The Impact of Plant-level Resource Reallocations and Technical Progress on U.S. Macroeconomic Growth

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Aggregate Productivity Growth

Petrin-Levinsohn (2008) build up from plant-level data an Aggregate(d) Solow Residual.

Adopt the spirit of estimation of an Aggregate Solow Residual that is defined as the change in aggregate value added minus the change in aggregate expenditures on primary inputs.

Decomposing Aggregate Productivity Growth

Given this Aggregate(d) Solow Residual, we can decompose into terms related to changes in aggregated plant-level technical efficiencies and changes in the reallocation of inputs across plants.

Choosing aggregate value added as the ”left hand side” results in reallocation weighting plant-level input reallocations with differences in marginal product-cost gaps.

PL extend Solow (1956), Hulten (1988), Hall (1990), and Basu and Fernald (2002) to plant-level.

Apply Decomposition to U.S. Manufacturing, 1976-1996

Investigate issues of implementation associated with using this type of plant-level data to estimate the Petrin-Levinsohn decomposition.

Estimate each plant's contribution to aggregate technical efficiency and reallocation.

Think about interpreting results in terms of macroeconomic models.

Findings

Both technical efficiency and reallocation are important in manufacturing.

Technical efficiency growth is more volatile.

Reallocation contributes positively to aggregate productivity growth in most years.

Reallocation of capital and intermediate inputs contribute the most to aggregate productivity growth.

Plan

- Define Aggregate(d) Solow Residual in Continuous Time
- Discuss Implementation in Discrete Time
- Results

Production Net of Fixed/Sunk Costs

- i indexes the N plants in the economy
- Q_i is output net of fixed/sunk costs
- production technology :

$$Q_i = Q^i(X_i, M_i, \omega_i) - F_i$$

  where $(X_i = X_{i1}, \ldots, X_{iK})$ are primary inputs, $(M_i = M_{i1}, \ldots, M_{iN})$ are intermediates, and ω_i is technical efficiency
- F_i fixed and sunk costs at plant i (normalized to units of output) like entry or "new product" development costs, hiring costs, firing costs, search costs, exit costs.

Final demand

Output from plant i going final demand is Y_i:

$$Y_i = Q_i - \sum_{j=1}^{N} M_{ji},$$

where $\sum_{j=1}^{N} M_{ji}$ is the total amount of i's output that serves as intermediate input.

Change in aggregate final demand is

$$\sum_{i=1}^{N} P_i dY_i$$

where $dY_i = dQ_i - \sum_{j=1}^{N} dM_{ji}$.

Aggregate(d) Productivity Growth (Petrin-Levinsohn)

The change in aggregate final demand minus the change in aggregate costs:

$$PL \equiv \sum_{i=1}^{N} P_i dY_i - \sum_{i=1}^{N} \sum_{k} W_{ik} dX_{ik},$$

where W_{ik} is price to rent or hire the kth primary input.

Extend Basu and Fernald (2002).

Decomposing PL

Lemma 1

If

$$PL \equiv \sum_i P_i dY_i - \sum_i \sum_k W_{ik} dX_{ik},$$

then assuming $Q^i(\cdot)$ is once differentiable for all i,

$$\begin{aligned} PL &= \sum_i P_i d\omega_i \\ &+ \sum_i \sum_k (P_i \frac{\partial Q}{\partial X_{ik}} - W_{ik}) dX_{ik} + \sum_i \sum_j (P_i \frac{\partial Q}{\partial M^i_j} - P_j) dM^i_j. \end{aligned} \quad (1)$$

Reallocation

If $W_{ik} = W_k$, then the change in PL from the reallocation of one unit of primary input k from j to i is

$$P_i \frac{\partial Q^i}{\partial X_{ik}} - P_j \frac{\partial Q^j}{\partial X_{jk}},$$

and aggregate reallocation from primary input k is

$$\sum_i \sum_k (P_i \frac{\partial Q^i}{\partial X_{ik}} - P_j \frac{\partial Q^j}{\partial X_{jk}}) dX_{ijk}$$

where dX_{ijk} is the amount of input k moving from plant j to plant i and zero otherwise.

Decomposing PL in Growth Rates

In growth rates we have

$$\begin{aligned} PL &= \sum_i D_i dln\omega_i \\ &+ \sum_i D_i \sum_k (\varepsilon_{ik} - s_{ik}) dlnX_{ik} + \sum_i D_i \sum_j (\varepsilon_{ij} - s_{ij}) dlnM_j^i, \end{aligned} \tag{2}$$

where the Domar weight is $D_i = \frac{P_i Q_i}{\sum_{i=1}^{N} P_i Y_i}$, ε_{ik} and ε_{ij} are the elasticities of output with respect to each input, and s_{ij} and s_{ik} are respective revenue shares.

The Annual Survey of Manufacturers and Census Data

We use the U.S. Census Bureau's Annual Survey of Manufactures which provide a nationally representative sample for the entire U.S. manufacturing sector.

The Annual Survey of Manufacturers (ASM) samples between 50,000 and 70,000 plants in U.S. manufacturing.

With probability one the ASM samples all plants with more than 250 employees and all plants that are part of very large companies - about 1/2 of plants.

The other half includes plants that are sampled from the population with a probability related to the plant's value of shipments within each 5-digit product class

Discrete Time Approximations

We use Tornquist-Divisia approximations for all of our calculations. We calculate growth as

$$PL_{G,t} = \sum_i \overline{D}_{it}^{v} \Delta ln VA_{it} - \sum_i \sum_k \overline{s}_{ikt} \Delta ln X_{ikt} \quad (3)$$

$\overline{D}_{it}^{v}$ is the average of plant *i*'s value-added share weights from period t-1 to period t

$\overline{s}_{ikt}$ is the average across the two periods of plant *i*'s expenditures for the kth primary input as a share of aggregate value-added.

Table 1: Percentage Growth Rates of Real GDP and Real Value-Added in Manufacturing, 1977-1996

		Real Value-Added in Manufacturing			
	(1)	(2)	(3)	(4)	(5)
Year	Real GDP	From NIPA	NBER-CES aggregates	Plant-level ASM (all)	Plant-level ASM (continuers)
1977	4.5	6.5	5.6	6.1	6.2
1978	5.0	3.8	5.2	4.7	5.5
1979	0.3	-0.3	3.8	3.3	6.4
1980	4.1	-9.8	-4.5	-6.0	-6.2
1981	1.7	0.4	1.9	0.8	2.7
1982	-2.0	-7.8	-3.5	-7.2	-8.0
1983	5.3	4.9	3.6	3.1	5.9
1984	6.6	6.3	5.8	11.0	8.6
1985	3.6	-1.3	2.2	-0.3	0.5
1986	3.8	1.6	0.5	-0.3	-0.3
1987	2.5	2.2	9.2	7.0	6.7
1988	3.4	3.8	4.2	4.0	5.1
1989	2.5	0.9	-0.9	4.5	-0.7
1990	0.4	-3.1	-0.7	-1.5	-2.5
1991	-0.8	-3.0	-2.3	-3.9	-3.6
1992	2.6	1.1	7.2	9.9	2.6
1993	2.0	1.3	3.4	-1.4	1.9
1994	3.6	4.9	8.5	11.7	6.8
1995	1.7	2.3	11.1	12.0	4.3
1996	2.6	-0.2	12.3	12.5	2.9
Mean	2.5	0.9	3.6	3.5	2.2
std. dev.	2.4	4.0	4.7	6.0	4.6

Correlations of Growth Rates

	GDP	NIPA MFG	NBER	All ASM plants
ASM continuers	0.78	0.90	0.78	0.79

Sources: Bureau of Economic Analysis, Annual Survey of Manufactures, NBER-CES productivity database, and authors' calculations.

Table 2: Percentage Growth Rates of Value-Added, Primary Input Costs and Aggregate Productivity in U.S. Manufacturing, 1977–1996.

Year	(1) Value Added	(2) Production labor costs	(3) Non-production labor costs	(4) Capital costs	(5) Aggregate Productivity (PL_APG)
1977	6.2	1.1	0.4	0.2	4.4
1978	5.5	0.9	0.5	0.4	3.6
1979	6.4	0.0	0.5	0.6	5.2
1980	-6.2	-2.1	0.6	0.4	-5.1
1981	2.7	-0.5	0.0	0.6	2.7
1982	-8.0	-3.6	-0.4	-0.2	-3.7
1983	5.9	0.0	-0.4	0.3	5.9
1984	8.5	1.4	0.2	0.0	6.8
1985	0.5	-0.5	0.3	0.7	0.0
1986	-0.3	-0.6	0.1	-4.4	4.5
1987	6.7	0.0	-0.3	1.6	5.3
1988	5.1	0.4	0.1	-1.0	5.6
1989	-0.7	-0.2	0.0	0.1	-0.7
1990	-2.5	-0.7	0.0	0.5	-2.3
1991	-3.6	-1.0	-0.3	0.4	-2.6
1992	2.6	-0.1	-0.5	1.7	1.5
1993	1.9	0.0	-0.3	-1.3	3.4
1994	6.8	0.4	-0.2	0.2	6.5
1995	4.3	0.0	0.1	0.3	3.9
1996	2.9	0.0	-0.2	0.5	2.6
Mean	2.2	-0.3	0.0	0.1	2.4
s.d.	4.6	1.1	0.3	1.2	3.6

Note: (1) - (2) - (3) - (4)= (5)

Approximation to Decomposition Using Gross Output

$$
\begin{aligned}
PL_{G,t} &= \sum_i \overline{D}_{it} \sum_k (\varepsilon_{ik} - \overline{c}_{ikt}) \Delta lnX_{ikt} + \sum_i \overline{D}_{it} \sum_j (\varepsilon_{ij} - \overline{c}_{ijt}) \Delta lnM_{ijt} \\
&+ \sum_i \overline{D}_{it} \Delta ln\omega_{it} - FixedCosts,
\end{aligned}
$$

D_{it} plant-level revenue to aggregate value added
ε_{ik} elasticities of output wrt inputs
c_{ij} = plant-specific revenue shares
Bars denote average of $t-1$ and t values.

Deflated Revenue

We deflate nominal gross output by a 4-digit industry price index for shipments, denoted P_s for time period s.

$$ln\frac{P_{it}Q_{it}}{P_t} = lnQ_{it} + lnP_{it} - lnP_t. \qquad (5)$$

When we estimate production function this price error will enter the technical efficiency residual.

Production Function Estimation

Our gross output production function specification includes three primary inputs: production worker labor (L^P), non-production worker labor (L^{NP}), and capital (K). We also have intermediate inputs, which includes the cost of parts and materials (M) and energy (E).

We posit a Cobb-Douglass production function and estimate production functions separately for each of our 459 4-digit SIC industries using OLS, Levinsohn-Petrin, and Wooldridge-LP.

Estimation

Given any estimator of production function coefficients our estimate of plant-level technical efficiency from the gross output specification is then

$$ln\widehat{\omega}_{it} = ln\frac{P_{it}Q_{it}}{P_{jt}} - (\widehat{\epsilon}_{jP}\, lnL_{it}^{P} + \widehat{\epsilon}_{jNP}\, lnL_{it}^{NP} + \widehat{\epsilon}_{jK}\, lnK_{it} + \widehat{\epsilon}_{jM}\, lnM_{it} + \widehat{\epsilon}_{jE}\, lnE_{it}) \quad (6)$$

where $\widehat{\epsilon}_{j.}$ denotes the estimated elasticities of output with respect to the inputs in 4-digit SIC industry j.

Table 3a: Aggregate Productivity Growth Decomposition
Technical Efficiency and Reallocation. U.S. Manufacturing 1977–1996

	Percentage Growth Rates of ...					
			PL_APG=TE+PL_RE		BHC=TE+BHC_RE	
	(1)	(2)	(3)	(4)	(5)	(6)
Year	Value Added	PL Aggregate Productivity (PL_APG)	Technical Efficiency (TE)	PL Reallocation (PL_RE)	BHC Productivity Index (BHC)	BHC Reallocation (BHC_RE)
1977	6.2	4.4	1.6	2.8	3.5	1.9
1978	5.5	3.6	1.2	2.4	2.5	1.3
1979	6.4	5.2	2.1	3.1	4.5	2.5
1980	-6.2	-5.1	-3.8	-1.3	5.8	9.5
1981	2.7	2.7	-0.5	3.2	2.2	2.7
1982	-8.0	-3.7	-1.6	-2.1	-21.0	-19.4
1983	5.9	5.9	5.5	0.5	-2.1	-7.6
1984	8.5	6.8	3.8	3.1	2.3	-1.5
1985	0.5	0.0	1.9	2.0	-9.1	-7.2
1986	-0.3	4.5	0.9	3.6	-21.8	-22.7
1987	6.7	5.3	2.1	3.2	-2.5	-4.7
1988	5.1	5.6	4.9	0.8	7.6	2.6
1989	-0.7	-0.7	-1.4	0.7	2.8	4.2
1990	-2.5	-2.3	-1.4	-0.9	1.9	3.3
1991	-3.6	-2.6	-1.7	-1.0	-12.3	-10.5
1992	2.6	1.5	0.1	1.4	-9.2	-9.3
1993	1.9	3.4	4.4	-0.9	11.3	6.9
1994	6.8	6.5	5.4	1.0	1.5	-3.9
1995	4.3	3.9	2.4	1.4	9.4	7.0
1996	2.9	2.6	1.7	1.0	8.1	6.5
Mean	2.2	2.4	1.2	1.2	-0.7	-1.9
s.d.	4.6	3.6	2.7	1.7	9.4	8.7

Gross Output Production Functions estimated by Levinsohn and Petrin (2003) estimator.

Correlations of Annual Growth Rates

	PL_APG	TE
TE	0.89	
BHC Index	0.30	0.37

Table 3b: Aggregate Productivity Growth Decomposition
Technical Efficiency and Reallocation. U.S. Manufacturing 1977–1996

	Percentage Growth Rates of ...					
			PL_APG=TE+PL_RE		BHC=TE+BHC_RE	
	(1)	(2)	(3)	(4)	(5)	(6)
Year	Value Added	PL Aggregate Productivity (PL_APG)	Technical Efficiency (TE)	PL Reallocation (PL_RE)	BHC Productivity Index (BHC)	BHC Reallocation (BHC_RE)
1977	6.2	4.4	0.9	3.5	2.9	2.1
1978	5.5	3.6	0.7	2.9	2.7	2.0
1979	6.4	5.2	1.8	3.4	4.3	2.5
1980	-6.2	-5.1	-3.1	-2.0	4.4	7.5
1981	2.7	2.7	-2.1	4.8	-0.6	1.5
1982	-8.0	-3.7	-1.0	-2.8	-12.3	-11.3
1983	5.9	5.9	4.3	1.6	-1.5	-5.8
1984	8.5	6.8	2.6	4.3	1.5	-1.1
1985	0.5	0.0	-2.4	2.5	-5.1	-2.6
1986	-0.3	4.5	0.8	3.7	-11.8	-12.6
1987	6.7	5.3	0.9	4.4	-3.2	-4.1
1988	5.1	5.6	4.6	1.0	6.7	2.1
1989	-0.7	-0.7	-1.3	0.6	1.7	3.0
1990	-2.5	-2.3	-1.2	-1.1	0.2	1.4
1991	-3.6	-2.6	-1.5	-1.2	-7.3	-5.8
1992	2.6	1.5	-0.5	2.0	-6.3	-5.8
1993	1.9	3.4	4.4	-1.0	9.7	5.3
1994	6.8	6.5	4.6	1.8	2.2	-2.4
1995	4.3	3.9	2.0	1.8	6.0	4.0
1996	2.9	2.6	1.9	0.8	7.8	6.0
Mean	2.2	2.4	0.8	1.6	0.1	-0.7
s.d.	4.6	3.6	2.5	2.2	6.2	5.5

Gross Output Production Functions estimated by OLS.

Correlations of Annual Growth Rates

	PL_APG	TE
TE	0.79	
BHC Index	0.31	0.45

Table 3c: Aggregate Productivity Growth Decomposition
Technical Efficiency and Reallocation. U.S. Manufacturing 1977–1996

	Percentage Growth Rates of ...					
			PL_APG=TE+PL_RE		BHC=TE+BHC_RE	
	(1)	(2)	(3)	(4)	(5)	(6)
Year	Value Added	PL Aggregate Productivity (PL_APG)	Technical Efficiency (TE)	PL Reallocation (PL_RE)	BHC Productivity Index (BHC)	BHC Reallocation (BHC_RE)
1977	6.2	4.4	0.7	3.7	3.1	2.4
1978	5.5	3.6	0.9	2.7	1.0	0.1
1979	6.4	5.2	2.3	3.0	4.8	2.5
1980	-6.2	-5.1	-2.9	-2.2	6.0	8.9
1981	2.7	2.7	-1.0	3.7	2.6	3.6
1982	-8.0	-3.7	-1.7	-2.1	-15.2	-13.5
1983	5.9	5.9	4.1	1.9	-1.4	-5.5
1984	8.5	6.8	2.0	4.9	1.5	-0.5
1985	0.5	0.0	-2.8	2.9	-10.0	-7.1
1986	-0.3	4.5	0.2	4.3	-15.0	-15.2
1987	6.7	5.3	1.2	4.1	-0.1	-1.3
1988	5.1	5.6	3.7	2.0	9.3	5.6
1989	-0.7	-0.7	-1.1	0.4	2.9	4.0
1990	-2.5	-2.3	-1.3	-1.0	-1.7	-0.4
1991	-3.6	-2.6	-1.3	-1.4	-8.8	-7.6
1992	2.6	1.5	-0.1	1.6	-5.2	-5.1
1993	1.9	3.4	3.8	-0.4	4.1	0.3
1994	6.8	6.5	4.2	2.3	6.7	2.5
1995	4.3	3.9	3.1	0.8	12.3	9.3
1996	2.9	2.6	1.7	0.9	6.1	4.4
Mean	2.2	2.4	0.8	1.6	0.1	-0.6
s.d.	4.6	3.6	2.3	2.2	7.6	6.6

Gross Output Production Functions estimated by Wooldridge (2005) modification of Levinsohn and Petrin (2003) estimator.

Correlations of Annual Growth Rates

	PL_APG	TE
TE	0.82	
BHC Index	0.37	0.54

Table 4a: Decomposition of Reallocation Term (equation 11): U.S. Manufacturing, 1977–1996

	Percentage Growth Rates of ...					
	(1)	(2)	(3)	(4)	(5)	(6)
		Reallocation "Gap" terms				
Year	PL Reallocation (PL_RE)	Production workers	Non-Production workers	Materials	Capital	Fixed costs
1977	2.8	0.8	0.2	1.6	0.1	0.0
1978	2.4	0.7	0.2	1.0	0.5	-0.1
1979	3.1	0.1	0.2	1.0	0.6	-1.3
1980	-1.3	-1.1	0.0	0.0	0.1	0.5
1981	3.2	0.1	0.0	-0.1	2.0	-1.1
1982	-2.1	-1.4	0.1	-0.8	-0.4	-0.4
1983	0.5	0.2	0.1	-0.1	0.3	0.0
1984	3.1	0.8	0.0	2.4	0.3	0.3
1985	2.0	0.1	0.0	0.7	0.6	-0.6
1986	3.6	0.0	0.1	0.4	2.8	-0.3
1987	3.1	0.1	0.2	0.6	1.6	-0.7
1988	0.8	0.5	0.1	0.9	-0.4	0.3
1989	0.7	0.2	0.0	0.4	0.2	0.2
1990	-0.9	-0.3	0.1	-0.5	0.5	0.6
1991	-1.0	-0.5	0.1	-0.4	0.3	0.4
1992	1.4	0.3	0.0	0.4	1.2	0.5
1993	-1.0	0.2	0.1	0.3	-0.6	0.9
1994	1.0	0.3	0.0	0.9	0.4	0.5
1995	1.4	0.0	0.2	1.2	0.5	0.4
1996	1.0	0.2	0.0	1.5	0.4	1.2
Mean	1.2	0.1	0.1	0.6	0.5	0.1
s.d.	1.7	0.5	0.1	0.7	0.8	0.6

Note: (1) = (2) + (3) + (4) + (5) - (6) (numbers may not add up exactly due to rounding.)

Gross Output Production Functions estimated by Levinsohn and Petrin (2003) estimator.

Table 4b: Decomposition of Reallocation Term (equation 11): U.S. Manufacturing, 1977–1996

	Percentage Growth Rates of ...						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Reallocation "Gap" terms					
Year	PL Reallocation (PL_RE)	Production workers	Non-Production workers	Materials	Energy	Capital	Fixed costs
1977	3.5	0.9	0.2	1.6	0.3	0.3	-0.3
1978	2.9	0.7	0.2	1.0	0.2	0.6	-0.2
1979	3.4	0.0	0.3	0.9	0.0	0.9	-1.3
1980	-2.0	-1.1	0.1	0.0	-0.2	0.2	1.0
1981	4.8	0.1	0.0	-0.1	0.8	2.6	-1.4
1982	-2.8	-1.4	0.0	-0.8	0.3	-0.6	0.2
1983	1.6	0.2	0.1	-0.1	0.7	0.5	-0.1
1984	4.3	0.8	0.0	2.4	0.7	0.3	-0.1
1985	2.5	0.1	0.0	0.7	0.4	0.9	0.4
1986	3.7	-0.1	0.1	0.4	0.7	2.3	-0.2
1987	4.4	0.1	0.2	0.6	0.3	2.6	-0.7
1988	1.0	0.6	0.1	0.9	0.6	-1.1	0.0
1989	0.6	0.2	0.1	0.5	-0.1	0.2	0.2
1990	-1.1	-0.4	0.1	-0.5	-0.3	0.7	0.7
1991	-1.2	-0.5	0.1	-0.5	-0.2	0.5	0.6
1992	2.0	0.3	0.0	0.4	0.0	1.8	0.5
1993	-1.0	0.2	0.1	0.3	0.3	-1.1	0.8
1994	1.8	0.3	-0.1	0.9	0.6	0.5	0.4
1995	1.8	0.0	0.2	1.2	0.2	0.6	0.4
1996	0.8	0.2	0.0	1.6	-0.3	0.6	1.3
Mean	1.6	0.1	0.1	0.6	0.2	0.7	0.1
s.d.	2.2	0.6	0.1	0.8	0.4	1.0	0.7

Note: (1) = (2) + (3) + (4) + (5) + (6) - (7) (numbers may not add up exactly due to rounding.)

Gross Output Production Functions estimated by OLS

Table 4c: Decomposition of Reallocation Term (equation 11): U.S. Manufacturing, 1977–1996

	Percentage Growth Rates of ...						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Reallocation "Gap" terms					
Year	PL Reallocation (PL_RE)	Production workers	Non-Production workers	Materials	Energy	Capital	Fixed costs
1977	3.7	0.4	0.0	2.4	0.4	0.1	-0.3
1978	2.7	0.5	0.0	1.4	0.1	0.4	-0.2
1979	3.0	0.2	0.1	0.7	0.1	0.5	-1.3
1980	-2.2	-0.3	0.0	-0.9	-0.4	0.2	0.9
1981	3.7	0.2	0.1	-0.1	0.7	1.4	-1.4
1982	-2.1	-0.6	0.2	-1.9	0.3	0.1	0.3
1983	1.9	0.0	0.1	0.5	0.8	0.4	-0.1
1984	4.9	0.4	0.0	3.4	0.7	0.3	-0.1
1985	2.9	0.2	-0.1	1.0	0.7	0.7	0.3
1986	4.3	0.2	0.1	0.6	0.6	2.7	-0.2
1987	4.1	0.2	0.2	0.9	0.5	1.6	-0.7
1988	2.0	0.5	0.1	1.3	0.6	-0.5	0.0
1989	0.4	0.3	0.0	0.4	-0.2	0.2	0.2
1990	-1.0	-0.1	0.0	-0.5	-0.1	0.5	0.7
1991	-1.4	-0.2	0.2	-0.8	-0.2	0.4	0.6
1992	1.6	0.2	0.1	0.7	-0.2	1.3	0.5
1993	-0.4	0.1	0.1	0.6	0.2	-0.7	0.8
1994	2.3	0.1	0.0	1.5	0.6	0.4	0.4
1995	0.8	0.0	0.1	1.3	-0.7	0.6	0.4
1996	0.9	0.2	0.1	1.8	-0.4	0.5	1.3
Mean	1.6	0.1	0.1	0.7	0.2	0.6	0.1
s.d.	2.2	0.3	0.1	1.2	0.5	0.7	0.7

Note: (1) = (2) + (3) + (4) + (5) + (6) - (7) (numbers may not add up exactly due to rounding.)

Gross Output Production Functions estimated by Wooldridge (2005) modification of Levinsohn and Petrin (2003) estimator.

Value-Added Results

Theory and setup can be developed for value-added instead of gross-output production function.

Biggest differences in terms of results is that estimated technical efficiency term now contains an additional term related to intermediate inputs (see Basu-Fernald (1995).)

Table A3c: Aggregate Productivity Growth Decomposition
Technical Efficiency and Reallocation. U.S. Manufacturing 1977–1999

	Percentage Growth Rates of ...					
			PL_APG=TE+PL_RE		BHC=TE+BHC_RE	
	(1)	(2)	(3)	(4)	(5)	(6)
Year	Value Added	PL Aggregate Productivity (PL_APG)	Technical Efficiency (TE)	PL Reallocation (PL_RE)	BHC Productivity Index (BHC)	BHC Reallocation (BHC_RE)
1977	5.4	4.2	3.9	0.3	-6.0	-9.9
1978	5.0	3.7	2.8	0.9	16.8	14.0
1979	4.4	3.8	3.3	0.5	10.0	6.7
1980	-4.6	-3.4	-3.9	0.5	4.3	8.3
1981	2.5	2.7	1.7	1.0	0.9	-0.8
1982	-6.0	-2.4	-2.1	-0.3	-13.0	-11.0
1983	5.8	5.9	5.6	0.3	25.4	19.8
1984	4.4	3.2	2.3	0.9	-30.0	-32.3
1985	3.4	3.3	1.8	1.5	14.3	12.5
1986	0.3	0.5	-0.9	1.4	1.2	2.1
1987	5.4	5.5	4.4	1.0	-6.6	-11.0
1988	4.5	4.0	2.9	1.0	23.7	20.8
1989	-0.2	-0.1	-1.0	0.9	-15.6	-14.6
1990	-2.1	-1.8	-3.0	1.2	-13.7	-10.7
1991	-1.1	-0.5	-1.7	1.2	6.9	8.6
1992	2.7	3.2	1.9	1.3	-30.3	-32.2
1993	1.6	1.7	0.6	1.1	8.9	8.3
1994	4.3	3.9	3.3	0.7	4.0	0.8
1995	5.2	4.8	3.1	1.7	10.7	7.6
1996	2.6	2.2	0.2	2.0	6.8	6.5
1997	8.4	6.6	5.0	1.6	-1.1	-6.1
1998	5.8	5.5	3.9	1.6	31.8	27.9
1999	4.7	4.5	3.4	1.1	3.0	-0.4
Mean	2.7	2.7	1.6	1.0	2.3	0.7
s.d.	3.5	2.7	2.6	0.5	15.8	15.2

Value-added Production Functions estimated by Wooldrige (2005) modification of Levinsohn and Petrin (2003) estimator.

Table A4c: Decomposition of Reallocation Term (equation 12): U.S. Manufacturing, 1977–1999

	Percentage Growth Rates of . . .				
	(1)	(2)	(3)	(4)	(5)
Year	Value Added	PL Reallocation (PL_RE)	Production worker "gap" term	Non-Production worker "gap" term	Capital "gap" term
1977	5.4	0.3	0.4	0.2	-0.3
1978	5.0	0.9	0.5	0.2	0.2
1979	4.4	0.5	0.1	0.1	0.3
1980	-4.6	0.5	-0.4	0.1	0.8
1981	2.5	1.0	0.1	0.0	0.9
1982	-6.0	-0.3	-1.0	0.0	0.7
1983	5.8	0.3	-0.3	0.0	0.7
1984	4.4	0.9	0.4	-0.1	0.6
1985	3.4	1.5	0.1	0.1	1.4
1986	0.3	1.4	0.1	0.1	1.2
1987	5.4	1.0	0.1	0.1	0.8
1988	4.5	1.0	0.3	0.0	0.7
1989	-0.2	0.9	0.1	0.1	0.7
1990	-2.1	1.2	-0.3	0.1	1.4
1991	-1.1	1.2	-0.2	0.2	1.2
1992	2.7	1.3	0.1	0.0	1.2
1993	1.6	1.1	-0.2	0.0	1.3
1994	4.3	0.7	0.0	-0.3	1.0
1995	5.2	1.7	0.0	0.1	1.5
1996	2.6	2.0	0.1	0.1	1.8
1997	8.4	1.6	0.2	0.0	1.4
1998	5.8	1.6	-0.2	0.0	1.9
1999	4.7	1.1	0.0	0.1	1.1

Value-added Production functions estimated by Wooldridge (2005), modification of Levinsohn and Petrin (2003) estimator.

The Bailey-Hulten-Campbell Index and Decomposition, Including Variants

In continuous time the original BHC index is given as:

$$BHC \equiv d\sum_i (s_i\, ln\omega_i) = \sum_i s_i\, dln\omega_i + \sum_i ln\omega_i\, ds_i,$$

where s_i is either the gross-output share or the labor share for plant i.

The BHC measure decomposes into a technical efficiency term and a reallocation term.

BHC Reallocation: $\sum_i ln\omega_i \, ds_i$

Suppose BHC uses labor share (will diverge from PL on technical efficiency).

Then difference between PL reallocation and BHC reallocation is driven by how the log-level efficiency term relates to the gaps.

In equilibrium plants choose input levels to equate expected marginal revenue with expected cost of the input, *regardless of their productivity level.*

Conclusions and Looking Forward

Apply Petrin-Levinsohn Decomposition to U.S Manufacturing data.

Both technical efficiency and reallocation play an important role in growth from 1976-1996 in U.S.

Reallocation is typically positive suggesting fixed/sunk costs/adjustment costs are important in models of growth (in addition to technical efficiency).

Measuring reallocation using U.S. as benchmark (Hsieh-Klenow) - U.S. is an economy with some frictions.

More work on investigating the components of the reallocation terms and on relating these terms for specific industries or the aggregate to known economic happenings.

Table A1: Growth Rates of Real GDP and Real Value-Added in Manufacturing, 1977-1999

Year	% Growth in Real GDP	% Growth in Real Value-Added in Manufacturing (from NIPA)	% Growth in Real Value-Added In Manufacturing (from ASM)	Manufacturing Value-Added Share of GDP (levels, from NIPA)
1977	4.5	6.5	5.4	0.21
1978	5.0	3.8	5.0	0.22
1979	0.3	-0.3	4.4	0.21
1980	4.1	-9.8	-4.6	0.21
1981	1.7	0.4	2.5	0.20
1982	-2.0	-7.8	-6.0	0.19
1983	5.3	4.9	5.8	0.18
1984	6.6	6.3	4.4	0.18
1985	3.6	-1.3	3.4	0.18
1986	3.8	1.6	0.3	0.17
1987	2.5	2.2	5.4	0.17
1988	3.4	3.8	4.5	0.17
1989	2.5	0.9	-0.2	0.17
1990	0.4	-3.1	-2.1	0.16
1991	-0.8	-3.0	-1.1	0.16
1992	2.6	1.1	2.7	0.16
1993	2.0	1.3	1.6	0.16
1994	3.6	4.9	4.3	0.16
1995	1.7	2.3	5.2	0.16
1996	2.6	-0.2	2.6	0.15
1997	3.9	3.4	8.4	0.15
1998	3.7	3.4	5.8	0.15
1999	3.7	0.0	4.7	0.15
Mean	2.5	0.9	2.7	
std. dev.	2.4	4.0	3.5	

Note: This table uses the value-added sample used in tables A3-A4.

Correlations of Growth Rates

	GDP	NIPA MFG
NIPA MFG	0.91	
ASM MFG	0.77	0.84

Source: Bureau of Economic Analysis, Annual Survey of Manufacure and authors' calculations.

Table A2: Growth Rates of Value Added, Primary Input Costs, and Aggregate Productivity in U.S. Manufacturing, 1977–1999

	Percentage Growth Rates of ...				
Year	Value Added	Production labor costs	Non-production labor costs	Capital costs	Aggregate Productivity (PL_APG)
1977	5.4	1.0	0.4	-0.2	4.2
1978	5.0	0.8	0.5	0.0	3.7
1979	4.4	0.0	0.4	0.1	3.8
1980	-4.6	-2.0	0.6	0.2	-3.4
1981	2.5	-0.5	0.0	0.3	2.7
1982	-6.0	-3.5	-0.4	0.3	-2.4
1983	5.8	0.0	-0.2	0.1	5.9
1984	4.4	1.0	0.2	0.0	3.2
1985	3.4	-0.5	0.3	0.2	3.3
1986	0.3	-0.6	0.1	0.3	0.5
1987	5.4	0.0	-0.2	0.2	5.5
1988	4.5	0.3	0.1	0.1	4.0
1989	-0.2	-0.2	0.0	0.1	-0.1
1990	-2.1	-0.6	0.0	0.3	-1.8
1991	-1.1	-0.8	-0.1	0.3	-0.5
1992	2.7	-0.1	-0.5	0.2	3.2
1993	1.6	0.0	-0.3	0.2	1.7
1994	4.3	0.3	-0.1	0.2	3.9
1995	5.2	0.1	0.0	0.3	4.8
1996	2.6	0.0	-0.1	0.5	2.2
1997	8.4	0.1	0.4	1.4	6.6
1998	5.8	-0.2	0.0	0.4	5.5
1999	4.7	-0.1	0.0	0.3	4.5
Mean	2.7	-0.2	0.1	0.3	2.7
s.d.	3.5	0.9	0.3	0.3	2.7

Note: This table uses the value-added sample used in tables A3-A4.

Table A5: Percentage Growth Rates of Real Value-Added in U.S. Manufacturing, 1977-1996

Year	(1) All ASM plants	(2) Continuers, Aggregates	(3) Excluding "true" entry & exit	(4) Estimation sample	(5) Continuers, Tornqvist index
1977	6.1	4.9	5.4	6.9	6.2
1978	4.7	4.8	4.1	4.4	5.5
1979	3.3	8.7	4.5	4.1	6.4
1980	-6.0	-5.8	-10.4	-10.5	-6.2
1981	0.8	0.3	3.9	3.8	2.7
1982	-7.2	-8.0	-7.4	-7.4	-8.0
1983	3.1	5.0	3.8	3.2	5.9
1984	11.0	5.1	11.3	11.3	8.5
1985	-0.3	0.6	0.0	-0.3	0.5
1986	-0.3	-0.4	-0.1	-0.6	-0.3
1987	7.0	6.2	7.5	7.1	6.7
1988	4.0	4.7	3.2	3.5	5.1
1989	4.5	0.2	3.2	4.0	-0.7
1990	-1.5	-1.7	-2.1	-1.8	-2.5
1991	-3.9	-2.4	-3.3	-3.5	-3.6
1992	9.9	4.2	10.6	10.4	2.6
1993	-1.4	-1.4	-2.1	-2.1	1.9
1994	11.7	11.0	12.0	11.5	6.8
1995	12.0	11.6	10.5	12.1	4.3
1996	12.5	13.4	12.2	12.1	2.9
Mean	3.5	3.0	3.3	3.4	2.2
std. dev.	6.0	5.7	6.4	6.5	4.6

Source: Annual Survey of Manufactures