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Technology Transfer to the USSR: An Econometric Analysis

MARTIN L. WEITZMAN

Department of Economics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

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A production-function study is undertaken that attempts to estimate the marginal productivity of machinery imported from the West for Soviet industry, and for the subsectors of chemicals, petroleum, and machinery during the period 1960–1975. The basic conclusion is that the marginal productivity of imported Western capital is not significantly different from that of capital of non-Western origin. It seems quite difficult to detect any influence of Western technology on the Soviet economy from the aggregate time-series data available to us. *J. Comp. Econ.*, June 1979, 3(2), pp. 167–177. Massachusetts Institute of Technology, Cambridge, Massachusetts.

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The transfer of technology from one country or region to another is a subject of controversial interest that touches aspects of engineering, economics, history, and politics. When Western nations are the exporter and the recipient is the Soviet Union, that subject takes on an added dimension.

The gain to the USSR from importing Western technology is not just another topic of academic research but in fact underlies a heated policy issue. There is perhaps no comparable area of Soviet economics where the results of model building can be so directly used (or abused) by policy makers.

While several case studies have been done,[1] until recently there has been no serious attempt to quantify on a macro level the overall impact of imported Western technology on the Soviet economy. Now we have the pioneering work of the SRI–WEFA group, especially that of Green and Levine.[2] On the basis of econometric estimates and simula-

[1] See, e.g., Amman *et al.*, 1977; Berliner, 1976; Hanson, 1975, 1976, 1977; Sutton, 1973.

[2] Green and Levine, 1976, 1977; Green and Jarsulic, 1975.

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tion runs with a large, computerized model, they conclude that imported Western equipment makes a disproportionately large contribution to Soviet economic growth.

That work deserves praise for recognizing a significant issue, for assembling data, and for attempting to pose and answer questions scientifically about technology transfer to the Soviet Union. But in my opinion, the econometrics of these studies is questionable and, to put it gently, their conclusions cannot be sustained.

Using production-function analysis, in this paper I attempt to estimate the marginal productivity of machinery imported from the West for Soviet industry, and for the subsectors of chemicals and petrochemicals, petroleum, and machine building and metal working during the period 1960–1975. The overwhelming conclusion is that the marginal productivity of imported Western capital is not significantly different from that of capital of non-Western origin. I believe a fair summary statement is that we are unable to detect any influence of Western technology on the Soviet economy from the aggregate time-series data available to us.

This paper focuses on the issue of whether or not imported Western capital has the same productivity for the USSR as domestically produced capital, which is a narrow test for the significance of imported technology. In principle, richer and more general models of transfer and diffusion might be considered, but in practice they would be too complicated to estimate empirically. The simple model suffices, I believe, as a vehicle for posing and answering the main question of interest.

The statistical methodology of this paper can be simply stated. The following symbols are employed:

t Time
K_d Domestically produced Soviet capital (more accurately, Soviet capital of non-Western origin)
K_i Soviet capital imported from the West
K Total Soviet capital $= K_d + K_i$
L Labor force
Y Output

Let

$$Y = F(t,K,L) \tag{1}$$

represent some estimate of the Soviet production function when no distinction is made between imported and domestic capital.

Let

$$Y = G(t,K_d,K_i,L) \tag{2}$$

represent a more general production function which differentiates between the possibly separate roles of domestic and imported capital, and which includes (1) as a special (nested) case. For example, a reasonable form might be

$$G(t,K_d,K_i,L) = F(t,K_d + wK_i,L), \tag{3}$$

where w is a "weight" on imported capital that specifies how much more productive it is than domestic capital. When $w = 1$, form (3) collapses into form (1).

The basic procedure is to run regressions of the forms (1) and (2) and test (with an appropriate F-statistic) the hypothesis that the nested form (1) is (or is not) different from form (2) at a statistically significant level. For the specification (3), this amounts to testing the null hypothesis that $w = 1$.

In this paper I will largely be operating with the restriction (3), which I consider to be a reasonable specification. For the aggregate production function (1), three forms will be utilized:

$$Y = Ae^{\lambda t}K^{\alpha}L^{1-\alpha} \tag{I}$$

(Cobb–Douglas with constant growth of technological progress),

$$Y = Ae^{\lambda t+lt^2}K^{\alpha}L^{1-\alpha} \tag{II}$$

(Cobb–Douglas with variable growth of technological progress),

$$Y = Ae^{\lambda t}(\delta K^{(\sigma-1)/\sigma} + (1 - \delta)L^{(\sigma-1)/\sigma})^{\sigma/(\sigma-1)} \tag{III}$$

(constant elasticity of substitution with constant growth of technological progress).

Several other specifications were tested but rejected for presentation (e.g., CES with variable growth of technological progress) because they yielded results that were either significantly worse (with more restricted forms) or insignificantly better (with less restricted forms). For completeness, results of a few alternative approaches are presented later.

The production functions (I)–(III) are constant returns to scale with Hicks-neutral technical change. The usual caveats about aggregate production functions apply, but this is hardly the place to go into them.

Data sources are discussed in the appendix, but basically I am using the same series as Green and Levine. Although there are problems of measurements and valuation, especially concerning imported capital, and there are the inevitable alternative ways of constructing some series, on the whole the data seem to be of usable quality. The time period is 1960–1975.

Regression results[3] for specifications (I)–(III) on Total Industry, Chemi-

[3] Numbers in parentheses are standard errors. For form (III), which is nonlinear, standard errors refer to a "linearized" version. (See Weitzman, 1970, Footnote 11, p. 680). The R^2 statistic is not reported, since it is rather meaningless for regressions in first-difference form. When the regressions in Table 1 are run in level form, the R^2 are all above 0.99.

cals and Petrochemicals, Petroleum, and Machine Building and Metal Working are presented in Table 1. All regressions were run in logarithmic first differences.[4]

Several things stand out from these regressions.

Generally speaking, specifications (II) and (III) have roughly similar explanatory powers but either is preferable to (I). These conclusions follow from nesting (I), (II), and (III) in the composite form

$$Y = e^{\lambda t + lt^2}(\delta K^{(\sigma-1)/\sigma} + (1 - \delta)L^{(\sigma-1)/\sigma})^{\sigma/(\sigma-1)}. \qquad \text{(IV)}$$

The appropriate F-test is

$$F_j = \frac{(SSR_j - SSR_{\text{IV}})/d}{SSR_{\text{IV}}/12} \qquad (j = \text{I, II, III}),$$

where d = difference in degrees of freedom between Eq. (IV) and j; 12 = degrees of freedom of (IV).

Note from Table 2 that (II) is never rejected, (I) is rejected for all sectors except Machine Building, and (III) is rejected for Chemicals and for Machine Building.

In this paper the aim is to test the importance of technology transfer, and I will not emphasize interpretation of production-function parameters, which is properly the subject of another paper. My purpose here is to show that, as a strictly statistical proposition, it is difficult to maintain the hypothesis that imported Western capital is different from domestically produced capital for the USSR. For some regressions the parameters assumed bizarre values, which I do not really believe. In principle, these regressions could be rerun with parameters constrained, but my feeling is there would be little difference in the resulting hypothesis testing relevant to this study.

For the sake of completeness, an approach is taken that forces a specification with "reasonable" or "standard" coefficient values. The Cobb–Douglas form (I) is employed where α (now denoted $\bar{\alpha}$) is *forced* to the value $\bar{\alpha} = 1/3$ and λ (now denoted $\bar{\lambda}$) is calculated in the standard way as an average annual residual over the 15-year period 1960–1975. Values of $\bar{\lambda}$, hereafter treated as fixed, are displayed in Table 3.

The basic specifications for testing the hypothesis that for the USSR imported Western capital has a marginal product significantly different from that of domestically produced capital are:

$$Y = Ae^{\lambda t}(K_d + wK_i)^{\alpha}L^{1-\alpha}, \qquad \text{(I)}$$

[4] The logarithmic form was deemed appropriate because errors are likely to be multiplicative. First differences are used to reduce autocorrelation (this is equivalent to regressing the so-called "growth equation"). When run in level form, the results are generally similar, but the Durbin–Watson statistic typically worsens.

TABLE 1

RESULTS OF THREE BASIC SPECIFICATIONS FOR SOVIET INDUSTRY AND SUBSECTORS

	λ	l	α	δ	σ	SSR (×10³)	DW
Total industry							
I	0.006		0.41			2.38	0.89
	(0.019)		(0.29)				
II	−0.007	1E-03	0.37			1.04	2.08
	(0.013)	(2.4E-04)	(0.20)				
III	0.002			0.99	100	1.42	1.46
	(0.015)			(0.019)	(5770)		
IV	−0.009	1.1E-03		0.12	0.78	1.04	2.07
	(0.030)	(2.1E-03)		(2.4)	(2.7)		
Chemicals							
I	0.049		−0.12			8.63	0.97
	(0.010)		(0.11)				
II	0.019	1.8E-03	−0.12			3.83	2.17
	(0.010)	(4.7E-04)	(0.075)				
III	0.051			−2.6E-06	0.31	5.06	1.35
	(0.007)			(2.4E-05)	(0.17)		
IV	0.025	1.4E-03		−2.2E-06	0.31	2.94	2.10
	(0.010)	(4.8E-04)		(2.6E-05)	(0.22)		
Petroleum							
I	0.036		0.40			10.3	1.20
	(0.021)		(0.27)				
II	0.046	−1.6E-03	0.62			7.16	1.82
	(0.019)	(6.9E-04)	(0.25)				
III	0.048			1.1E-07	0.17	6.71	1.53
	(0.013)			(1.1E-06)	(0.088)		
IV	0.031	7.6E-07		2.7E-07	0.18	6.10	1.51
	(0.044)	(1.9E-03)		(4.1E-06)	(0.16)		
Machine building							
I	−0.015		0.96			3.01	2.48
	(0.010)		(0.18)				
II	−0.015	1.1E-03	0.61			2.11	2.85
	(0.008)	(4.8E-04)	(0.21)				
III	−0.009			0.99	100	2.86	2.40
	(0.011)			(0.009)	(23,400)		
IV	−0.023	1.7E-03		4.2E-05	0.36	1.90	2.98
	(0.013)	(1E-03)		(6.7E-04)	(0.35)		

TABLE 2

F-TEST FOR SPECIFICATION

		Total	Chemicals	Petroleum	Machine building	$F(d, 12)$ 0.95
$(d = 2)$	I	7.77	11.64	4.11	3.53	3.89
$(d = 1)$	II	0.081	3.64	2.08	1.32	4.75
$(d = 1)$	III	4.46	8.70	1.21	6.08	4.75

$$Y = Ae^{\lambda t + lt^2}(K_d + wK_i)^{\alpha} L^{1-\alpha}, \quad \text{(II}')$$

$$Y = Ae^{\lambda t}(\delta(K_d + wK_i)^{(\sigma-1)/\sigma} + (1 - \delta)L^{(\sigma-1)/\sigma})^{\sigma/(\sigma-1)}, \quad \text{(III}')$$

$$Y = Ae^{\bar{\lambda} t}(K_d + wK_i)^{\bar{\alpha}} L^{1-\bar{\alpha}}. \quad \text{(V)}$$

In all cases, the null hypothesis is $w = 1$. All regressions are run in logarithmic first-difference form.

Table 4 presents the results of interest. The first three columns show the sum of squared residuals (times 10^3) when w is a priori fixed at values $\bar{w} = 0, \bar{w} = 1$, and $\bar{w} = 100$. Generally speaking, the error-sum-of-squares function is extremely flat in w, indicating how little effect there is from wildly different values of that parameter. The optimal value of w, denoted w^*, is given in the fourth column and its (minimum over all w) sum of squared residuals in the fifth column. The last column exhibits 95% nonlinear confidence intervals[5] for w. These confidence intervals bracket all values of w satisfying

$$\frac{SSR_r(w) - SSR_{unr}(w^*)}{SSR_{unr}(w^*)/df} \leq F_{0.975}(1, df). \quad (4)$$

This is the standard *F*-test[6] on the percentage difference in the sum of

[5] An arbitrary upper bound of 1000 was placed on the confidence intervals, so as to avoid calculating the *SSR* for higher values of w. When all regressions are run in level rather than in first-difference form, the 95% confidence intervals are as follows:

	Total	Chemicals	Petroleum	Machine Building
I	(−45, 1000)	(4, 1000)	(−10, 1000)	(−6, 9)
II	(−45, 1000)	(−10, 1000)	(−10, −4)	(−8, 24)
III	(−31, 65)	(−1, 71)	(−10, 1000)	(−7, 10)
IV	(−31, 210)	(−6, 40)	(−5, 6)	(−15, 1000)

Note that these values are roughly the same as those reported in Table 4.

[6] This test has the appropriate large-sample properties for a nonlinear regression. The 0.975 percentile of F is used because the 95% confidence interval is two-sided.

TABLE 3

AVERAGE ANNUAL GROWTH OF RESIDUAL WHEN SHARE OF CAPITAL IS ⅓, SHARE OF LABOR IS ⅔

Total industry	$\bar{\lambda} = 1.13\%$
Chemicals	$\bar{\lambda} = 1.45\%$
Petroleum	$\bar{\lambda} = 4.30\%$
Machine building	$\bar{\lambda} = 1.77\%$

squared residuals between the restricted and unrestricted hypotheses, corrected for degrees of freedom, which are as follows:

$$df_{\mathrm{I}} = 13, \quad df_{\mathrm{II}} = 12, \quad df_{\mathrm{III}} = 12, \quad df_{\mathrm{V}} = 15.$$

The last column indicates in a rather dramatic fashion how little statistical power is provided by different values of w. Generally speaking, we are strongly unable to reject the hypothesis $w = 1$. A very wide range of

TABLE 4

TESTING THE HYPOTHESIS $w = 1$

Industry	$\bar{w}$ 0	1	100	w^*	Minimum SSR	95% Confidence interval
Total						
I	2.323	2.375	2.578	−11.89	1.924	(−48, 1000)
II	1.030	1.042	1.316	−4.885	0.999	(−48, 1000)
III	1.392	1.420	2.439	−5.675	1.295	(−28, 24)
V	2.348	2.389	5.076	−13.77	1.975	(−24, 10)
Chemicals						
I	8.924	8.631	7.728	10.71	5.282	(3, 168)
II	3.878	3.827	4.361	1000	4.244	(−11, 1000)
III	5.962	5.063	7.166	4.856	4.151	(−1, 27)
V	20.47	19.47	39.44	4.632	18.27	(−2, 26)
Petroleum						
I	10.71	10.28	9.812	7.145	8.506	(−10, 1000)
II	7.064	7.156	9.809	−1.262	7.015	(−10, 1000)
III	6.879	6.711	6.251	40	6.237	(−3, 1000)
V	10.77	10.44	12.58	7.229	9.725	(−3, 434)
Machine building						
I	3.044	3.012	7.032	1.740	3.006	(−8, 19)
II	2.013	2.105	3.317	0.2675	2.103	(−23, 67)
III	2.868	2.856	5.902	1.020	2.856	(−10, 26)
V	5.699	5.726	7.281	−5.571	5.607	(−17, 585)

TABLE 5

TOTAL INDUSTRY

t	K	K_i	L	Y
1960	80.	1.39	22620	53.4
1961	88.7	1.64	23817	56.25
1962	100.	1.92	24667	60.41
1963	111.	2.22	25442	63.88
1964	124.	2.47	26317	67.36
1965	137.	2.65	27447	72.45
1966	150.	2.78	28514	77.28
1967	163.	2.93	29448	83.41
1968	176.	3.21	30428	88.83
1969	190.	3.66	31159	93.48
1970	208.	4.18	31593	100.
1971	227.	4.47	32030	106.24
1972	246.	4.62	32461	111.64
1973	266.	5.02	32875	118.24
1974	288.5	5.42	33433	125.47
1975	313.3	5.99	34054	132.76

values for the marginal product of imported Western capital is consistent with the four specifications tried.[7]

For contrast, two alternative functional forms that treated imported and domestically produced capital as separate factors of production were tested:

$$Y = Ae^{\lambda t}K_d^{\alpha}K_i^{\beta}L^{1-\alpha-\beta}, \tag{VI}$$

$$Y = Ae^{\lambda t+lt^2}K_d^{\alpha}K_i^{\beta}L^{1-\alpha-\beta}. \tag{VII}$$

Personally, I consider (VI) and (VII) to be bad specifications because the elasticity of substitution between domestic and imported capital ought to be far greater than the elasticity of substitution between capital and labor. A specification like (VI) and (VII) is biased toward yielding a high marginal product of imported capital because there is so little of it relative to the other factor, and there is a severe restriction on the degree to which domestic capital can substitute for it. Moreover, (VI) and (VII) are inappropriate for hypothesis testing because they do not nest into (1).

In all (eight) cases the regressions on logarithmic first-difference versions of (VI) and (VII), with the single exception of Petroleum (VI), yielded values of β either negative or insignificantly different from zero.

What can we conclude from the results of the present paper's exercises

[7] The only w significantly different from 1 is Chem I, which is an inferior specification to Chem II or Chem III and (see Table 1) yields a negative capital coefficient.

TABLE 6

CHEMICALS AND PETROCHEMICALS

t	K	K_i	L	Y
1960	3.9	0.19	792	38.19
1961	4.6	0.31	868	41.77
1962	5.2	0.41	951	46.47
1963	7.2	0.47	1042	50.87
1964	9.1	0.55	1142	57.39
1965	10.7	0.62	1251	66.12
1966	12.5	0.68	1346	72.48
1967	13.7	0.76	1424	79.77
1968	15.7	0.87	1468	85.07
1969	16.3	0.98	1523	90.31
1970	18.1	1.04	1568	100.
1971	20.7	1.06	1598	108.07
1972	22.8	1.09	1626	115.07
1973	24.5	1.17	1667	125.08
1974	26.95	1.23	1706	137.2
1975	29.6	1.29	1753	152.69

in applied production-function analysis? It seems to me that an almost inescapable conclusion is the following. There is no evidence on the basis of currently available data that imported Western capital is more productive or less productive for the Soviet economy than capital of non-Western origin.

TABLE 7

PETROLEUM PRODUCTS

t	K	K_i	L	Y
1960	5.8	0.25	196	40.05
1961	6.3	0.3	200	45.12
1962	6.9	0.37	204	51.22
1963	7.5	0.47	205	57.3
1964	8.3	0.58	221	62.06
1965	9.1	0.72	229	68.24
1966	10.1	0.86	242	74.24
1967	11.1	0.94	252	80.92
1968	12.	1.04	254	86.63
1969	13.9	1.17	256	92.29
1970	15.	1.28	263	100.
1971	16.3	1.36	263	106.91
1972	18.1	1.45	265	114.02
1973	19.67	1.51	268	122.31
1974	21.62	1.54	268	131.78
1975	23.85	1.63	269	141.2

TABLE 8

MACHINE BUILDING AND METAL WORKING

t	K	K_i	L	Y
1960	16.2	0.53	7206	47.05
1961	17.7	0.6	7682	49.84
1962	20.	0.67	8189	56.07
1963	22.3	0.75	8729	59.84
1964	24.4	0.82	9305	64.36
1965	27.	0.91	9905	69.07
1966	28.5	0.97	10400	73.47
1967	31.7	1.02	19846	79.55
1968	34.7	1.08	11282	86.55
1969	37.4	1.19	11698	93.16
1970	41.	1.35	12017	100.
1971	45.6	1.58	12369	109.73
1972	50.8	1.69	12718	119.21
1973	55.7	1.86	13049	130.65
1974	61.22	2.06	13424	142.81
1975	67.67	2.31	13816	154.29

APPENDIX: DATA

All data, displayed in Tables 5–8, are from the Stanford Research Institute–Wharton Econometric Forecasting Associates data bank. I would like to thank Daniel Bond for making them available and Donald Green for his full cooperation. The numbers are the same as those employed in the latest Green–Levine paper, and a fuller description is contained in that source.

Briefly, total capital stock is the official Soviet "basic funds" series in 1955 rubles, adjusted by Cohn. The capital of a given year is the stock in place on January 1 of that year.

Imported Western capital is a constructed series built up out of import data and made compatible with the total capital series. A discussion is contained in the Green–Levine and Green–Jarsulic papers. Because of ambiguities inherent in valuation and interpretation, and also because of the unavoidable assumptions involved in converting investment data into capital stock, the imported Western capital series is easily the most controversial of this study.

Domestically produced capital (more accurately, capital of non-Western origin) is defined as the difference between total and imported Western capital.

Labor figures are due to Rapaway at the Department of Commerce, and are measured in thousands of persons employed.

Output indices are the standard Office of Economic Research index numbers, compiled in 1976.

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