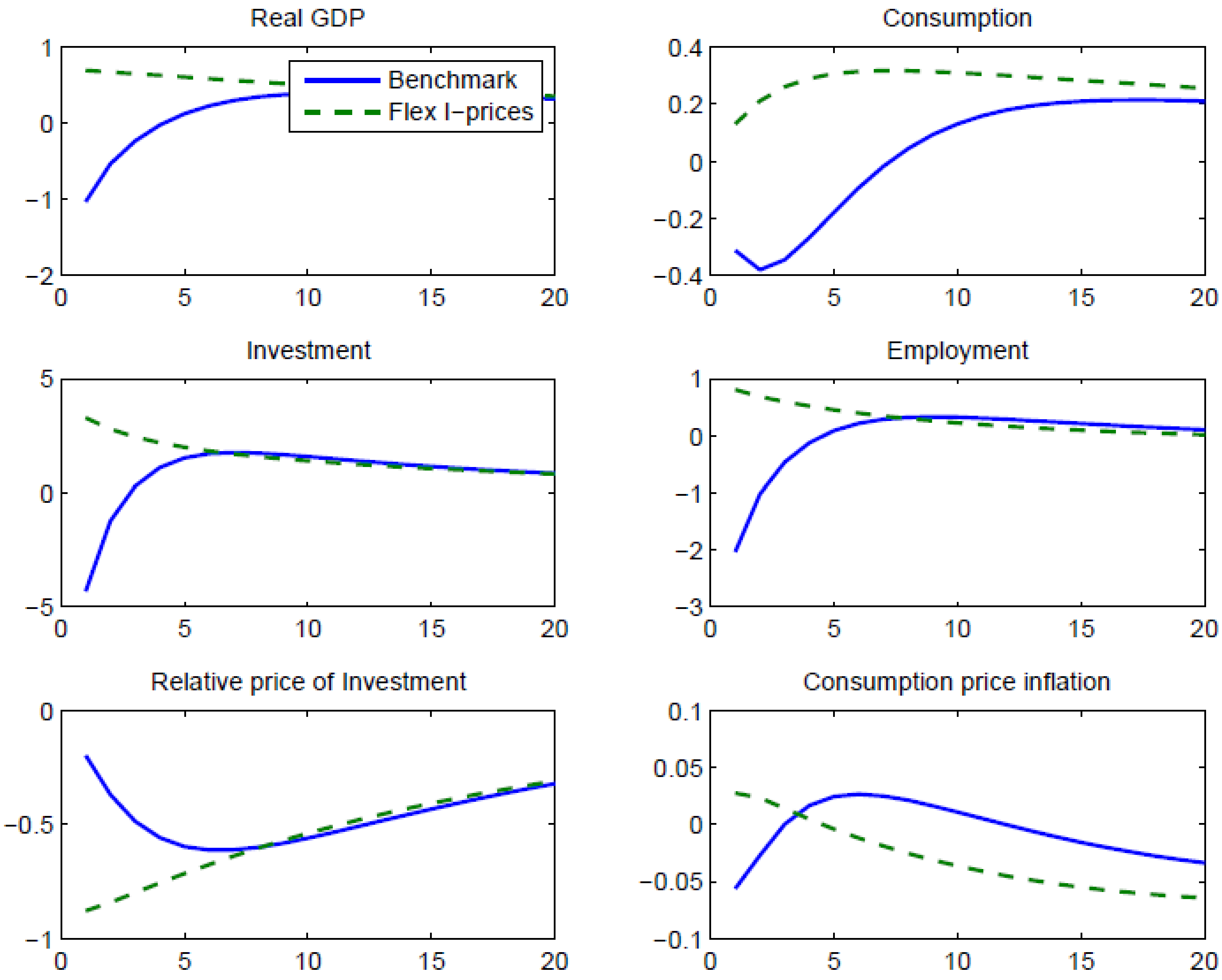

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(2)	Investment (equip.)	**-2.66**	**-1.91**	1.13	1.33	**2.14**	-1.16	0.06	0.24	0.84
		(0.81)	***(0.61)***	*(0.58)*	*(0.90)*	***(0.85)***	*(0.89)*	*(0.26)*	*(0.29)*	*(0.44)*
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		(0.12)	*(0.07)*	*(0.11)*	***(0.13)***	***(0.14)***	*(0.16)*	*(0.06)*	*(0.03)*	*(0.06)*
(5)	Investment (nonres. Struct.	-1.27	**-2.07**	-0.16	-0.64	**3.43**	0.34	0.02	-0.36	0.45
		(0.78)	***(0.49)***	*(0.57)*	*(0.85)*	***(0.92)***	*(0.88)*	*(0.32)*	*(0.41)*	*(0.44)*
(6)	Hours	**-0.74**	**-0.49**	0.29	0.00	**0.65**	-0.38	0.00	0.08	0.21
		(0.24)	***(0.17)***	*(0.24)*	*(0.30)*	***(0.32)***	*(0.30)*	*(0.12)*	*(0.07)*	*(0.15)*
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Empirical Implications: Low EIS and Permanent Tech Shocks

- With permanent technology shocks and King-Plosser-Rebelo utility and relatively low elasticity of intertemporal substitution (≈ 0.3), investment technology shocks also have very little immediate effects on labor hours, though they do raise investment in a way that consumption technology shocks do not.

Comments

- With log preferences, $\ln(A)$ is additively-separable:
  - *Any* stochastic process for A has no effect on optimal decision rules for N, X and I.

- More general King-Plosser-Rebelo preferences:
  - If A follows a geometric random walk it has no effect on optimal decision rules for N, X and I.

What is “technology”?

- Is ‘technology’ the economy’s PPF?
- The change in production functions for domestic C and I?

  - We use the first, broader, definition.

Notes

- Trade technology is the terms of trade
- Suppose there are no intermediate-inputs and one of each final-use commodity (e.g., a single consumption good)
  - Final-use technology is technology in that commodity
  - Our definition is correct for typical two-sector macro model
- Otherwise, takes account of intermediate-input flows
  - If all sectors face same input prices and have identical factor shares (including intermediates), then relative final-goods prices reflect relative technologies
  - Again, our definition is correct for typical special cases used in macro (e.g., Greenwood, Hercowitz, Krusell)

We aggregate commodity technology shocks to final uses with constant-share aggregation

Output elasticity = $\gamma_i \bullet$(factor share in cost)

$$\Gamma = \begin{pmatrix} \gamma_1 & & & 0 \\ & \ddots & & \\ & & \gamma_n & \\ 0 & & & 1 \end{pmatrix}$$

Effect of technology shock on vector of outputs

$$= dz + \Gamma B dz + \Gamma^2 B^2 dz + \ldots$$

$$= [I + \Gamma B + \Gamma^2 B^2 + \ldots] dz$$

$$= [I - \Gamma B]^{-1} dz$$

Motivation: In benchmark RBC model, consumption-technology shocks are neutral

- Suppose utility is logarithmic U = ln(C) – $v(L)$
- Let A be multiplicative technology for producing non-durable consumption

- Consumption-technology neutrality proposition:
    - In two-sector RBC model, stochastic process for A does not affect labor hours L, investment J, or the quantity of resources devoted to producing consumption goods (X)
  - A affects only production of nondurable consumption goods

Social-planner's problem for two-sector growth model, with CRS, identical production technologies

$$\max_{C,J,K_C,K_J,L_C,L_J} E_0 \sum_{t=0}^{\infty} \beta^t [\ln(C_t) - v(L_t)]$$

$$s.t. \quad C = AZ \cdot F(K_C, L_C)$$

$$J = Z \cdot F(K_J, L_J)$$

$$K = K_C + K_J, \quad L = L_C + L_J$$

$$K_{t+1} = J_t + (1-\delta)K_t$$

Define $X = Z \cdot F(K_C, L_C)$. so $C = AX$

This is special case of following problem, where A_t is additively separable, and thus doesn't affect decision rules

$$\max_{C,J,L,X} E_0 \sum_{t=0}^{\infty} \beta^t [\ln(C_t) - v(L_t)]$$

$$s.t. \quad C_t = A_t X_t$$

$$X_t + J_t = F(K_t, L_t, Z_t)$$

$$K_{t+1} = J_t + (1-\delta) K_t$$

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Equivalent problem:

$$\max_{L,J,X} E_0 \sum_{t=0}^{\infty} \beta^t [\ln(A_t) + \ln(X_t) - v(L_t)]$$

$$s.t. \quad X_t + J_t = F(K_t, L_t, Z_t)$$

$$K_{t+1} = J_t + (1-\delta)K_t$$

Empirically, do shocks to different final sectors have different economic effects?

What we do instead

- Seek a more robust way to measure relative technology
- Use industry data to estimate underlying shocks
  - Production-function regressions a la BFK (2006)
- Then aggregate using I-O tables to final-use technology changes for C, I, etc.
- Present findings, implications for business-cycle models

Outline

1. Introduction: Declining relative price of equipment
2. **Motivation: Consumption-technology neutrality**
3. Conceptual issues in empirical measurement
    1. Mapping simple dynamic model to complicated world
    2. Terms of trade as a form of technology
    3. Manipulating input-output (I-O) tables
4. Data and empirical results: Bottom-up v. top-down
5. Interpretation

Motivation: In benchmark RBC model, consumption-specific technology shocks have no dynamic effects

- Suppose period utility is logarithmic $U = \ln(C) + v(1\text{-}L)$
- Let A be multiplicative technology that affects only production of non-durable consumption

$$C = AZ \cdot F^C(K_C, L_C) \equiv AX$$

$$J = Z \cdot F^J(K_J, L_J)$$

Note: This model is benchmark Greenwood-Hercowitz-Krusell model, with a different normalization of the two shocks

We normalized on:

$$C = Z^C \cdot F^C(K_C, L_C) = AZ \cdot F^C(K_C, L_C)$$

$$J = Z^I \cdot F^J(K_J, L_J) = Z \cdot F^J(K_J, L_J)$$

Investment-specific technical change literature normalizes differently:

$$C = Z^C \cdot F^C(K_C, L_C) = Z^{\text{Neutral}} \cdot F^C(K_C, L_C)$$

$$J = Z^I F^J(K_J, L_J) = qZ^{\text{Neutral}} \cdot F^J(K_J, L_J)$$

We interpret terms of trade as a form of technology

- In closed economy, by definition, only domestic factors affect ability to convert consumption goods to investment goods
- In open economy, *foreign* technology or demand might affect ability to obtain consumption/investment with unchanged labor and investment

- Purpose of exports is to import
  - trade is a special (linear) technology, with terms-of-trade changes as technology shocks

Two issues arise in input-output data to measure relevant intermediate-input matrix *B*

- Final use is by *commodity*, productivity data (dz_i) are by *industry*
  - I-O make table maps commodity production to industries

- Final-use is from *total* commodity supply, not domestic production
  - I-O use table tells us both production and imports

What does an input-output use table look like?

Nominal commodity-by-commodity use table

	1	2	C	J	X	M	Row Total
1	Y_1^1	Y_1^2	Y_1^C	Y_1^J	Y_1^X	$-Y_1^M$	Y_1^D
2	Y_2^1	Y_2^2	Y_2^C	Y_2^J	Y_2^X	$-Y_2^M$	Y_2^D
K	K^1	K^2	…	…	…	…	K
L	L^1	L^2	…	…	…	…	L
Column total	Y_1^D	Y_2^D	C	J	X	$-M$	

- Columns give inputs into domestic production
- Rows give “uses” of the commodity

We define a "trade goods" commodity, which uses commodity exports as an input to produce imports

Nominal commodity-by-commodity use table

	1	2	Trade goods	C	J	X	M	Row Total
1	Y_1^1	Y_1^2		Y_1^C	Y_1^J	Y_1^X	$-Y_1^M$	Y_1^D
2	Y_2^1	Y_2^2		Y_2^C	Y_2^J	Y_2^X	$-Y_2^M$	Y_2^D
Trade goods								
K	K^1	K^2		$\ldots$	$\ldots$	$\ldots$	$\ldots$	K
L	L^1	L^2		$\ldots$	$\ldots$	$\ldots$	$\ldots$	L
Column total	Y_1^D	Y_2^D		C	J	X	$-M$	

- Exports represent intermediate inputs into trade-goods production.
- Imports are used as intermediate inputs to produce commodity supply

We define a "trade goods" commodity, which uses commodity exports as an input to produce imports

Nominal commodity-by-commodity use table

	1	2	Trade goods	C	J		M	Row Total
1	Y_1^1	Y_1^2	Y_1^X	Y_1^C	Y_1^J		$-Y_1^M$	Y_1^D
2	Y_2^1	Y_2^2	Y_2^X	Y_2^C	Y_2^J		$-Y_2^M$	Y_2^D
Trade goods								
K	K^1	K^2		…	…	…	…	K
L	L^1	L^2		…	…	…	…	L
Column total	Y_1^D	Y_2^D	X	C	J		$-M$	

- Exports represent intermediate inputs into trade-goods production.
- Imports are used as intermediate inputs to produce supplies of other commodities

We define a "trade goods" commodity, which uses commodity exports as an input to produce imports

Nominal commodity-by-commodity use table

	1	2	Trade goods	C	J			Row Total
1	Y_1^1	Y_1^2	Y_1^X	Y_1^C	Y_1^J			
2	Y_2^1	Y_2^2	Y_2^X	Y_2^C	Y_2^J			
Trade goods	Y_1^M	Y_2^M						
K	K^1	K^2		…	…	…	…	K
L	L^1	L^2		…	…	…	…	L
Column total			X	C	J			

- Exports represent intermediate inputs into trade-goods production.
- Imports are used as intermediate inputs to produce commodity supply

Net exports are one use of trade goods, representing a claim on future imports

Nominal commodity-by-commodity use table

	1	2	Trade goods	C	J	NX	Row Total
1	Y_1^1	Y_1^2	Y_1^X	Y_1^C	Y_1^J		
2	Y_2^1	Y_2^2	Y_2^X	Y_2^C	Y_2^J		
Trade goods	Y_1^M	Y_2^M				$X-M$	
K	K^1	K^2		$\dots$	$\dots$	$\dots$	K
L	L^1	L^2		$\dots$	$\dots$	$\dots$	L
Column total			X	C	J		

- NX are a form of final expenditure, much like investment.

Tables now add up, in terms of commodity supply!

Nominal commodity-by-commodity use table

	1	2	Trade goods	C	J	NX	Row Total
1	Y_1^1	Y_1^2	Y_1^X	Y_1^C	Y_1^J		Y_1^S
2	Y_2^1	Y_2^2	Y_2^X	Y_2^C	Y_2^J		Y_2^S
Trade goods	Y_1^M	Y_2^M				$X-M$	X
K	K^1	K^2		$\dots$	$\dots$	$\dots$	K
L	L^1	L^2		$\dots$	$\dots$	$\dots$	L
Column total	Y_1^S	Y_2^S	X	C	J	$X-M$	

We now transpose use matrix (for notational ease), and take row shares

Use table, in (transposed) share form

$$
\left[\begin{array}{c|ccc|cc}
 & 1 & 2 & \text{Trade goods} & K & L \\
\hline
1 & b_{11} & b_{12} & b_{13} & s_{1K} & s_{1L} \\
2 & b_{21} & b_{22} & b_{23} & s_{2K} & s_{2L} \\
\text{Trade goods} & b_{31} & b_{32} & 0 & \dots & \dots \\
\hline
C & b_{C1} & b_{C2} & 0 & \dots & \dots \\
J & b_{J1} & b_{J2} & 0 & \dots & \dots \\
NX & 0 & 0 & 1 & \dots & \dots
\end{array}\right]
=
\left[\begin{array}{ccc}
B & \begin{array}{c}|\\ s_K \\ |\end{array} & \begin{array}{c}|\\ s_L \\ |\end{array} \\
[- \; b_C \; -] & & \\
[- \; b_J \; -] & & \\
[- \; b_{NX} \; -] & &
\end{array}\right]
$$

What is trade goods "technology"? The terms of trade

- We export in order to import
  - Commodity exports are (intermediate) inputs into producing trade goods
  - 'Output' is imports plus net exports
    - nominal value = export value $P_X X$

- Real output = Goods we can import = $P_X X/P_M$

- Trade technology = output growth - input growth

$$= [d \ln(P_X / P_M) + d \ln X] - d \ln X$$

$$= d \ln(P_X / P_M)$$

Does typical orthogonality assumption between "neutral" (consumption) and "investment-specific" technology hold?

GHK assumptions:

$$C = Z^C \cdot F^C(K_C, L_C) = Z^N \cdot F^C(K_C, L_C),$$

$$J = Z^I \cdot F^J(K_J, L_J) = qZ^N \cdot F^J(K_J, L_J)$$

Correlations of final-use TFP

	1960-2004	1960-1982	1982-2004
(1) Corr(dz_J, dz_C)	0.83	0.90	0.75
(2) Corr(dz_{JE}, dz_C)	0.74	0.82	0.67
(3) Corr(dz_{JE} - dz_C, dz_C)	0.18	0.27	-0.02
(4) Corr(dz_{JE}- dz_C, dz_J)	0.61	0.58	0.54

Subscripts: *J* is overall investment, *JE* is equipment and software, *C* is nondurables and services consumption.

Equipment investment technology and consumption technology are quite positively correlated…

Correlations of BFK "purified" final-use technology

	1960-2004	1960-1982	1982-2004
(1) Corr(dz_J, dz_C)	0.70	0.73	0.75
(2) Corr(dz_{JE}, dz_C)	0.45	0.43	0.60
(3) Corr(dz_{JE} - dz_C, dz_C)	-0.06	-0.09	-0.01
(4) Corr(dz_{JE}- dz_C, dz_J)	0.59	0.53	0.57

Subscripts: *J* is overall investment, *JE* is equipment and software, *C* is nondurables and services consumption.

Equipment technology improves reduce output and hours—consumption technology improvements raise output

	Technology shocks												
	Equipment and consumer durables				Consumption (nondurables and services)				Net Exports				
	dzjecd	dzjecd(-1)	dzjecd(-2)	dzjecd(-3)	dzc	dzc(-1)	dzc(-2)	dzc(-3)	dznx	dznx(-1)	dznx(-2)	dznx(-3)	R^2
GDP	-0.62	-0.37	0.12	-0.05	0.65	0.57	0.00	0.10	-0.06	0.17	0.04	0.10	0.58
	(0.16)	*(0.13)*	*(0.14)*	*(0.11)*	*(0.19)*	*(0.22)*	*(0.39)*	*(0.22)*	*(0.1)*	*(0.06)*	*(0.09)*	*(0.04)*	
Investment	-1.98	-2.12	0.10	0.26	1.77	2.24	-0.41	-0.65	-0.36	0.40	0.40	0.32	0.59
(equipment and software)	*(0.51)*	*(0.54)*	*(0.38)*	*(0.28)*	*(0.63)*	*(0.76)*	*(1)*	*(0.93)*	*(0.27)*	*(0.21)*	*(0.19)*	*(0.11)*	
Consumer durables	-0.76	-0.43	0.45	-0.32	1.49	1.57	-0.79	0.05	-0.10	0.63	-0.11	0.19	0.52
	(0.43)	*(0.36)*	*(0.43)*	*(0.32)*	*(0.47)*	*(0.76)*	*(1.29)*	*(0.53)*	*(0.29)*	*(0.19)*	*(0.19)*	*(0.12)*	
Consumption	-0.30	-0.15	-0.06	-0.04	0.33	0.37	0.32	0.16	0.07	0.07	0.01	0.03	0.55
(Nondur+serv)	*(0.06)*	*(0.08)*	*(0.08)*	*(0.06)*	*(0.07)*	*(0.1)*	*(0.19)*	*(0.1)*	*(0.05)*	*(0.04)*	*(0.03)*	*(0.02)*	
Investment	-1.93	-2.67	-0.49	0.19	1.64	1.89	1.19	-0.85	-0.08	-0.28	0.31	0.51	0.38
(nonresidential structures)	*(0.74)*	*(0.76)*	*(0.43)*	*(0.28)*	*(1)*	*(1.01)*	*(1.56)*	*(1)*	*(0.33)*	*(0.3)*	*(0.24)*	*(0.22)*	
Investment	-2.04	0.19	0.14	-1.17	2.96	0.88	-0.62	0.57	0.19	1.66	0.06	-0.01	0.60
(residential structures)	*(0.77)*	*(0.84)*	*(0.65)*	*(0.64)*	*(0.75)*	*(1.72)*	*(2.41)*	*(1.66)*	*(0.59)*	*(0.67)*	*(0.36)*	*(0.33)*	
Exports	-1.25	-0.90	0.13	0.18	0.75	-0.39	0.52	0.12	-0.13	0.15	0.28	0.47	0.37
	(0.44)	*(0.5)*	*(0.51)*	*(0.36)*	*(0.63)*	*(0.79)*	*(1.61)*	*(1.06)*	*(0.28)*	*(0.22)*	*(0.19)*	*(0.15)*	
Imports	-1.84	-1.10	0.08	-0.44	1.73	0.06	1.18	0.63	0.45	0.55	0.23	0.14	0.57
	(0.47)	*(0.33)*	*(0.27)*	*(0.22)*	*(0.75)*	*(0.81)*	*(1.21)*	*(0.58)*	*(0.28)*	*(0.2)*	*(0.2)*	*(0.12)*	

Dep. Variables are growth rates of variables shown. Regressors are BFK final-sector technology shocks. Instruments are corresponding measures, with shocks to terms of trade, ag, mining, and govt. zeroed out. Std errors robust to heteroskedasticity and autocorrelation.

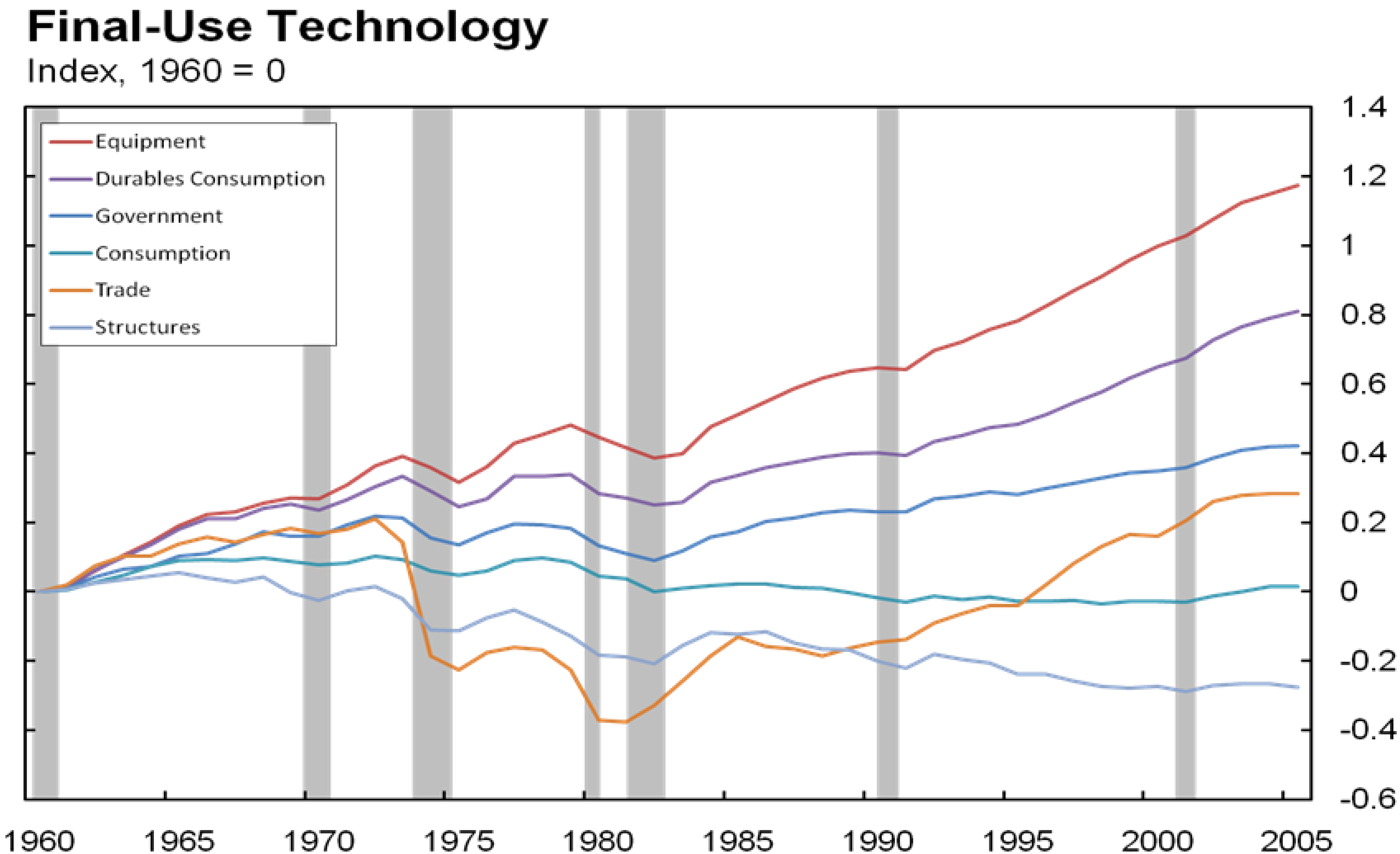
Table 6

		Equipment and consumer durables				Consumption (nondurables and services)				Net Exports			
		dzjecd	dzjecd(-1)	dzjecd(-2)	dzjecd(-3)	dzc	dzc(-1)	dzc(-2)	dzc(-3)	dznx	dznx(-1)	dznx(-2)	dznx(-3)
1	Hours	-0.61	-0.61	0.07	0.06	0.12	0.58	-0.05	-0.09	-0.04	0.14	0.11	0.11
		(0.17)	(0.18)	(0.18)	(0.13)	(0.19)	(0.23)	(0.4)	(0.27)	(0.11)	(0.06)	(0.08)	(0.05)
2	Wage	-0.01	-0.20	-0.29	-0.25	0.44	0.11	0.54	0.30	-0.04	-0.09	-0.14	-0.05
	(Jorgenson)	(0.15)	(0.14)	(0.17)	(0.11)	(0.18)	(0.25)	(0.53)	(0.21)	(0.11)	(0.09)	(0.06)	(0.05)
3	GDP deflator	-0.24	-0.24	-0.32	-0.08	-0.05	0.10	0.34	-0.03	-0.07	-0.15	-0.02	-0.03
	(Jorgenson, GCV-adj.)	(0.09)	(0.1)	(0.12)	(0.08)	(0.11)	(0.16)	(0.28)	(0.16)	(0.04)	(0.06)	(0.03)	(0.03)
4	Rel price: CNDS to Equip	0.15	-0.12	0.27	0.20	-0.39	0.04	-0.57	-0.40	-0.19	0.21	0.07	0.09
	(Jorgenson, GCV-adj.)	(0.17)	(0.18)	(0.09)	(0.11)	(0.2)	(0.26)	(0.33)	(0.34)	(0.11)	(0.09)	(0.09)	(0.04)
5	Con. price	-0.13	-0.29	-0.23	-0.05	-0.13	0.11	0.13	-0.03	-0.20	-0.08	-0.03	0.00
	(Jorgenson, GCV-adj.)	(0.1)	(0.11)	(0.11)	(0.09)	(0.13)	(0.17)	(0.28)	(0.16)	(0.05)	(0.05)	(0.04)	(0.03)
6	Equip price	-0.28	-0.17	-0.50	-0.24	0.26	0.06	0.70	0.37	-0.01	-0.30	-0.10	-0.09
	(Jorgenson, GCV-adj.)	(0.12)	(0.13)	(0.12)	(0.09)	(0.17)	(0.29)	(0.34)	(0.3)	(0.08)	(0.09)	(0.07)	(0.03)
7	Structures price	-0.10	-0.24	-0.32	-0.13	-0.21	0.23	0.54	0.01	-0.12	-0.12	0.04	0.00
	(Jorgenson, GCV-adj.)	(0.13)	(0.13)	(0.17)	(0.11)	(0.29)	(0.27)	(0.47)	(0.24)	(0.08)	(0.1)	(0.06)	(0.04)
8	Export price	-0.34	-0.27	-0.39	-0.05	0.24	0.14	0.71	-0.06	-0.15	-0.27	0.00	-0.05
	(Jorgenson, GCV-adj.)	(0.14)	(0.12)	(0.17)	(0.11)	(0.16)	(0.28)	(0.51)	(0.24)	(0.1)	(0.09)	(0.05)	(0.05)
9	Import price	0.54	-0.10	-0.38	-0.12	0.31	-0.05	0.86	0.08	-0.93	-0.28	-0.05	-0.07
	(Jorgenson, GCV-adj.)	(0.14)	(0.15)	(0.17)	(0.1)	(0.15)	(0.32)	(0.58)	(0.24)	(0.13)	(0.11)	(0.06)	(0.05)
10	Fed Funds Rate	-0.10	-0.86	-0.42	-0.35	-0.36	0.45	-0.29	0.27	-0.26	0.05	-0.12	0.13
		(0.17)	(0.23)	(0.12)	(0.08)	(0.26)	(0.4)	(0.56)	(0.39)	(0.16)	(0.11)	(0.08)	(0.07)
11	10-year Treasury	-0.20	-0.45	-0.31	-0.23	0.02	-0.19	-0.06	-0.12	-0.03	0.01	-0.02	0.08
		(0.06)	(0.1)	(0.05)	(0.05)	(0.1)	(0.19)	(0.21)	(0.12)	(0.06)	(0.04)	(0.03)	(0.03)
12	Tobin's q	0.12	2.90			-0.66	-1.63			2.07	-1.04		
		(1.29)	(1.08)			(2.57)	(1.42)			(0.42)	(0.37)		

Begin by using industry TFP

- Assume (for a start) that industry Solow (TFP) residual is the right measure of industry technical change
- Jorgenson data give us input-output (make) table B and the final-use vectors b

E&S and con. durables TFP rises faster than for nondurables and services, government, or structures



Cumulated log change in final-use TFP