MULTIFACTOR PRODUCTIVITY IN TRANSPORTATION: ESTIMATION, COMPARISONS, BENEFITS (1987-2003)

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Productivity

The production framework below is used to illustrate the measurement of labor productivity and multifactor productivity.

Output = f (Labor, Capital, Land, Intermediate Inputs) T

Output depends on the inputs of labor, capital, land, and intermediates inputs; and on technology (T).

Productivity

Labor productivity (Single-factor productivity) = Output/Labor

Multifactor productivity

= Output/(Labor + Capital + Land + Intermediate Inputs)

Multifactor productivity (MFP) refers to the productivity of all the inputs used in the production process. MFP indicates the overall production efficiency of an industry (sector or economy).

Two Points in MFP Estimation

1) Relative importance of the inputs in production: cost shares

2) Time horizon:

a) At a point in time, the output of an industry depends on the quantity of the inputs and the technology used.

b) Over time, the output of the industry can increase through two basic ways:

1) By increasing the quantity of the inputs, and/or

2) By increasing the productivity of the inputs

a) Any factor other than increasing input quantity

Example:
Production Relationship - Air Transportation

Output: Number of passengers transported (and amount of freight transported)

Inputs:

1) Labor: pilots, cabin attendants, mechanics, etc.;
2) Capital: airplanes, computers, air terminals, etc.;
3) Land: for buildings of air carriers, air terminals, runways;
4) Intermediate inputs: supplies purchased, airplane fuel, electricity.

Measurement of inputs: in real terms

Measurement of input weights: in nominal terms

Example:

Production Relationship - Air Transportation

Technology:

Air transportation subsector needs to use Technology (T) in order to deliver the service (output) of transporting passengers (and freight).

1) Types of inputs used (number and type/size of airplanes), and
2) Mixture of the inputs – e.g., the number and type of airplanes to number of pilots, maintenance mechanics

Measurement of MFP (affected by Technology): as residual, after accounting for increases in the quantities of the inputs.

Example :
Increasing Output over Time - Air Transportation

1) Increases in quantity of the inputs => Use of more airplanes (capital) and pilots (labor); and more fuel (intermediate input).

2) Increases in the productivity of the inputs (MFP) - affected by "technological advances." This includes a variety of factors, other than increases in input quantity:

a) Bigger airplanes and appropriate engines (better-quality capital) that carry more passengers (more output); lower cost per passenger/ton freight

b) Faster airplanes (better-quality capital)that can reach their destination sooner (hence, more output)

c) Reduction in the number of pilots (three to two) possible by technological advances of the airplane piloting systems

Estimation of Multifactor Productivity

Two basic approaches:

1) Basic growth-accounting (Solow, Kendrick)

a) MFP estimated as a residual after accounting for increases in the input quantities

b) Empirical relationship used to estimate growth of multifactor productivity by the basic growth-accounting methodology:

$$\frac{\Delta T}{T} = \frac{\Delta Q}{Q} - [(\alpha * \frac{\Delta \text{Labor}}{\text{Labor}}) + (\beta * \frac{\Delta \text{Capital}}{\text{Capital}}) + (\gamma * \frac{\Delta \text{Intermediate Inputs}}{\text{Intermediate Inputs}})]$$

Where, α, β, and γ are cost shares of inputs in total industry cost.

2) Tornqvist approach

Multifactor Productivity:

(1)
$$Ln\left(\frac{A_t}{A_{t-1}}\right) = Ln\left(\frac{Q_t}{Q_{t-1}}\right) - \left[W_k\left(Ln\frac{K_t}{K_{t-1}}\right) + W_l\left(Ln\frac{L_t}{L_{t-1}}\right) + W_m\left(Ln\frac{M_t}{M_{t-1}}\right)\right]$$

Ln = Natural log *A = MFP* *Q = Output*

K = Capital *L = Labor* *M = Intermediate Inputs*

W= Weight of Input (share of industry cost)

Tornqvist process involves taking antilog of combined inputs, and chaining that index.

MFP Estimation in Transportation Subsectors: BLS, BTS

1) MFP estimation by BLS - Tornqvist
   a) Air transportation – NAICS data
   b) Rail transportation - SIC data

2) MFP estimation by BTS – NAICS data
   a) Basic truck transportation MFP – Growth-accounting methodology (without land)
   b) Basic truck MFP – Tornqvist (without land; with land)
   c) Enhanced truck MFP - Tornqvist (public capital: highways; land measure)- preliminary
   d) Pipeline MFP – Basic growth-accounting; Tornqvist - preliminary

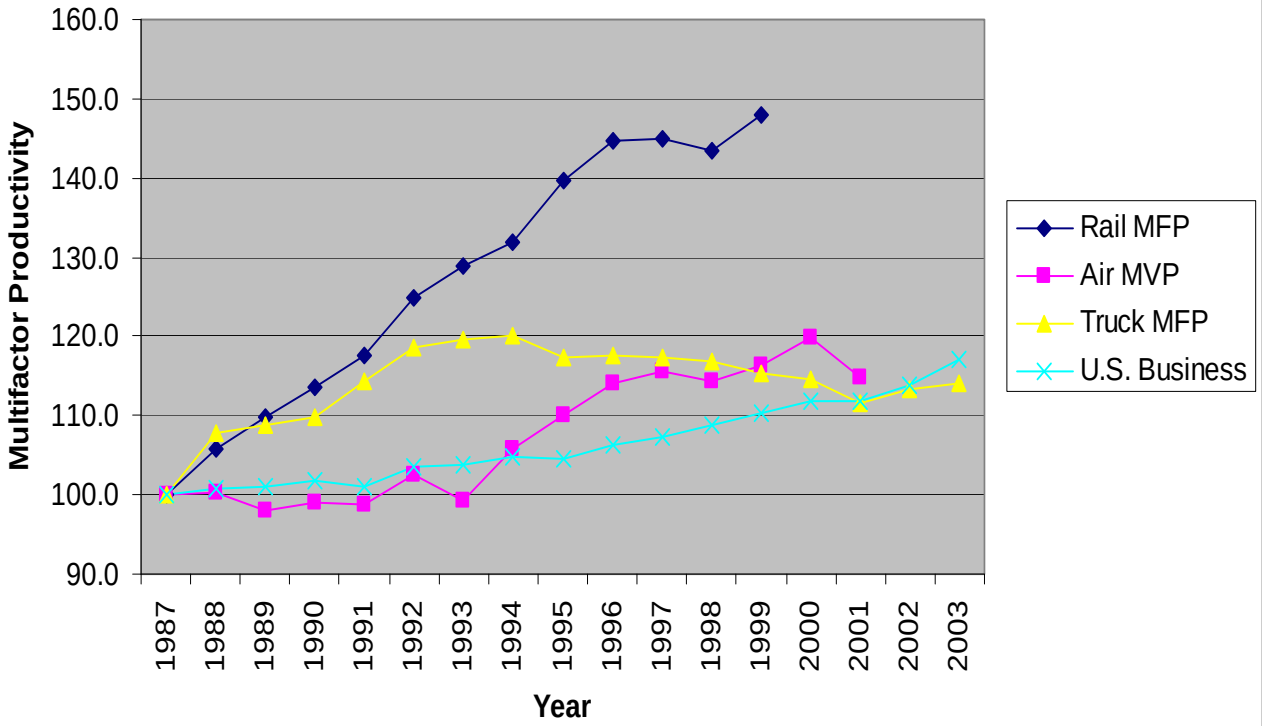
3) Data used by BTS
   a) BEA: output, labor, capital, intermediate inputs - Real terms; current dollars

MULTIFACTOR PRODUCTIVITY IN TRUCKING							
	Growth-Accounting Methodology			Tornqvist Methodology			
		(Without land)		(Without land)		(With land)	
Year	Growth of Gross Output – Quantity Index (%)(2000 =100)	Growth of combined weighted inputs (%)	MFP – growth (%)	MFP Index	MFP - growth (%)	MFP Index	MFP - growth (%)
	'(1)	'(2)	'(3)	'(4)	'(5)	'(6)	'(7)
1987				86.0		87.3	
1988	12.4	4.7	7.7	93.4	8.6	94.0	7.7
1989	4.8	3.8	1.0	94.4	1.0	95.0	1.0
1990	5.7	5.2	0.6	95.3	1.0	95.8	0.9
1991	2.0	(2.1)	4.1	99.3	4.2	99.8	4.1
1992	8.3	4.5	3.8	103.1	3.9	103.6	3.8
1993	4.0	3.3	0.7	103.9	0.7	104.4	0.8
1994	9.3	8.8	0.6	104.4	0.5	104.9	0.4
1995	2.7	5.0	(2.3)	102.1	-2.2	102.5	-2.3
1996	5.4	5.3	0.2	102.3	0.2	102.6	0.1
1997	4.6	4.8	(0.2)	102.1	-0.2	102.4	-0.2
1998	7.3	7.7	(0.4)	101.7	-0.4	101.9	-0.5
1999	5.3	6.6	(1.3)	100.5	-1.2	100.6	-1.3
2000	2.5	3.1	(0.6)	100.0	-0.5	100.0	-0.6
2001	(6.2)	(3.7)	(2.5)	97.6	-2.4	97.5	-2.5
2002	(1.7)	(3.1)	1.4	99.0	1.4	98.9	1.4
2003	(6.0)	(6.4)	0.4	99.7	0.7	99.6	0.7

MULTIFACTOR PRODUCTIVITY IN TRUCKING					
Tornqvist Methodology					
	MFP	MFP		Time	Growth of MFP
Year	Index	(Growth - %)		Period	(Annual %)
	'(1)	'(2)		'(3)	'(4)
1987	87.3				
1988	94.0	7.7			
1989	95.0	1.0			
1990	95.8	0.9		1987-1990	3.2
1991	99.8	4.1			
1992	103.6	3.8			
1993	104.4	0.8			
1994	104.9	0.4			
1995	102.5	-2.3		1987-1995	2.0
1996	102.6	0.1			
1997	102.4	-0.2			
1998	101.9	-0.5			
1999	100.6	-1.3			
2000	100.0	-0.6			
2001	97.5	-2.5			
2002	98.9	1.4		1995-2003	-0.4
2003	99.6	0.7		2001-2003	1.1
				1987-2003	0.8

MULTIFACTOR PRODUCTIVITY OF RAIL, AIR, TRUCKING, AND THE U.S. PRIVATE BUSINESS SECTOR									
	Levels of MFP				**Growth Rates of MFP**				
					(Annual percentage rates)				
Year	Rail MFP	Air MFP	Truck MFP	U.S. Private Business Sector	Time Period	Rail MFP	Air MFP	Truck MFP	U.S. Private Business Sector
	'(1)	'(2)	'(3)	'(4)	'(5)	'(6)	'(7)	'(8)	'(9)
1987	100.0	100.0	100.0	100.0					
1988	105.8	100.2	107.7	100.8					
1989	109.8	98.2	108.8	101.1					
1990	113.7	99.0	109.8	101.7	1987-1990	4.4	-0.3	3.2	0.6
1991	117.5	98.8	114.3	101.1					
1992	125.0	102.4	118.7	103.6					
1993	129.0	99.3	119.6	103.9					
1994	131.8	105.8	120.1	104.8					
1995	139.6	110.0	117.4	104.9	1987-1995	4.3	1.2	2.0	0.6
1996	144.8	114.2	117.6	106.3					
1997	144.9	115.5	117.3	107.3					
1998	143.4	114.3	116.7	108.9					
1999	147.9	116.4	115.2	110.3	1995-1999	1.5	1.4	-0.5	1.3
2000		119.9	114.6	111.8					
2001		114.9	111.7	111.9	1995-2001		0.7	-0.8	1.1
2002			113.3	113.8					
2003			114.1	117.0	1987-1999	3.3	1.3	1.2	0.8
					1987-2000		1.4	1.1	0.9
					1987-2001		1.0	0.8	0.8
					1987-2002			0.8	0.9

Chart 1: MFP in Transportation Industries and U.S. Private Business Sector



Comparisons:
Transportation Subsectors & U.S. Economy

A. During 1987-1995, the three transportation industries experienced MFP growth at higher rates than the U.S. economy (0.6% annually):

Rail MFP = 4.3% annually

Truck MFP = 2.0% annually

Air MFP = 1.2% annually

B. During 1987-1999, the three transportation industries experience MFP growth at higher rates than the U.S. economy (0.8% annually):

Rail MFP = 3.3% annually

Air MFP = 1.3% annually

Truck MFP = 1.2% annually

Benefits from Increases in MFP

1) At the industry level, an increase in MFP (level, growth rate) indicates increase in the productivity of the factor inputs.
   a) Industry is getting more benefit – in terms of output – from using the available inputs (resources).
   b) More output can be produced -> More people can share the benefits from higher levels of output/income.

2) Comparison of the transportation industries to the U.S. economy - observed faster growth of MFP in transportation industries.
   a) Indicates positive contribution of transportation industries to the economy's productivity.
   b) Growth in productivity -> Growth of output/income
   c) Improvement in the standard of living in the U.S. economy (income per capita)

Benefits of MFP Increases

3) Empirical Assessment of MFP increases in Air Transportation:

1) Productivity increases => Larger difference between cost per unit and price per unit => Higher profits

2) Allocation of higher profits by firm/industry

a) Keep in the firm (higher retained income)

b) Lower prices

c) Higher labor compensation

4) Qualification to benefits of MFP increases: negative externalities – e.g., air pollution