DISCUSSION PAPER SERIES

No. 6013

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INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

www.cepr.org

Available online at: www.cepr.org/pubs/dps/DP6013.asp

ISSN 0265-8003

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Discussion Paper No. 6013
December 2006

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CEPR Discussion Paper No. 6013

December 2006

ABSTRACT

Lucas and Anti-Lucas Paradoxes*

The capital-output ratio is more than 40% lower in the poor countries than in the richest ones. Comparing TFP in manufacturing and in the economy at large, we show that the Balassa-Samuelson effect explains the bulk of this scarcity: TFP in manufacturing is indeed about 40% lower than TFP in the aggregate economy. This discrepancy is one for one translated into higher prices of equipment goods, which explains that capital is scarce in volume, but not in value terms. This quantifies our interpretation of the Lucas paradox. When focusing on manufacturing, a tradable sector for which relative prices differences should not be essential, the initial paradox is actually turned into an anti-Lucas paradox: it is in the poorest countries that the capital output ratio is higher. We argue that lack of productive infrastructure is essential in explaining this anti-paradox. We finally examine the role of institutional quality. We show that public capital under provision, as reflected in low levels of infrastructure stock, is the key channel through which poor institutions hamper capital accumulation.

JEL Classification: O11
Keywords: Lucas paradox and total factor productivity

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*This paper is part of the OECD Development Centre research programme. It does not necessarily reflect the views of the OECD.

Submitted 18 November 2006

1 Introduction

When Lucas asked: "Why doesn't capital flow from rich to poor countries?", he unleashed a huge literature that went beyond his own answer to the question. In his view, externalities to human capital accumulation were key to explaining the paradox which made the neo-classical model unsuited to analyze economic growth. Since Lucas' article, the idea that externalities to factors of production may exist has been deflated, making the paradox even more paradoxical. The now dominant view, exposed notably in Hall and Jones (1999), that TFP is lower in poor countries *ceteris paribus*, only gives a partial answer to the Lucas paradox. It does predict a lower amount of capital per head, or per unit of human capital, but not a lower ratio of capital per unit produced.

And yet, as we shall recall in the text, the capital-output ratio is more than 40% lower in poor countries than in the richest ones. Following and expanding the earlier work of Cohen and Soto (2002) Hsieh and Klenow (2003), and, more recently, Caselli and Freyer (2006), we argue however that the paradox, so stated, simply arises from the use of PPP data to calculate the capital-output ratio. Since the relative price of output is low in low-income countries, the use of PPP prices overestimates the market value of the productivity of physical capital in these countries. When market prices are used, one finds that the capital-output ratios are amazingly similar across countries. In other words, there is simply no Lucas paradox when the returns to capital are appropriately measured. This is confirmed econometrically: the elasticity of the capital output ratio to the relative price of capital is indeed equal to minus one.

The next question then becomes: why is the relative price of investment goods higher in poor countries? A number of papers have addressed this issue, emphasizing the role of capital taxation as a prime suspect (e.g. Jones, 1994). In this paper, we quantify the "Balassa Samuelson hypothesis" (see Balassa (1964), Samuelson (1964) and Summers and Heston (1991)), according to which poor countries have low productivity in the tradable sector relative to the non-tradable one. In a simple two sectors model, relative price differences should offset relative TFP differences. Building on previous work (see Causa and Cohen (2006)), we compute total factor productivity in the manufacturing sector to which, we assume, the equipment good sector belongs and which we take as a proxy of the tradable good sector. Following Balassa and Samuelson, we expect TFP to be lower in manufacturing, hence explaining a higher relative price of capital in the poorest countries. This is indeed what is observed.We then test econometrically whether the elasticity of the relative price of capital with respect to the difference between aggregate TFP- involving all sectors in the economy-and manufacturing TFP is indeed equal to unity. Again the answer is positive. The order of magnitudes involved are the following. When infrastructure capital is taken into account, aggregate TFP in poor countries amounts to 87 per cent of rich countries' TFP. The corresponding figure for manufacturing is 59 per cent. This implies a relative price differential of 50 per cent, which is what is needed to explain the capital-output ratio differences.

As a simple way to warrant this interpretation, one can focus on the manufacturing sector itself. To the extent that this is both a tradable good sector and a sector that produces equipment goods, the Lucas paradox should disappear. When comparing the manufacturing capital output ratio across countries, we show that this is indeed the case. In fact, the initial paradox is turned into what could be called an anti-Lucas paradox: it is in the poorest countries that the capital output ratio is higher! How can that be? One intuitive explanation is the lack of public capital. When electricity is scarce in a country, private investors must bring with them their own generators. We do find such a negative correlation in the data. The impact of infrastructure on aggregate capital accumulation, however, is, as expected, positive. The less infrastructure there is in a country, the less aggregate capital there is. As we shall document, however, about two third of the impact of infrastructure is mediated by its impact of relative prices.The interpretation that we suggest is the following: poor infrastructures are source of price distortions, in that they make it difficult to trade and import capital goods.

We finally explore the role of another argument that has attracted lots of attention, as a prime explanation of the Lucas paradox itself: institutional weaknesses. More specifically, we refer to the threat of diversion, encompassing the prevalence of corruption, the risk of expropriation and the lack of properly functioning property rights. What role does it play? If institutional quality were the causal explanation of the Lucas paradox, we should also observe a low capital-output ration in the manufacturing sector. The simple observation of an anti Lucas paradox in the manufacturing sector casts doubt on the institutional explanation of the Lucas paradox. While we do find a negative and significant correlation between capital scarcity, measured as a fraction of aggregate GDP, and institutional weakness, we show that this correlation disappears when controlling for infrastructure. We conclude that poor institutions do not hamper capital accumulation through fear of expropriation but more directly through the lack of proper infrastructures that are typically associated with weak states.

2 A framework of analysis

In this section we follow the earlier literature by decomposing the differences in output levels between rich and poor countries through a simple neo-classical model. We assume that aggregate output (Q_{it}) of country i at time t is a

Cobb-Douglas function of human and physical capital, H_{it} and K_{it} respectively, infrastructure, Z_{it},and total factor productivity (A_{it}):

$$Q_{it} = A_{it} K_{it}^{\alpha} Z_{it}^{\beta} H_{it}^{\gamma} \tag{1}$$

We use lower-cases for representing the same variables divided by the number of workers. We impose constant returns to scale, namely that $\alpha + \beta + \gamma = 1$[1]. This allows us to write:

$$q_{it} = A_{it}(k_{it}/h_{it})^{\alpha}(z_{it}/h_{it})^{\beta} h_{it}$$

which is the form under which we shall present the results.

Human capital is drawn from Cohen and Soto (2002) and physical capital from Easterly and Levine (2001). As proxy for infrastructure, we follow Canning (1999 and 2000) and chose the production of electricity in the country (see Causa and Cohen, 2006, on a discussion of why this proxy is relevant and appendix 1 for sources). The values of α is conventionally taken to be 0.33. The value of β is drawn from Canning (1999) and assumed equal to 0.085.

We take the rich countries as the numeraire for each of the five items: output, capital, infrastructure, human capital and TFP. We then compare in each region the contribution of each item, appropriately weighted, to the overall productivity of the economy. We restrict the analysis to a sub-sample of countries for which we also dispose of manufacturing data (see country grouping in Appendix).

Except for Sub-Saharan Africa, the averages presented here do not really differ from that obtained when using the entire sample of Summers and Heston data (see Cohen and Soto (2002) for a similar decomposition with a broader country coverage). The African sub-sample, however, is more productive than the full SH sample.We get an average productivity of 19% the rich countries' levels, as opposed to 12% for the full sample.

Table 1 presents the key results.

Table 1. Productivity differences- The aggregate economy (1990)

	q	$(k/h)^{\alpha}$	$(z/h)^{\beta}$	h	A
Rich countries	1.00	1.00	1.00	1.00	1.00
Other European	0.68	0.90	0.94	0.83	0.97
Non high	0.31	0.65	0.88	0.63	0.87
Non-high w/o SSA	0.34	0.68	0.88	0.65	0.87
SSA	0.19	0.50	0.87	0.54	0.80
SEAP	0.32	0.67	0.85	0.64	0.88
MENA	0.27	0.59	0.88	0.48	1.07
LATINCA	0.35	0.69	0.90	0.67	0.85

[1] See for instance Pritchett (2001), Krueger and Lindahl (2001) or Temple (2001).

Sources and country grouping: see appendix

Let us briefly comment this table. Each of the four components of the production function in middle- and low-income countries excluding sub-Saharan Africa are above 65% of the level of rich countries. This does not appear to be a big handicap. However the average output per worker is 34% of that observed in rich countries. Multiplying small or relatively benign handicaps can yield a dramatic effect on a country's income.

This decomposition illustrates why many authors have failed to find a one dimensional explanation of the poverty of nations, be it human or physical capital. It is argued, somehow by default, that differences in total factor productivity are the main source of cross country income differences. As one can see from table 1, however, TFP never appears to be the weak link of the chain, even in SSA. Indeed, if factors of productions could be helicoptered in the poor countries to reach their levels in rich countries, the productivity gap would boil down to 13% outside Africa and to 20% in Sub-Saharan Africa.

Similarly, in sub-Saharan Africa, each of the three components of the production function is on average above 50% of the levels observed in rich countries, while the average output level is only two tenth of rich countries'. Neither human nor physical capital nor infrastructure alone can explain much. Altogether they become a powerful explanation.

Table 1 suggests why Singapore's strategy, relying on human and physical capital and infrastructure accumulation, worked: by fixing three out of four components of the production function, a country can go a long way towards solving its development problem. As number of scholars have been discussing, Singapore's success story has been by far the result of high factor accumulation, rather than that of total factor productivity gains (see Young, 1995).

The table also explains the strength of migrants' economic motivations: their education level allows them to multiply by two (=0.63/0.31) their income as they move from middle- and low-income countries to rich countries. In the case of Sub Saharan Africa, a migrant worker can earn as much as three times more than in her origin country (=0.54/0.19).

3 The Lucas Paradox

3.1 In the economy at large

In the Cobb-Douglas case, the benchmark on which this paper relies, the marginal productivity of K is proportional to its average productivity:

$$\frac{\partial Q_{it}}{\partial K_{it}} = \alpha \frac{Q_{it}}{K_{it}}$$

Assuming that α is the same across countries, differences in the return to capital are simply reflected in differences in average values of the output-capital ratio. In such a framework, the potential for capital mobility is huge, as shown in Table 2 below.

Table 2. The Capital Output ratio

	CAPITAL/OUTPUT RATIO
Rich countries	1.00
Other European	0.87
Non high	0.61
Non-high w/o SSA	0.64
SSA	0.45
SEAP	0.69
MENA	0.36
LATINCA	0.63

Sources and country grouping: see appendix

The capital-output ratio in middle- and low-income countries (excluding sub-Saharan Africa) is more than one third lower than in rich countries. In the case of sub-Saharan Africa, the ratio is more than twice lower while it is nearly two thirds lower in the MENA region. If physical productivity is measured by the inverse of the capital output ratio, why is capital not flowing from rich to poor countries? This is the question asked by Lucas (1990). As mentioned earlier, Lucas himself pointed to the role of externalities. Note however that the capital output ratio should be equalized even in the case when $\alpha + \beta + \gamma > 1$.

The interpretation that we want to give comes as follows. Aggregate data on output-capital ratios based on PPP prices (which usually serve as a basis for tables such as the one reported above) do not provide information on the actual return on physical capital. A proper comparison of the returns across countries requires the use of market prices to evaluate the profitability of capital. We have to compare the cost of capital to the true (uncorrected for PPP prices) market value of output. Calling this relative price $p(Q_{it})/p(K_{it})$, the marginal productivity of K valued at market prices is given by,

$$\frac{p(Q_{it})}{p(K_{it})}\frac{\partial Q_{it}}{\partial K_{it}} = \alpha \frac{p(Q_{it})Q_{it}}{p(K_{it})K_{it}}$$

In order to assess the return on capital relevant for investment decisions, one needs to weight the physical productivity of capital (such as measured in Table 2) by the relative price of goods. This relative price is shown in Table 3.

Table 3. The relative price of capital

(rich countries as reference)

Rich countries	1.00
Other European	1.28
Non high	1.84
Non-high w/o SSA	1.76
SSA	2.23
SEAP	1.52
MENA	3.20
LATINCA	1.70

Sources and country grouping: see appendix

We observe a wide variation of the relative price. We then reprice the capita-output ratio. This is shown in table 4.

Table 4. Capital-Output ratio in current $

(rich countries as reference)

Rich countries	1.00
Other European	1.10
Non high	1.03
Non-high w/o SSA	1.03
SSA	1.05
SEAP	0.94
MENA	1.04
LATINCA	1.05

Sources and country grouping: see appendix

The results are dramatic. Correcting by the relative price of capital wipes-out the discrepancies in the return to capital reported in table 2. Once this correction is made, the return on capital, measured as the capital-output ratio at market prices, is fairly equivalent in all groups of countries. There is no Lucas paradox left to explain.

3.2 Econometric evidence

In order to look beyond average statistics, let us now investigate econometrically if the capital-output ratio, when measued in volume terms, is well explained by the relative price of investment to GDP. If our intuition is correct on the explanation of the Lucas paradox, we should find an elasticity of minus one between these two variables. The sample that we use is detailed in the appendix. It consists of the same 51 countries that were used to describe the preceding tables. The results come as follows.

Table 5. Regression of the capital-output ratio on the relative price of capital

	OLS	GMM	OLS	GMM
	(1)	(2)	(3)	(4)
Log (P_I/P_Q)	-1.002***	-1.208***	-1.076***	-1.152***
	(0.134)	(0.25)	(0.129).	(0.180)
Continental Dummies	Yes	Yes	No	No
R square	0.83	0.84	0.81	0.83
Overidentification test (p value)		p=0.71		p=0.51

Sources: see appendix.
Instruments: Percentage of land within 100km from the coast;
(log) Coastal population density in 1965- Sources: Gallup et al.(1999)
Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

In this table and in the sequel, we use two-step efficient generalized method of moments (GMM) estimator. See Baum, C.F., Schaffer, M.E., and Stillman, S.(2003)

Regressions (1) and (3) present OLS estimates with and without geographic dummies. In both instances we find an estimate of minus one, as suggested by our interpretation of the Lucas Paradox. We then report in columns (2) and (4) IV estimates of the same relationship, where the set of instruments reflect different dimensions of a country's degree of openness. The idea is that the more open a country is, the less distortions there exists between the traded sector (which equipment goods are part of) and the rest of the economy. Our instruments are the percentage of land within 100km of the coast and the (log of) the coastal population density in 1965. Both variables are from Gallup et al (1999). Overidentification tests do not reject the exogeneity of these instruments. In all cases, we find that the elasticity of the capital output ratio is fairly robust to the inclusion of the geographical dummies, and to the instrumentation.

4 Explaining the relative price of capital

The next step is then to explain the relative price of investment. One of the most robust empirical findings is the higher price of investment goods (relative to the aggregate price level - the so called "GDP price level") in poor countries. A number of papers have already pointed to this pattern as one of the main drivers of cross country income differences (see Jones (1994), Lee (1995), Chari et al. (1996), McGrattan and Schmitz (1999), Eaton and Kortum (2001), Restuccia and Urrita(2001), Schmitz (2001)). The higher relative price of investment in poor countries is considered to be the result of a number of constraints lying in the area of public policy, among which high tariff rates on imports of investment goods , and high tax rates on domestic production of investment goods[2].

[2]See Schmitz (2001) for an empirical investigation of the impact of the government production of investment goods on labour productivity in Egypt during the 60s.

Let us follow here the Balassa-Samuelson intuition. In a simple neo-classical model, the relative price of capital is simply driven by TFP differences between the aggregate economy and the sector that produces the capital good. The latter, in what follows, is measured through the lenses of manufacturing data. We use the dataset produced by Causa and Cohen (2006), based on UNIDO industrial statistics.

4.1 TFP in manufacturing

Let us first replicate for manufacturing the results obtained in table 1 for the economy at large. The stock of physical capital k is now restricted to manufacturing private capital, such as calculated from UNIDO investment statistics (see appendix for sources and data construction). We take α =0.30 and β = 0.14, based on econometric estimates presented in details in Causa and Cohen (2006). We use the same sample of 51 countries as before. The data for human capital and infrastructure are the same as those that were used for the aggregate economy.

Table 6. Productivity differences- The manufacturing sector (1990)

	q	$(k/h)^{\alpha}$	$(z/h)^{\beta}$	h	A
Rich countries	1.00	1.00	1.00	1.00	1.00
Other European	0.40	0.82	0.91	0.81	0.66
Non high	0.24	0.80	0.81	0.63	0.58
Non-high w/o SSA	0.24	0.77	0.82	0.66	0.59
SSA	0.21	0.93	0.76	0.51	0.58
SEAP	0.23	0.77	0.77	0.65	0.59
MENA	0.21	0.75	0.83	0.58	0.58
LATINCA	0.27	0.78	0.84	0.67	0.62

Sources and country grouping: see appendix

Comparing table 6 to table 1, one sees a number of important results. Productivity is lower in manufacturing than in the economy at large, with TFP being 42% lower in the poor countries than in the rich, while it was only 13% lower for aggregate GDP. The discrepancy is particularly important in Middle East and North African countries, where aggregate TFP is at par with high income countries, while being among the worst in manufacturing. Altogether however, the general pattern remains, as for GDP, that all items are equally important. In manufacturing too, handicaps acting multiplicatively turn out to be devastating.

4.2 Econometrics of prices and TFP

The manufacturing sector in poor countries being less productive than the rest of the economy, it has to command a higher price. Theoretically, the elasticity of price differences to TFP differences should equal minus one. Using the same sample as before, we then turn to estimating the relationship between the relative price of investment and the differential of TFP between manufacturing and aggregate GDP to test whether this theoretical prediction holds.

We estimate a cross country equation in which the dependent variable is the (log) difference between the price level of investment and the price level of GDP ($LPINV/PGDP$) and ask whether it is explained by the (log) differences of TFP in the aggregate economy ($LTFPGDP$) and that in manufacturing ($LTFPMANU$).

The regression is potentially flawed with both measurement error and omitted variable bias; we address these concerns below. Let us first present OLS estimates in table 7

.

Table 7. Prices and Productivity (1)

	OLS	OLS	OLS
	(1)	(2)	(3)
Dependent variable	LPINV/PGDP	LPINV/PGDP	LPINV/PGDP
Explanatory variables			
LTFPGDP	0.51*		
	(0.224)		
LTFPMANU	-0.35**		
	(0.101)		
DIFFLTFP		-0.38**	-0.37**
		(0.117)	(0.105)
LNRGDPW			-0.25**
			(0.072)
Geo controls	YES	YES	YES
SSA included?	YES	YES	YES
Sample	53	53	53
Year	1990	1990	1990
Observations	53	53	53
R2	0.6759	0.669	0.7345
F Statistic	14.36	16.64	18.35

Sources= see appendix.
LTFPGDP: log(aggregate TFP); LTFPMANU=log(TFP in manufacturing)
DIFFLTFP=LTFPGDP-LTFPMANU; LNRGDPW= log(GDP per worker)
Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

In column (1), we allow the elasticity of the relative price to differ between manufacturing and aggregate TFP. Consistent with the predictions, the estimated elasticities are positive for the latter and negative for the former, and they are not very far from each other in absolute terms. Manufacturing productivity is negatively correlated to the price of investment goods while aggregate productivity is positively correlated with it. Interestingly, TFP differentials yield more significant results than average labour productivity (not reported). Note that the parameter for manufacturing TFP is estimated more precisely. When we impose the identity on the two coefficients (col. (2) and (3)), the estimated elasticity amounts to -0.39 . Column (3) controls for PPP income per worker; although the estimated coefficient is potentially biased due to endogeneity, our concern is here to see whether its inclusion affects the value of the estimated elasticity; this does not appear to be the case. The negative significant value on the GDP per worker coefficient basically captures what a number of scholars have pointed to, namely the fact that the relative price of investment is higher in poor countries, as highlighted in the previous section; the causality is difficult to infer, however.

The following table presents estimated coefficients from instrumental variables. Our first concern being attenuation bias caused by measurement error of TFP differences, we instrument the latter with the (log) ratio of physical capital on human capital in manufacturing and in the aggregate economy. These variables directly contribute to the "bad" measurement of TFP differences. TFP being measured as a residual, its measurement is directly contaminated by errors on inputs. When we do so, we find that the elasticity climbs up to unity. This is exactly what the two sector model predicts. We also test whether the level of income per worker plays a role.This is indeed the case for the full sample, but this role disappears when sub Saharan countries Africa are taken out of the sample.

Table 8. Prices and productivity (2)

	GMM	GMM	GMM	GMM
Dependent variable	LPINV/PGDP	LPINV/PGDP	LPINV/PGDP	LPINV/PGDP
Explanatory variables :				
DIFFLTFP	-0.934*	-1.04**	-1.093*	-1.026**
	-0.333	-0.197	-0.295	-0.202
LNRGDPW		-0.278*		-0.149
		-0.126		-0.162
Geo controls	YES	YES	YES	YES
SSA included?	YES	YES	NO	NO
Sample	53	53	47	47
Year	1990	1990	1990	1990
R2	-	-	-	-
F statistic	-	-	-	-
GMM Estimation related tests:	0.033	0.0483	0.167	0.219
Hansen J Statistic	0.033	0.0483	0.167	0.219
(overidentification test).P-val				
Centred R2 (second stage)	0.299	0.205	0.056	0.1765
UnCentred R2 (second stage)	0.4389	0.364	0.185	0.288

Definition: see table 7; sources: see appendix

Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

Instruments: (log) ratio of physical capital on human capital in manufacturing and in the aggregate economy.

4.3 Where do we stand?

With these estimations in mind, where do we stand with respect to the Lucas paradox? We see from tables 1 and 6 that TFP in poor countries stands respectively at 0.59 in manufacturing and 0.87 in total GDP. This implies a relative differential of 150%. The Lucas paradox itself, as seen from table 4, implies a price differential of 1/0.64 that is 1.56. On average, one can then argue that the TFP differential explains the bulk of the Lucas paradox.

5 The anti-Lucas paradox

5.1 Capital abundance

If our intuition about the role of relative prices in solving the Lucas paradox is correct, then we should find that the capital to output ratio in the manufacturing sector is similar across countries. This is so because this is mainly a tradable sector and so we should not observe large differences in its relative price worldwide.

We thus compute capital-output ratios in manufacturing and obtain the following results:

Table 9. Capital-output ratio in the manufacturing sector

Reference	1.00
Other European	1.29
Non-high	1.43
Non-high w:o SSA	1.39
SSA	1.61
SEAP	1.54
MENA	1.57
LATINCA	1.27

Sources and country grouping: see appendix.

This table shows that, on average, poor countries do not exhibit any shortage of capital in the manufacturing sector. In fact, we find that these countries have more capital per worker than the average of rich countries. This is exactly the opposite of what we observe with aggregate PPP data and contradicts the Lucas paradox.

5.2 Explaining the anti-Lucas paradox

How do we account for the anti-Lucas paradox? One can point to the anecdotal evidence stressing that manufacturing entrepreneurs in poor countries do substitute private capital for public one in the case of power shortages and interruptions. The low level and quality of power generation in poor countries makes it unlikely to run a production unit without self provision of electric generation equipment. [3].

We present below specifications where the dependent variable is the capital output ratio in each manufacturing industry (23 sectors, according to 3 digit ISIC classification, rev. 2, 3-digit[4]), and the explanatory variable the country specific infrastructure per unit of human capital (this normalisation allows accounting for the relative scarcity of infrastructure). We control for industry specific effects and geographic fixed effects in all our regressions (not reported in the table). We first present simple robust OLS results.

[3] See Causa and Cohen (2006) for a discussion on infrastructure shortages and a presentation of illustrative evidence based on field work reports.

[4] See Causa and Cohen (2006) for a presentation of the industrial dataset used here.

Column (1) documents the anti-Lucas paradox: a low level of average manufacturing labour productivity is associated with a high level of industrial capital intensity, everything else being equal. Column (2) shows that the lack of infrastructure (in relative terms) is a good candidate for the explanation: infrastructure undercapitalisation is associated with manufacturing capital overcapitalisation. Finally, equation (3) shows that when endogeneity bias is properly addressed, lack of infrastructure does crowd out the explanatory power of low productivity as a cause of the anti-Lucas paradox.

Table 10: Anti-Lucas paradox

Method	OLS	OLS	GMM
	(1)	(2)	(3)
Dependent variable:	Ln (capital output ratio)	Ln (capital output ratio)	Ln (capital output ratio)
Explanatory variables			
Ln(y)	-.174***		-0.025
	(.034)		(0.123)
Ln (Z/H)		-0.117***	-0.322***
		(.036)	(0.091)
Industry fixed effects?	YES	YES	YES
Geographical controls?	YES	YES	YES
R squared	0.18	0.17	0.11
(overidentification test).P-val			0.13

Instruments: (log) settler mortality; source Acemoglu et al.(2001)
(log) Coastal population density in 1965; Sources: Gallup et al. (1999)
Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%
Ln(y)=ln(industrial productivity); Ln(Z/H)=ln(Infrastructure/Human capital)
sources: see appendix

5.3 New insights on the Lucas Paradox

The anti-Lucas paradox suggests that infrastructure shortages induce private capital accumulation in the manufacturing sector. What is their impact on the aggregate capital stock?

The answer is presented in columns (1) and (2) of table 13 below. As expected, the impact goes in the opposite direction. Infrastructure boosts aggregate capital accumulation, confirming literature findings on complementarity between the two (see Canning, 2000, among others) Through which channel does this occur?

The impact might be direct: lack of infrastructure reduces aggregate capital formation through composition effects (remember that aggregate capital stock includes infrastructure stock in the definition that we give). But the impact might also be indirect, namely, through the channel of relative prices.

Poor infrastructure, acting as a barrier to trade, foreign direct investment, and competition, is bound to create serious price distortions. Figure 1 shows the relationship between transportation cost, such as proxied by the "CIF/ FOB" ratio (computed from IMF trade data[5]), and the relative scarcity of infrastructure. A clear pattern emerges, suggesting that poor infrastructure is associated with rising trading costs.

This assumption is consistent with the idea that that the quality and the quantity of countries' infrastructure and public services affect the amount of input that actual reaches the producer, and conversely the amount of output that actually reaches the consumer. Poor infrastructure imposes costs not only on international trade, but also on domestic trade. As an interesting framework for interpreting these results, Martin and Rogers (1994) model such a cost through an iceberg formulation, whereby not only international trade but also local transaction is affected by infrastructure. In their paper, this bears consequences in terms of industrial concentration and in particular international firm location.

[Figure 1 here]

The intuition is confirmed in column (3), where we find that the role of infrastructure is reduced by about two thirds when relative prices are taken into account.

Table 11. The impact of infrastructures on aggregate capital

Method	OLS	IV	OLS
	(1)	(2)	(3)
Dependent variable	Log(K/Q)	Log(K/Q)	Log(K/Q)
Explanatory variables:			
Log(Z/H)	0.280***	0.314***	0.105**
	(0.07)	(0.127)	(0.050)
Log (P_I/P_Q)			-0.877 ***
			(0.157)
Method	OLS	IV	
R square	0.64	0.60	0.84
Overidentification test (p value)		p=0.09	

Definition: see table 7 and 10.

Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

Instrumented: log (Z/H).Instruments: Settler mortality from Acemoglu et al. (2000); (log) Coastal population density in 1965 and Percentage of land within 100km from the coast Sources: Gallup et al. (1999)

[5] See Brunner, A. and K. Naknoi (2003), on which the data we use are based.

Let us then investigate the direct influence of infrastructure on prices.

The analysis is reported in table 12 below. Column (1) shows that the overall influence is significant. The point estimate is consistent with the results in column (3) above. Column (2) shows that the estimated parameter is robust to IV estimation, with relative prices being instrumented with (the log of) settler mortality rate (from Acemoglu et al. , 2001) and the (log) of Frankel and Romer (1999) predicted trade share. We then add the TFP differential as an explanatory variable, instrumenting the latter variable with the (log) ratios of physical to human capital in the manufacturing and aggregate economy, as previously. We find that both explanatory variables remain significant, with the estimated parameter on the TFP differential not significantly different from its theoretical value of minus one.

Table 12. The impact of infrastructures on the relative price of capital

Method	OLS	IV	IV
	(1)	(2)	(3)
Dependent variable	*Log* (P_I/P_Q)	*Log* (P_I/P_Q)	*Log* (P_I/P_Q)
Explanatory variables:			
Log(Z/H)	-0.199***	-0.184**	-0.205***
	(0.063)	(0.082)	(0.046)
Log(Diff TFP)			-0.894***
			(0.193)
Geographical controls	YES	YES	YES
Method	OLS	IV	IV
R square	0.56	0.60	0.47
Overidentification test (p value)		p= 0.11	p= 0.13

Definition: see table 7 and 10; Sources: see appendix

Columns (2) Instruments: settler mortality rate (from Acemoglu et al. , 2001) and the (log) of Frankel and Romer (1999) predicted trade share

column (3): Instrumented: Log (DiffTFP)

(Excluded) instruments: Log of ratio of physical capital on human capital in manufacturing and in the aggregate economy.

Sources: see appendix.

Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

5.4 The role of institutions in explaining the Lucas paradox

The theoretical and empirical explanations to the Lucas paradox have recently put forward the primacy of differences in institutional settings across countries. Alfaro et al. (2006), for instance, claim that institutional quality is the "leading causal variable" beyond the Lucas Paradox. The authors conclude that policies aimed at strengthening the protection of property rights, reducing corruption, increasing government stability, bureaucratic quality and law and order should be at the top list of policy makers seeking to increase capital flows to poor countries. They argue that while recent literature has stressed the importance of sound institutions for achieving long run development, it has been rather silent on the underlying mechanisms; foreign capital flows, conclude the authors, may thus be the channel through which institutions affect long run development.

If institutional quality were the causal explanation of the Lucas paradox, we should observe the same phenomenon in the manufacturing sector. The last section clearly demonstrates that this is not the case. Thus, the simple observation of an anti Lucas paradox in the manufacturing sector casts doubt the institutional explanation of the Lucas paradox.

Let us go further in this section and analyze the channels through which institutional differences may play a role. Our strategy follows a simple line. We select an index of government anti-diversion policies ("GADP" in what follows) reported and used in Hall and Jones (1999) based on International Country Risk Guide data. This index is more significant, for the purpose of our exercise, than the broader social infrastructure index favoured by Hall and Jones, because it encompasses a number of institutional features that have been found to influence both capital flows (Alfaro et al., 2006) and income per worker itself (Hall and Jones, 1999, Acemoglu et al. , 2001). The use of the Sachs and Warner (1995) openness index, as included in the Hall and Jones social infrastructure index[6], is less relevant to the institutional debate we want to focus on[7]. The government, as the efficient instrument of antidiversion efforts, must support productive activity in two ways: by deterring private diversion, and at the same time refraining from diverting itself. The index reported by Hall and Jones covers both aspects, encompassing thus rule of law, corruption, and fear of expropriation.

The analysis starts by table 13. We see that GADP is significant, although hardly so when entered in a univariate specification. Most importantly, we find that the correlation vanishes when controlling for relative prices. This result holds in an instrumental variable setting, as comparison of columns 2 and 3 shows.

Table 13. The impact of institutions on capital accumulation

[6] The Hall and Jones (1999) social infrastructure index is the average of GADP and the Sachs and Warner openness index.

[7] Note however that our results do not depend on the selection of the GADP index.

Method	OLS	OLS	GMM
	(1)	(2)	(3)
Dependent variable	Log(K/Q)	Log(K/Q)	Log(K/Q)
Explanatory variables:			
GADP	1.34**	-0.109	0.988
	(0.65)	(0.316)	(0.998)
Log (P_I/P_Q)		-1.02	-1.299
		(0.16)	(0.393)
R square	0.47	0.83	0.69
Overidentification test (p value)			0.11

GADP=see text and Hall and Jones (1999)

Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

Col (3) Instrumented: log relative price of capital and GADP

Instruments: settler mortality rate (from Acemoglu et al. , 2001) and the (log) of Frankel and Romer (1999) predicted trade share

The results presented in table 13 suggest an indirect influence of institutional quality on capital accumulation, occurring through its impact on the relative price of capital. This channel is examined in table 14.

Column (1) in table 14 shows that the direct influence of GADP is significant. When controlling however by the two other variables of table 12, namely infrastructure and TFP differences (column 2), this influence vanishes entirely. Institutions do matter, as column (1) shows, in explaining price distortion. More than for the protection of citizens' productive activities' from expropriation or predation, institutional settings are responsible for the provision of productive infrastructure capital.

Table 14. The role of institutions on relative prices

Method	OLS	GMM
	(1)	(2)
Dependent variable	*Log* (P_I/P_Q)	*Log* (P_I/P_Q)
Explanatory variables:		
GADP	-1.418	0.147
	(0.492)	(0.423)
log(Z/H)		-0.217***
		(0.058)
Diff TFP		-0.925***
		(0.23)
R square	0.63	0.44
Overidentification test (p value)		p=0.44

Definition: see table 7 and 14

Robust standard errors in parenthesis. signficant at: * =10%, **=5%; ***=1%

Column (2): Instrumented: Log (DiffTFP)

(Excluded) instruments: - (Log of) ratio of physical capital on human capital in manufacturing and in the aggregate economy

These results echo the literature relating public investment to the security of property rights. Keefer and Knack (2002) argue that insecure property rights not only drive down private investment, but also distort important public policy decisions of government. They document significant variation in public investment across countries with secure and insecure property rights, showing that the observed public investment as a fraction of national income or private investment is higher in the latter than the former.

Our results imply a positive correlation between government anti diversion policies and the (relative) stock of public capital, thus apparently contradicting Keefer and Knack (2002). This contradiction can be explained in two ways. One can assume that states in which the protection of property rights is weak suffer from insufficient fiscal resources, making it difficult to finance public investment (in line with Barro (1990)). One can otherwise argue, going in Keefer and Knack' (2002) direction, that a corrupted state is not necessarily interested in economic productive investment, but rather in the kind of investment that allows rents to be extorted. Indeed, the authors show that the relationship between observed public investment and the quality of infrastructure is highest in the countries where property rights are secure, and where, therefore, incentive to extract high rents in the form of "white elephants", are lowest. This also echoes literature findings (De Long and Summers, 1991, Levine and Renelt, 1992, Devarajan et al., 1996), according to which, conditional on a certain level of institutional quality, public investment has a positive impact on growth. Our interpretation of these results is that the under provision of public, productive capital induces distortive costs to the economy, as reflected in the relative price of investment and finally in the Lucas Paradox.

6 Conclusion

We have argued in this paper that the Lucas paradox is readily explained by TFP differences between the manufacturing sector and the aggregate economy. This has long been a conjecture of the literature (indeed at the core of the Balassa-Samuelson literature or more recently in Hsieh and Klenow). This paper makes the point empirically. Altogether, we show that TFP in the economy at large is not as low as many authors would have thought, when infrastructure is taken into account. At the end, it does not take a "very" low TFP in manufacturing to account for the paradox.

The anti-Lucas paradox presented in this paper casts doubt on more direct explanations of the Lucas paradox, such as the existence of a risk premium to compensate for fear of expropriation.Once the direct role of infrastructure and Balassa Samuelson effects (though TFP differences) are taken into account, no role is left for institutional discrepancies to explain the paradox. Institutions do matter, however. Our thesis is that institutional quality shapes government productive investment in core infrastructure services: roads, ports, power, water, sanitation... More than for the fear of being expropriated, it is for the fear of lacking access to transportation networks, water, and electricity, that investors are reluctant to do business in poor countries.

7 Bibliography

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APPENDIX

Sample

Table 1. Country Groupings

REFERENCE	OTHER EUROPEAN	Non High without SSA	SSA	SEAP	MENA	LATINCA
Australia		Bangladesh	Cameroon	Bngldsh	Egypt	Bolivia
Austria	Cyprus	Bolivia	CAR	Fiji	Jordan	Brazil
Belgium	Denmrk	Brazil	S. Africa	India	Morocco	Chile
Canada	Greece	Chile	Senegal	Indonesia	Turkey	Colombia
Finland	Hungary	Colombia	Zambia	Korea,		Costa Rica
France	Portugal	Costa Rica	Zimbabwe	Malaysia		Ecuador
Italy		Ecuador		Philippine		Honduras
Japan		Egypt		Singapore		Mexico
Netherlands		Fiji		Thailand		Panama
Norway		Honduras				Peru
Spain		Hungary				Trinidad&T
Sweden		India				Uruguay
UK		Indonesia				Venezuela
USA		Jordan				
		Korea, rep.				
		Malaysia				
		Mexico				
		Morocco				
		Panama				
		Peru				
		Philippines				
		Thailand				
		Trinidad T				
		Turkey				
		Uruguay				
		Venezuela				

Data description

Aggregate data

Aggregate data refer to 1990.

- Real GDP per worker, chain index.

Source: Penn World Tables, version 5.6 (in 1985 I$)(PWT).

- Physical capital per worker (K) in the aggregate economy

Sources: Easterly and Levine (2001), based on PWT 5.6 non residential capital estimates. (in 1985 I$)(PWT).

- Human capital per worker (H) in country *i* is defined as $h_i = \exp(\phi(s_i))$ where $\phi(s_i) = 0.1 \cdot s_i$. The variable s_i indicates average years of schooling in country i from the Cohen and Soto database (2002), and 0.1 represents a 10 per cent return to education estimated in Mincerian wage regressions. See Cohen and Soto (2002)

- Infrastructure per worker (Z) refers to electricity generating capacity per worker in country i . We use Z/H as a measure of infrastructure scarcity.

Sources: Canning (1998), World Development indicators (various issues). Number of workers in the economy computed from PWT.

- Ln (pinv/pgdp) measures the ratio of the price level of investment over the aggregate price level ("price level of GDP")

Sources: PWT.

Manufacturing data

Manufacturing data are based on UNIDO industrial statistics, 3-digit, rev. 2 of ISIC classification.

Manufacturing data refer to 1990 and are expressed in current US $.

The interested reader might refer to Causa and Cohen (2006) for a detailed description of the industrial dataset used in this work, based on UNIDO statistics. A number of adjustment are made to the raw UNIDO dataset. Outlying observations are dropped based on an econometric procedure presented in the paper. Following this first "screening", we eliminate five sectors non representative, for a number of reasons explained in the paper, of a country's manufacturing productivity (in particular petroleum sectors). The remaining sectors represent on average 90% of manufacturing employment in both high and low income countries.

- k_{ij} : physical capital per worker in country *i*, sector *j*. UNIDO provides data on investment on an industry-level basis. The variable refers to the value of purchases and own-account construction of fixed assets during the reference year, less the value of corresponding sales. The perpetual inventory method is used to construct the capital series, assuming a 10 per cent depreciation rate. The investment series begin in 1963 for most countries, which gives a reasonable period for the capital stock estimates to lose their dependence on an initial-conditions assumption. Following the assumption that the steady-state investment/capital ratio equals 10 per cent to calculate the initial stock, the stock in the year 1990 is obtained by using data on the average investment-value added ratio over the period for sector *j*.

Sources: UNIDO Industrial Statistics Database 2001

TFP differences

Diff ln(TFP) is defined as the TFP differential between the manufacturing sector and the aggregate economy, when account is taken of human capital, physical capital, and infrastructure capital. They follow the decomposition given in tables 1 and 6. Human capital is by definition the same at the aggregate level and in manufacturing in each country. Infrastructure is measured by the same variable but its estimated impact on productivity varies whether one consider aggregate labour productivity or manufacturing labour productivity. The weights are discussed in Causa and Cohen (2006).

Institutions and geography

- Ln (FR): Frankel & Romer (1999) predicted trade share, as estimated by geographical determinants

Source: Frankel and Romer (1999)

- Log of - Coastal population density in 1965
- Percentage of land within 100km from the coast

Source: Gallup *et al*.(1999)

- GADP: index of government anti-diversion policies -

Sources: Hall and Jones (1999)

- Log of Settler mortality rates (deaths per 1000's)

Source: Acemoglu *et al.* (2001)

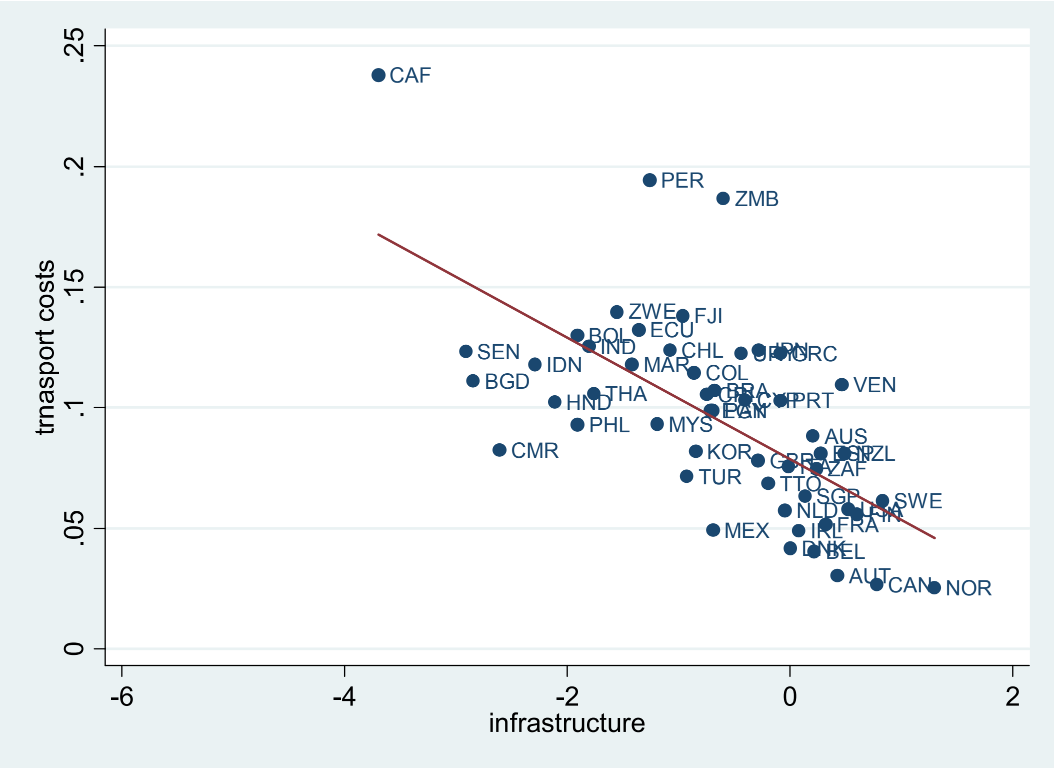
- Log of CIF/FOB Ratio: transport costs are estimated as follows:

$$CIF / FOB = \frac{\widetilde{M}_{cif}}{\widetilde{X}_{fob}}$$

where CIF indicates costs including customs, insurance and freight and FOB indicates free on board. Exports and imports are total trade figures from IMF, *IFS*. The measure used is an average of yearly data over the decade 1970-1980.

Source: Brunner and Naknoi (2003), (http://www.imf.org/external/pubs/ft/wp/2003/wp0354.pdf).

Figure 1. INFRASTRUCTURE (per unit of human capital) and TRANSPORTATION COST



Source: See above.