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Infrastructure and Private-Sector Productivity

Robert Ford,
Pierre Poret

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No. 91 INFRASTRUCTURE AND PRIVATE-SECTOR PRODUCTIVITY

by

Robert Ford
Country Studies III Division

and

Pierre Poret
General Economics Division

January 1991

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

A recent study by David Aschauer suggested a novel explanation for the slowdown of private-sector total factor productivity (TFP) in the United States in the early 1970s. He argues that it is due to the roughly contemporaneous slowdown in the rate of investment in public-sector infrastructure. Using data for eleven OECD countries, this note provides only mixed support for Aschauer's hypothesis. With series starting in the 1960s for most countries, regression analysis found a significant effect of infrastructure on TFP in about half the countries. A longer-term perspective was also examined for the United States. On the basis of data going back to the end of the 19th century, it appears that there was no relationship between infrastructure and TFP until after World War II.

* * * * * *

Une étude récente de David Aschauer suggérait une nouvelle explication pour le ralentissement de la productivité totale des facteurs (PTF) dans le secteur des entreprises aux Etats-Unis durant les années 1970 : il s'expliquerait par le ralentissement approximativement contemporain des dépenses d'infrastructure du secteur public. Utilisant des données pour onze pays de l'OCDE, cette note n'apporte qu'un soutien partiel à l'hypothèse de Aschauer. Avec des séries commençant dans les années 1960 pour la plupart des pays, l'analyse économétrique met en evidence un effet significatif des infrastructures sur la PTF pour environ la moité des pays. Une perspective de plus long terme a été aussi envisagée pour les Etats-Unis. Sur la base de données remontant à la fin du dix-neuvième siècle, il apparaît qu'il n'y a pas de relation entre infrastructure et PTF jusqu'à l'après-seconde guerre mondiale.

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INFRASTRUCTURE AND PRIVATE-SECTOR PRODUCTIVITY

INTRODUCTION AND SUMMARY

The idea that investment in infrastructure may influence productivity is intuitively appealing: one need only imagine an economy with trucks but no roads, or ships without ports. In a recent attempt to pin down such a relationship more precisely, Aschauer (1989) linked aggregate productivity to the public-sector capital stock, and argued that the puzzling productivity slowdown in the United States in the early 1970s could be explained by the roughly contemporaneous slowdown in the rate of investment in infrastructure. To make the case, he assumed an aggregate Cobb-Douglas production function in which output was produced by the usual private-sector capital and labour inputs, plus public-sector capital. For the United States, he found an obvious visual relationship between private-sector total factor productivity and infrastructure capital (his Figure 1), which was confirmed by regression analysis.

While this finding could be criticised on several grounds (1), this note seeks to test it by applying the same methodology to a broader range of data: two definitions of infrastructure for eleven OECD countries. The new data provided only mixed support for Aschauer's hypothesis: while total factor productivity growth slowed in the 1970s in almost all the countries examined, this was accompanied by a deceleration in infrastructure in only about half of them. These results are not very sensitive to which definition of infrastructure is used. With series going back to the 1960s for most countries, regression analysis also confirmed a statistically significant effect of infrastructure on private-sector output in about half the countries. Finally, the longer-term nature of the relationship between productivity and infrastructure was investigated. On the one hand, a significant cross-country correlation between these two variables was found. On the other hand, data for the United States going back to the end of last century suggest there is no relationship between productivity and infrastructure capital in the United States, except in the post-war period examined by Aschauer.

THE MODEL

A Cobb-Douglas production function is assumed to produce private-sector output using a bundle of private-sector inputs (denoted PIN) and infrastructure capital (INF):

[1] $Q = a + b*PIN + c*INF$,

where all variables are in logarithms. Total factor productivity (TFP) of the private-sector inputs is:

[2] $TFP = Q - PIN = a + c*INF - (1 - b)*PIN$.

If i) there are constant returns to scale in the private-sector inputs only and, therefore, possibly increasing returns to scale for all inputs, and ii) private-sector inputs are priced at their marginal products, then b = 1 and private inputs do not affect TFP. But, if there are diminishing returns to private inputs, they will accrue rent from the infrastructure and b will therefore be less than 1. Constant returns to scale over <u>all</u> inputs imply b = 1 - c.

This model leads to the estimating equation:

[3] $TFP = a0 + a1*(INF - PIN) + a2*PIN + a3*IFU$,

which is the same as Equation 1.7 in Aschauer's Table 1, but rearranged slightly. A capacity utilisation measure (IFU) is added to account for cyclical variations in TFP. Comparing [3] to [2], a1 (= c) is the contribution of infrastructure to productivity (and to output) and a2 (= b + c-1) is the sum of the contributions of private factors and infrastructure less one. Thus, a1 is zero if infrastructure does not contribute to TFP. If a1 = -a2, b = 1 and there are constant returns to scale in private inputs alone. If there are constant returns to scale over all factors, a2 is zero.

THE DATA

The bundle of private-sector inputs is computed by weighting the logs of private-sector capital and employment by sample-average factor shares. Experimentation with more complex weighting methods, such as that used by Aschauer, suggested that this procedure is not crucial to the results. The private-sector output, employment and capital stock series are drawn from the OECD's Analytical Data Base (except for the data used in the U.S. regressions reported in Table 1). This provides series that are as far as possible comparable across countries, although variations in definitions and data-collection methods virtually preclude full comparability. Data for the infrastructure capital stocks are from the OECD's "Flows and Stocks of Fixed Capital", except for the "narrow" definition (see below) for France, which was cumulated from investment data. The capacity utilisation series refer to the manufacturing sector only and are drawn from the OECD's Main Economic Indicators. These are the least comparable of the series used. For example, measures for some countries are quantitative, but for others they are constructed from qualitative survey responses. All data are annual.

Although Aschauer concentrated on public-sector infrastructure investment, the split between public and private infrastructure varies widely from country to country, perhaps for historical reasons. Thus, two concepts of infrastructure are used in estimation. The "narrow" definition is the capital stock of "producers of government services", and the "broad" definition includes in addition equipment and structures in electricity, gas and water, and structures in transport and communication. The broad definition is somewhat more internationally comparable, and also complements Aschauer's examination of sub-aggregates of the government capital stock. Neither definition includes the military capital stock.

Chart A shows the two definitions of infrastructure capital and TFP for the ten OECD countries for which data are available. All series are in level form, but have been detrended with simple time trends. In all countries, except Greece, both measures of infrastructure are hump-shaped, peaking in the early-to-mid 1970s (2). In half of the countries -- the United States, Japan, Germany, Canada and Belgium -- TFP has roughly the same pattern, a correlation which is picked up by the regressions. For the other countries, there is no such correlation.

THE RESULTS

Table 1 replicates regression 1.7 in Aschauer's Table 1 using very similar data concepts. The first set of regressions is in level form, as in Aschauer. Infrastructure contributes to private-sector productivity and, since a1 and a2 are of similar absolute magnitude, the results support the hypothesis of constant returns to scale for private-sector inputs alone, and increasing returns to scale overall. By contrast, Aschauer found constant returns to scale across all factors. However, as the series are non-stationary and the Dickey-Fuller test (ADF) suggests they are not cointegrated, the first-difference specification used in the second set of regressions in Table 1 seems preferable. These results suggest a less important, but still significant, role for infrastructure and a more important role for the private-sector inputs. Moreover, the magnitude of the coefficients suggests increasing returns to scale in the private-sector inputs -- the point estimate for b (in equation [1]) from regression B.2 is 1.25.

Regression results for nine countries (no capacity utilisation measure is available for Greece before 1982) are shown in Tables 2 and 3. The first table shows the results with the narrow definition of infrastructure and the second with the broad one. All series are differenced. Both types of infrastructure are statistically significant for the United States, Germany, Canada, and Australia. Only the narrow definition is significant for France (when no correction is made for auto-correlation) and Finland (when a correction is made for auto-correlation). Only the broad definition is significant in Belgium and Japan (if auto-correlation is corrected). Among those countries for which infrastructure is significant, the implications for returns to scale vary widely: for the United States, Germany, the United Kingdom and Canada, the private-sector input alone seems to have increasing returns to scale; returns across all factors of production seem to be increasing for the United States, constant for Germany and decreasing for the other countries (3).

Although it is not apparent in the tables, a feature of the regressions worth noting is the importance of the capacity utilisation term. The residuals from regressions excluding this term (not shown) are highly auto-correlated, and applying an auto-correlation correction results in the statistical insignificance of virtually all regressors for all countries. This emphasises that the relationship between infrastructure and productivity is a longer-term, rather than a cyclical, one.

The longer-term nature of the relationship raises one difficulty in interpreting the regression results: each country in the sample experienced only one prolonged TFP slowdown over the sample period. Was the experience of the 1970's unique, or can other productivity slowdowns also be explained by the pattern of infrastructure investment?

Two approaches were taken in trying to answer this question. The first uses cross-section data. If the country-specific correlation between infrastructure and TFP in the 1970s was just a coincidence, one would not expect any particular cross-country correlation between these two variables. Equation [3], specified in first differences, was estimated on a cross-country basis using sample-average values for the variables. However, the capacity utilisation term was omitted as it contributes to explaining short-term fluctuations, rather than to long-term trends. The results suggest a high and significant elasticity of TFP with respect to infrastructure (Table 4). The broad definition explains a larger proportion of the cross-country variance of TFP growth than the narrow definition.

The second approach was to examine a long time-series for the United States, covering the period 1890 to 1948. Total factor productivity and public-sector capital stock data (corresponding to the "narrow" definition) are from Kendrick (1961), the Bureau of Labour Statistics and the Bureau of Economic Analysis. Visual examination of the raw series indicated that a linear time trend was not appropriate. Instead, piecewise linear trends were used, with kinks in 1929 and 1948. Chart B shows the resulting detrended series. The post-war correlation highlighted by Aschauer is clearly visible. However, the decline in the public capital stock appears to lag that in TFP, which may suggest a "reverse causation" (4). No systematic pattern is evident in the rest of the data, except the simultaneous rise in both series during the decade following 1933 (5).

NOTES

1. Some obvious possibilities are: none of the other proposed explanations for the slowdown were included in his regressions; the causality may be reversed, since the productivity slowdown may have squeezed government budgets and led to less infrastructure capital formation; the wrong production function was used; the rather high weight estimated for government capital is "implausible": interpreted in a growth-accounting framework, it implies that the return to infrastructure is three times that to private-sector capital; and the results may be sensitive to the definition of "infrastructure", to the sample period, or be unique to the United States.

2. The detrending emphasises the deceleration of the series while obscuring changes in their levels. Thus in some countries (the United States, for example) the infrastructure stocks have not only decelerated but have actually declined. In others (Germany, for example) they have decelerated, but continued to grow.

3. For Norway, the point estimates imply that the private input bundle-has negative effect on private-sector output, suggesting some problem with the data for that country.

4. Although Aschauer used lagged infrastructure as an instrument to attempt to control for simultaneity bias, the prolonged nature of the slowdown makes it unlikely that this procedure could have identified the direction of causation.

5. Regressions were also carried out using the equation [3] in first difference. However, no capacity-utilisation measure was available. Results suggested that the infrastructure elasticity of TFP was negative (-.06), although not significant (t=.2), over the 1890-1929 period. They confirmed the visual impression of a positive (.25) -- yet insignificant (t=.9) -- elasticity over the 1930-1948 period.

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Aschauer, D.A. (1989), "Is public expenditure productive?", Journal of Monetary Economics 23, (March), pp. 177-200.

Kendrick, J.W. (1961), Productivity Trends in the United States, a study by the National Bureau of Economic Research, New York, Princeton University Press.

Phillips, P.C.B. and S. Ouliaris (1990), "Asymptotic properties of residual based tests for cointegration", Econometrica, No. 1, (January), pp. 165-193.

Table 1

Effect of the public sector capital stock on total factor productivity for the United States (1949-1987)

The model: $TFP = a + a_0 time + a_1(INF-PIN) + a_2 PIN + a_3 IFU$ (a)

	a	a_0 x 100	a_1	a_2	a_3	SEE x 100	adj. R^2	DW	ADF (b)	Rho 1 Rho 2 (c)
A. Level										
1)	0.41 (0.7)	4.45 (0.9)	0.46 (5.9)	0.11 (0.5)	..	2.98	0.962	0.67	-2.19	.. ..
2)	-1.85 (-6.0)	1.68 (8.7)	0.30 (10.7)	-0.38 (-4.6)	0.51 (16.8)	0.99	0.996	1.24	-2.80	.. ..
3)	-1.28 (2.9)	1.62 (4.9)	0.30 (6.4)	-0.37 (-2.6)	0.39 (10.4)	0.82	0.996	2.13	..	0.85 -0.32
B. First-difference										
1)	2.26 (4.7)	.. ..	0.22 (2.1)	-0.60 (-3.1)	0.45 (10.7)	0.95	0.79	1.96	..	.. ..
2)	1.97 (9.2)	.. ..	0.25 (2.7)	-0.50 (-2.6)	0.42 (9.4)	0.88	0.76	2.13	..	-0.05 -0.05

a) Definition of the variables: TFP: total factor productivity (Tornqvist index. Source: BLS); INF: general-government real net capital stock; PIN: combination of private inputs; IFU: capacity utilisation indicator from business surveys in manufacturing. All variables are in logs.

b) Cointegration regression Augmented Dickey-Fuller statistic. The asymptotic critical values at the 5 per cent level above which one rejects the null hypothesis of no cointegration are -4.74 and -5.02 with 4 and 5 regressors, respectively. Phillips and Ouliaris (1990), p. 190, Table IIc).

c) With Cochrane-Orcutt correction for second-order auto-correlation.

Table 2

Effect of infrastructure (narrow definition) on total factor productivity

The model: $\Delta\ TFP = a_o + a_1\Delta\ (INF-PIN) + a_2\Delta\ PIN + a_3\Delta IFU$ (a)

		a_0 x 100	a_1	a_2	a_3	SEE x 100	adj.R^2	DW	Rho 1 / Rho 2
United States 1957-88		1.99 (4.1)	0.29 (3.1)	-0.56 (-2.9)	0.39 (10.6)	0.76	0.82	2.2	.. ..
	(b)	1.90 (4.3)	0.30 (3.9)	-0.52 (-3.0)	0.40 (11.4)	0.77	0.82	1.89	-0.19 -0.04
Japan 1969-88		-1.96 (-0.9)	0.15 (0.5)	1.57 (2.2)	0.14 (1.3)	2.28	0.28	1.9	.. ..
	(b)	0.49 (0.4)	0.25 (1.3)	0.18 (0.3)	0.23 (3.4)	1.54	0.46	2.2	-0.29 0.06
Germany 1961-87		0.34 (0.9)	0.53 (5.8)	-0.00 (-0.0)	0.46 (9.3)	0.82	0.80	2.3	.. ..
	(b)	0.31 (0.9)	0.53 (6.1)	0.02 (0.1)	0.46 (9.3)	0.84	0.78	1.8	-0.16 0.07
France 1967-88		-1.15 (-1.6)	0.70 (3.7)	0.73 (3.9)	0.22 (5.1)	0.71	0.73	1.6	.. ..
	(b)	-0.12 (-0.1)	0.41 (1.2)	0.67 (2.5)	0.18 (4.0)	0.71	0.70	2.0	0.27 0.11
United Kingdom 1973-88		1.13 (1.1)	0.15 (0.5)	-0.70 (-1.6)	0.09 (4.6)	1.67	0.56	2.3	.. ..
	(b)	1.67 (1.6)	-0.03 (-0.1)	-0.35 (-0.9)	0.06 (3.1)	1.48	0.53	2.4	-0.19 -0.34
Canada 1963-88		0.19 (0.3)	0.63 (5.5)	0.27 (1.7)	0.28 (9.7)	0.77	0.83	1.8	.. ..
	(b)	0.21 (0.3)	0.66 (4.1)	0.27 (1.4)	0.28 (9.4)	0.79	0.81	2.0	0.08 0.11
Belgium 1967-88		-0.00 (-0.0)	0.57 (3.4)	0.79 (2.3)	0.21 (2.8)	1.40	0.50	3.0	.. ..
	(b)	-0.01 (-0.3)	0.52 (6.1)	0.85 (4.7)	0.15 (2.7)	1.15	0.64	2.0	-0.72 -0.14
Finland 1967-88		0.32 (0.3)	0.54 (1.8)	1.20 (2.7)	0.03 (2.6)	1.52	0.51	2.3	.. ..
	(b)	-0.45 (-0.8)	0.89 (5.3)	1.04 (5.1)	0.04 (6.2)	1.14	0.70	1.4	-0.48 -0.54
Norway		0.66 (0.3)	0.80 (1.5)	-0.11 (-0.2)	0.07 (3.1)	1.61	0.51	1.6	
	(b)	3.51 (1.9)	0.15 (0.3)	-1.13 (-2.3)	0.09 (5.3)	1.19	0.65	1.7	-0.13 0.21
Australia 1967-87		0.88 (1.3)	0.43 (2.4)	0.79 (0.3)	0.06 (5.2)	1.22	0.57	2.2	.. ..
	(b)	0.61 (1.1)	0.34 (2.4)	0.18 (0.9)	0.06 (4.7)	1.24	0.52	1.9	-0.26 -0.23

a) Definition of the variables: TFP: total factor productivity (fixed-weight index); *INF: capital stock of producers of government services; PIN: combination of private inputs; IFU:* capacity utilisation indicator from business surveys in manufacturing. All variables are in logs.

b) With Cochrane-Orcutt correction for second-order autocorrelation.

Table 3

Effect of infrastructure (broad definition) on total factor productivity

The model: $\Delta\ TFP = a_o + a_1\Delta\ (INF\text{-}PIN) + a_2\Delta\ PIN + a_3\Delta IFU$ (a)

		a_0 x 100	a_1	a_2	a_3	SEE x 100	adj.R^2	DW	Rho 1 Rho 2
United States 1957-88		2.13 (4.4)	0.33 (2.7)	-0.60 (-3.1)	0.41 (10.9)	0.79	0.81	2.1	.. ..
	(b)	2.11 (4.3)	0.34 (2.9)	-0.59 (-3.0)	0.41 (11.2)	0.80	0.80	1.9	-0.09 0.05
Japan 1969-88		3.02 (-1.4)	0.34 (1.2)	1.54 (2.3)	0.16 (1.6)	2.20	0.33	1.9	.. ..
	(b)	-0.97 (-0.8)	0.39 (2.2)	0.4 (0.9)	0.23 (3.9)	1.4	0.55	2.3	-0.39 0.01
Germany 1961-87		-0.40 (-0.9)	0.66 (6.4)	0.06 (0.4)	0.48 (10.1)	0.77	0.82	2.4	.. ..
	(b)	-0.48 (-1.4)	0.68 (8.2)	0.10 (0.7)	0.48 (10.2)	0.77	0.82	1.9	-0.26 -0.09
France 1971-87		0.93 (0.6)	0.15 (0.3)	0.52 (1.9)	0.17 (3.4)	0.71	0.60	1.9	.. ..
	(b)	2.38 (2.5)	-0.34 (-1.1)	0.38 (2.6)	0.17 (4.0)	0.59	0.65	2.2	-0.53 -0.39
United Kingdom 1973-87		1.10 (0.7)	0.29 (0.5)	-0.65 (-1.1)	0.09 (4.4)	1.74	0.55	2.2	.. ..
	(b)	2.00 (1.4)	-0.18 (-0.3)	-0.51 (-1.0)	0.06 (2.8)	1.54	2.22	0.5	-0.25 -0.38
Canada 1963-88		-0.69 (-0.8)	0.77 (4.3)	0.45 (2.0)	0.30 (8.9)	0.87	0.78	1.3	.. ..
	(b)	-0.37 (-0.3)	0.71 (2.3)	0.36 (1.1)	0.29 (8.8)	0.85	0.78	2.0	0.30 0.16
Belgium 1967-88		-0.36 (-0.5)	0.57 (3.2)	0.96 (2.6)	0.22 (2.8)	1.42	0.48	3.0	.. ..
	(b)	-0.43 (-1.2)	0.54 (5.6)	1.03 (5.3)	0.15 (2.6)	1.21	0.60	2.0	-0.70 -0.13
Finland 1967-88		1.33 (1.2)	0.27 (0.9)	0.90 (2.0)	0.03 (2.4)	1.61	0.44	2.1	.. ..
	(b)	1.04 (1.3)	0.40 (1.6)	0.79 (2.4)	0.04 (3.4)	1.59	0.42	1.4	-0.17 -0.42
Norway 1975-86		1.62 (0.6)	0.54 (0.9)	-0.22 (-0.3)	0.07 (2.7)	1.73	0.43	1.5	.. ..
	(b)	4.88 (2.4)	-0.19 (-0.4)	-1.55 (-2.7)	0.09 (5.4)	1.18	0.66	1.8	-0.09 0.30
Australia 1967-87		0.00 (0.0)	0.70 (2.7)	0.36 (1.2)	0.06 (5.5)	1.18	0.60	2.3	.. ..
	(b)	-0.32 (-0.6)	0.58 (3.2)	0.50 (2.5)	0.06 (5.1)	1.17	0.57	1.9	-0.36 -0.40

a) Definition of the variables: TFP: total factor productivity (fixed-weight index); INF: infrastructure capital (broad definition); PIN: combination of private inputs; IFU: capacity utilisation indicator from business surveys in manufacturing. All variables are in logs.

b) With Cochrane-Orcutt correction for second-order autocorrelation.

Table 4

Cross-country regressions

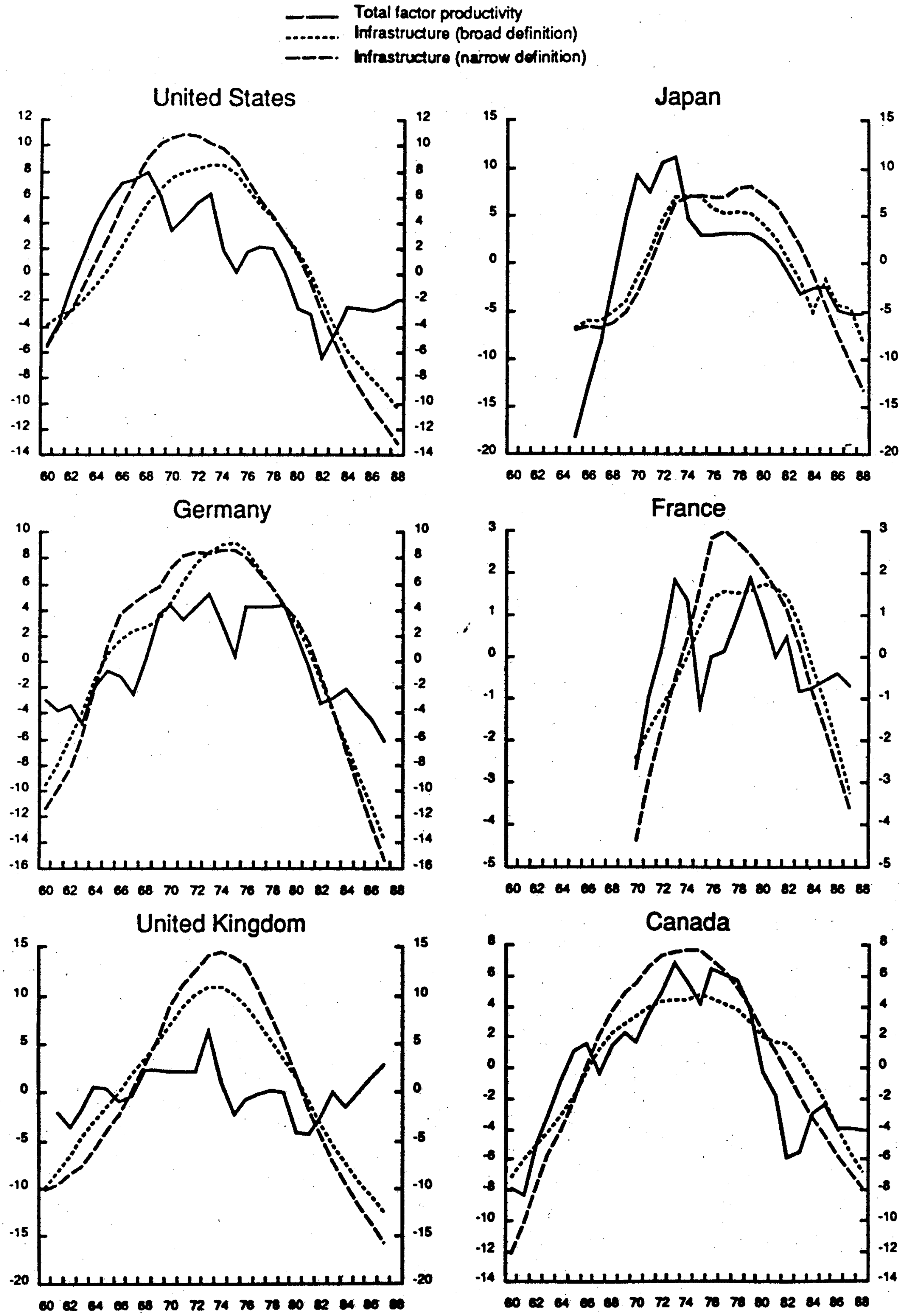
The model: $\overline{\Delta\ TFP} = a_0 + a_1\ \overline{\Delta(INF - PIN)} + a_2\ \overline{\Delta\ PIN}$ (a)

	a_0 x 100	a_1	a_2	$\bar{R}^2$	SEE
Narrow definition of infrastructure	0.5 (0.9)	0.45 (4.5)	0.24 (1.2)	0.66	0.51
Broad definition	0.5 (1.4)	0.48 (5.9)	0.07 (0.5)	0.77	0.40

a) See note a in Tables 2 and 3 for the definition of the variables.

The bar denotes the country-specific historical average growth rate of the variables.

Chart A. Productivity and infrastructure (a)



a) All series detrended with linear time trends.

Chart A (cont.). Productivity and infrastructure

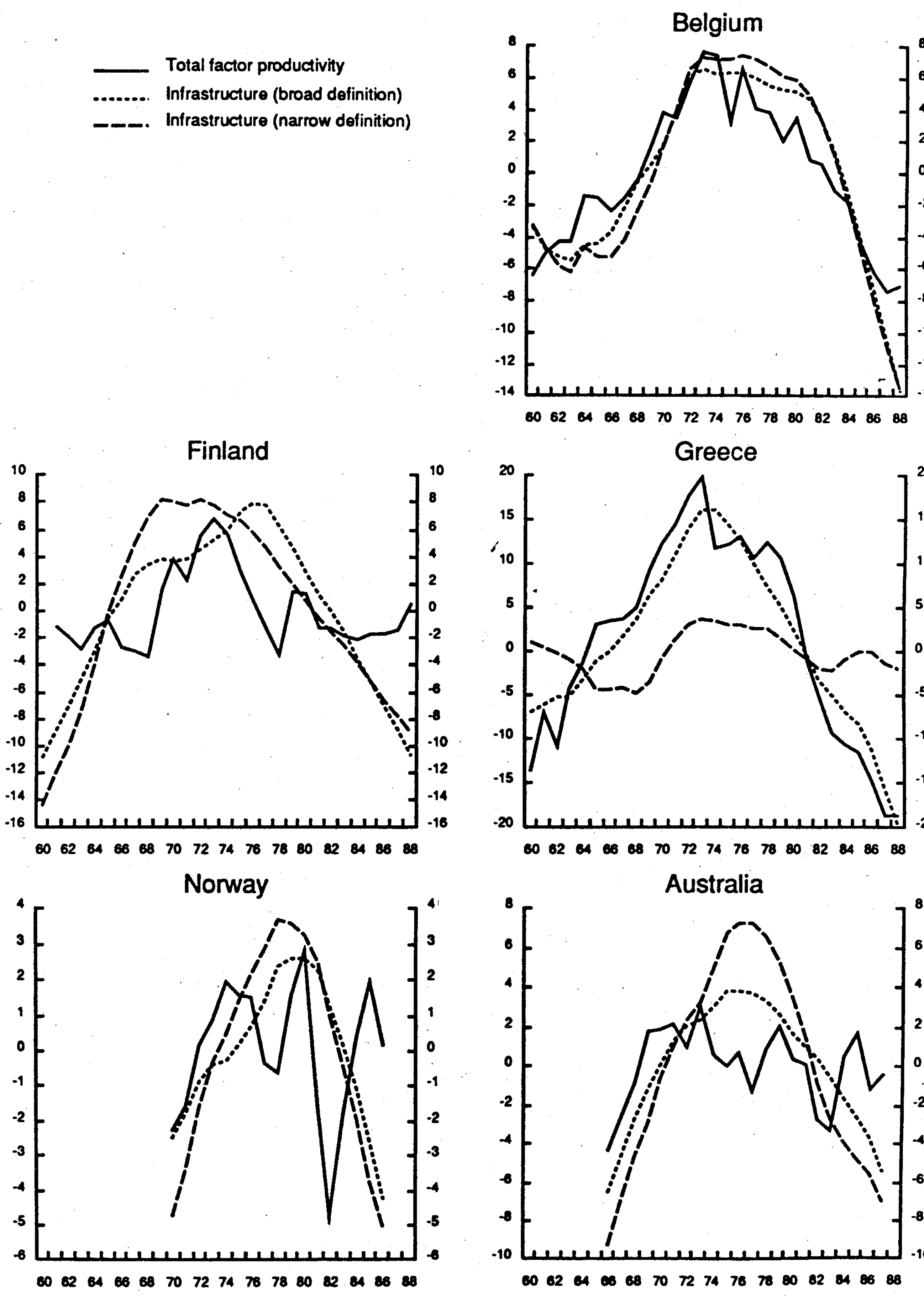
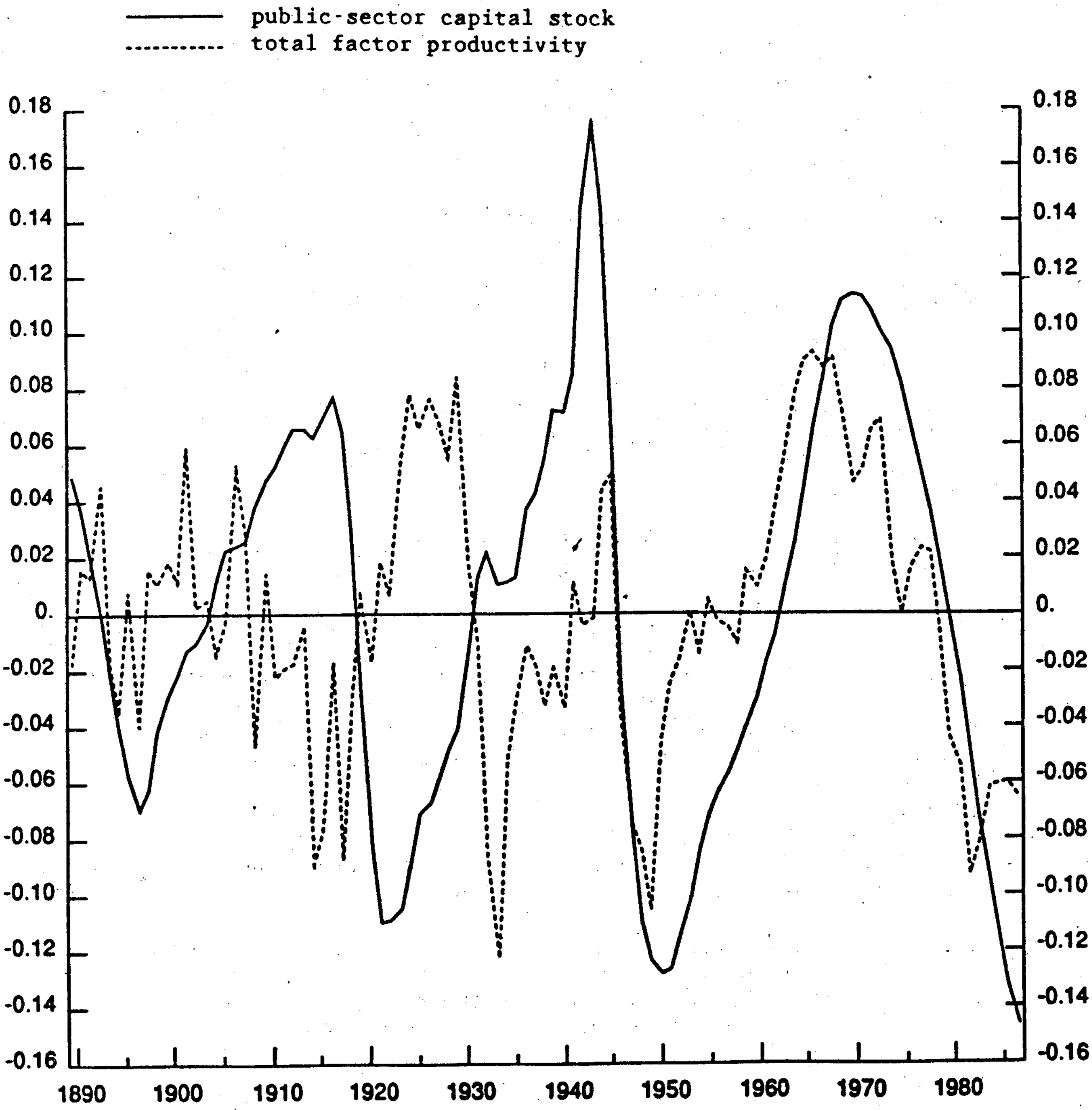


Chart B. Infrastructure and productivity for the United States (1889-1987) (a)



a) Both series detrended with piecewise-linear time trends.

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