WP/95/113

INTERNATIONAL MONETARY FUND

Research Department

Relative Prices, Economic Growth and Tax Policy

Prepared by Michael Sarel 1/

Authorized for distribution by Peter Wickham

November 1995

Abstract

This paper examines the role of relative prices in economic growth and the possibility that relative prices are (or can be) partly determined by tax policy. In the opening section, the paper links relative prices to tax policy. Using an extension to a standard model of economic growth, it demonstrates that under certain conditions a simple tax policy, that determines the relative price of investment, can affect the investment rate and the permanent growth rate of the economy. The paper develops a method to obtain consistent data on relative prices for a large set of countries. Using these data in cross-country regressions, it examines how economic growth is affected by relative prices. The results of these empirical tests identify the relative prices as a key factor affecting investment and growth.

JEL Classification Numbers:
H20, 040

1/ The author would like to thank Se-jik Kim, Gian Maria Milesi-Ferretti, Assaf Razin, Peter Wickham and participants in the Research Department's Informal Seminar Series for their helpful comments.

Contents

Summary

This paper examines the role of relative prices in economic growth and the possibility that relative prices are (or can be) partly determined by tax policy.

The paper starts with a theoretical part, in which it first links relative prices to tax policy, and then demonstrates that, under certain conditions, a simple tax policy that determines the relative price of investment can affect the investment rate and the permanent growth rate of the economy.

The paper continues with an empirical part, in which it first develops a method to obtain consistent data on relative prices for a large set of countries. Then, using these data, it examines the effect of relative prices in the economy on the rate of economic growth. As a general framework for the empirical tests, it uses the reduced forms derived from the growth model that was presented in the theoretical part. The results of these empirical tests identify the relative prices as a key factor affecting investment and growth.

The theoretical part of the paper provides a possible interpretation of the empirical part, as well as a motivation for this type of empirical work. However, the methodology used to obtain cross-country data on relative prices and the results obtained in the empirical part of the paper are interesting in their own right. They do not necessarily depend on the predictions that were derived or the specific assumptions that were made in the theoretical part. Accordingly, the views presented in the theoretical part are just one possible interpretation of the empirical results, and any policy implications of these views should be treated with extreme caution.

I. Introduction

This paper examines the role of relative prices in economic growth and the possibility that relative prices are (or can be) partly determined by tax policy.

In Section II, the paper links relative prices to tax policy. By decomposing government operations into two separate branches, a traditional branch and a growth-promoting branch, it is able to concentrate on the role that the government and the tax system play in economic growth, through the way they affect the relative prices.

In Section III, the paper presents a simple extension to a standard model of economic growth. It demonstrates that under certain conditions a simple tax policy of the government can affect the permanent growth rate of the economy. It does this by affecting the relative price of investment and, as a result, by increasing the investment rate. The growth model yields a simple reduced form of the growth rate, which specifies that the growth rate is a linear function of the output/investment price ratio. The section also presents additional theoretical results concerning the investment rate. All the mathematical derivations of the model are shown in Appendix I.

In Section IV, the paper develops a method to obtain cross-country data for a large set of countries on relative prices. In particular, it measures the ratio between the general price level and the price of the basket of investment goods. It also argues that income levels affect different prices asymmetrically, and empirical evidence regarding this point is presented in Appendix II.

In Section V, the paper presents empirical evidence regarding the effects of relative price of investment on long-run growth. The empirical tests include different regression specifications and are applied to different samples of observations. In all cases, the empirical results identify relative prices as a key factor affecting growth.

Finally, in Section VI, the paper offers concluding remarks and discusses policy implications.

II. An Alternative View of Tax Policy and Economic Growth

The topic of tax policy and economic growth has been examined in many recent studies. 1/ Usually, these studies assume the existence of government expenditures that provide services to consumers or to producers. These expenditures are determined by the policy makers, either exogenously

---

1/ The paper by Milesi-Ferretti and Roubini (1995) is one of the latest, and it also contains an excellent survey of this literature.

or endogenously (through an optimization process). 1/ Some taxes are then required in order to finance the government's expenditures. These studies have primarily been concerned with the optimal taxation of factor incomes, and in most models policy makers basically face a choice between a labor income tax and a capital income tax. Some of these studies also discuss expenditure (or consumption) taxes, but usually in the context of finding the most efficient way to raise revenue in order to finance a given level of expenditures.

There are at least three major problems associated with these types of studies. First, their conclusions are strongly affected by particular assumptions about the elasticity of labor supply and about the nature of human capital accumulation. 2/ Second, the lack of empirical data, that could be used to support or to reject the conclusions of the different models, is a serious problem. 3/ Third, the difference across countries regarding tax definitions and tax statistics make a cross-country analysis particularly difficult, especially in the case of empirical studies that include developing countries. 4/

We take a different view on the role of the government and the tax system. We presume that the government has two distinct functions, performed by two separate branches of government, each with its own budget and with an independent responsibility to balance its budget. The first function of the government is the traditional one: to supply government services, either for consumers or for producers, and to finance these services by income, consumption or other types of taxes. The second function of the government is to implement some kind of industrial or

---

1/ See, for example, the models presented by Barro (1990) and by Barro and Sala-i-Martin (1992).

2/ For example, if these studies assume that the labor supply and the investment in human capital are relatively inelastic, they find that it is better to tax labor income than to tax capital income.

3/ This problem is nicely described by Easterly and Rebelo (1992): "While the study of the effects of taxation in growth models continues to be an extremely active research area, there is little empirical work on this topic. This scarcity of empirical work is due to the difficulties involved in measuring the relevant marginal tax rates".

4/ Therefore, the usual way most studies analyze the effects of different tax policies on growth is through numerical simulations, choosing various sets of parameters. This method, however, does not provide direct evidence on growth effects of tax policy. It can only prove that tax policy may have, for some values of the parameters, an important effect on growth.

development policy, in order to promote economic growth. 1/ One of the chief policy instruments used by governments in order to implement this industrial policy is a mix of taxes and subsidies that affect relative prices, thus promoting certain economic activities while discouraging others. 2/

There is much anecdotal evidence that governments indeed use tax policy to manipulate relative prices in order to boost economic growth. Pai (1991), for example, describes the tax policy in Taiwan Province of China during the past forty years, from his perspective as the Chairman of the Board of the Export-Import Bank: "the remarkable economic development has not been achieved without effort. The hard work of the people and the effective development strategies of the government deserve much of the credit for the achievement. But tax policy also has played an important role in our development and contributed much to the progress we have enjoyed". After he describes the various tax measures that were adopted by the government during the last forty years, he concludes: "It is very clear that the tax incentives described above were aimed at promoting investment in productive enterprises, stimulating export sales, and encouraging saving". Finally, he notes: "Though it is difficult to quantify the contribution of tax incentives to the outstanding performance of the economy, it is generally acknowledged that sound tax policies and their timely adoption deserve part of the credit". As another example, Bahl, Kim and Park (1985) write: "Korean tax policy was much oriented to supporting rapid economic growth".

III. A Simple Growth Theory

This section presents a simple extension to a standard model of economic growth. It demonstrates that, under certain conditions, a simple tax policy of the government can determine the permanent growth rate of the economy. The tax policy does this by affecting the relative price of investment and, as a result, by increasing the investment rate. The growth model yields a simple reduced form, which specifies that the growth rate of output per person is a linear function of the output/investment price ratio. This section also presents additional theoretical results concerning the investment rate.

1/ This function of the government is summarized by De Long and Summers (1991): "it is often alleged that a number of countries have succeeded in growing rapidly by pursuing a government-led 'developmental state' approach to development. The rationale for this policy is that countries which adopt the price and quantity structure of more affluent nations are more likely to grow than those that possess the structure of poorer countries. The government should jump-start the industrialization process by transforming economic structure faster than private entrepreneurs would".

2/ It is important to note, however, that this industrial policy can also rely on other policy instruments, such as price controls, legal measures, political pressures and moral suasion.

The model is a simple extension of the standard "*Ak*" growth model, presented by Rebelo (1991). The economy consists of many identical consumers-producers. They produce a single good (y), and its price is normalized to 1. 1/ The capital stock, k, has a broad interpretation and may include human capital.

The technology of production is linear:

$$y = A\,k \tag{1}$$

The produced good (y) can be transformed at zero cost into a consumption good (c) or into an investment good (i). There is a government in this economy, and its only role is to tax consumption (at rate τ) and to subsidize investment (at rate σ). The government must always have a balanced budget, but can decide upon the tax rate (or, alternatively, upon the subsidy rate). The government can also decide to subsidize consumption and to tax investment (in this case, τ and σ are negative numbers).

As a result of the tax-subsidy scheme, the representative consumer-producer in this economy faces the price $1+\tau$ for each unit of consumption, and $1-\sigma$ for each unit of investment. 2/

From the point of view of the consumer-producer:

$$\frac{P_i}{P_c} = \frac{1-\sigma}{1+\tau} \tag{2}$$

The consumer-producer faces the following problem:

$$Max \int_0^{\infty} e^{-\rho t}\, \frac{c^{1-\theta}-1}{1-\theta}\, dt \tag{3}$$

1/ In order to simplify the notation, we ignore time subscripts and use per-capita measures for all variables. In general, the assumptions and notations follow the standard practice in the literature. See, for example, Barro and Sala-i-Martin (1995).

2/ We assume that there are many consumers-producers and each one takes the tax and the subsidy rates as given. This is a crucial assumption and it is the main force behind the model's results. Instead, one could make the assumption that the consumers-producers collude and take into account the balanced budget requirement of the government ($\sigma i = \tau c$). In this case, however, the tax-subsidy scheme will have absolutely no real effects. The intuition for this result is the following: because the government operates under a balanced budget requirement and it collects taxes and distributes subsidies to the same individuals, they will stick to the solution that is optimal in the absence of any government action.

The budget constraint is:

$$\dot{k} = \frac{y - (1+\tau)\, c}{1 - \sigma} - (\delta + n)\, k \tag{4}$$

All the mathematical derivations of the model are shown in Appendix I. The growth rate of output per person is:

$$\frac{\dot{y}}{y} = \frac{1}{\theta} \left[\frac{A}{1-\sigma} - \delta - n - \rho \right] \tag{5}$$

The term $1/(1-\sigma)$ is equal to the ratio between the output price and the investment price (after subsidy). Therefore, equation (5) can be expressed as a reduced form that can be estimated using data on the rate of population growth and on the relative price of investment:

$$\frac{\dot{y}}{y} = - \frac{\delta + \rho}{\theta} - \frac{1}{\theta}\, n + \frac{A}{\theta}\, \frac{P}{P_i} \tag{6}$$

In this economy, the growth rate of output per person depends positively on the subsidy rate σ (or, alternatively, on the price ratio P/P_i). Equation (5) points out how, by controlling the tax-subsidy rates, the government can determine the permanent growth rate. If σ=0 (and then also τ=0), the economy grows at a "natural rate". A positive rate of σ (and of τ) increases the growth rate above this natural rate, while a negative rate of σ (and of τ) reduces the growth rate below this rate.

However, increasing the growth rate above its "natural rate", by subsidizing investment, is not an optimal policy from a welfare point of view. The reason is that the present decrease in welfare (caused by the immediate reduction in consumption) more than offsets the present value of the future increase in welfare (caused by the higher growth rate).

In addition to its predictions about the growth rate, the model is also able to make specific projections regarding the investment rate, s. In Appendix 1, we derive the following results:

$$s = \frac{(\theta-1)\delta-\rho}{\theta\, A} + \frac{\theta-1}{\theta\, A}\, n + \frac{1}{\theta}\, \frac{P}{P_i} \tag{7}$$

and

$$\frac{\dot{y}}{y} = A\, s - \delta - n \tag{8}$$

Equations (7) and (8) are reduced forms of the investment rate (in terms of the price ratio P/P_i) and of the growth rate (in terms of the

investment rate s). They can easily be estimated. Equation (7) predicts a positive effect of the price ratio P/P_i on the investment rate. Equation (8) predicts that all the positive effect of the price ratio P/P_i on the growth rate works through increased investment. In other words, it predicts that once we include the investment rate as an explanatory variable in a regression, the coefficient of P/P_i is expected to be zero.

IV. The Data on Relative Prices

This section develops a method to obtain cross-country data for a large set of countries. on relative prices. In particular, it measures the ratio between the general price level and the price of the basket of investment goods. It also argues that income levels affect asymmetrically different prices, and empirical evidence regarding this point is presented in Appendix II.

The data used in this study covers 104 countries during the period 1960-90 and is derived from the PWT 5.6a database. 1/ This database contains, among other variables, information on population (N), income per person in PPP 1985 dollars (y), and shares in GDP of private consumption (c), investment (i) and government consumption (g), all calculated in PPP current dollars. More importantly (for the purpose of this study), the database compares across countries the specific prices of the private consumption basket (P_c), the investment basket (P_i) and the government consumption basket (P_g). 2/

The construction of the price indices for c, i and g is explained in detail by Summers and Heston (1991) and their references. The main idea is to divide the GDP into 150 detailed categories (approximately 110 consumption, 35 investment and 5 government). All of a country's individual final output items are assigned to one or another of the categories. Price comparisons for more than 1500 carefully defined commodities and services are made, in order to determine the price index of each category. It is important to note that the item prices provided are final product prices, including taxes and subsidies.

The prices of the main categories, P_c, P_i and P_g, can be aggregated to a general price level:

1/ The PWT 5.6a database is a 1995 NBER update to the PWT 5.0 database, described by Summers and Heston (1991). The database covers the period 1950-92. For many countries, however, the information is not available before 1960, while for others it ends in 1990. Therefore, we restrict our sample to the 104 countries for which PWT 5.6a contains complete and continuous annual information during the period 1960-90.

2/ The PWT database counts all types of construction activities, including residential construction, as investment. Expenditure on other durable goods is counted as consumption. Unfortunately, like most national accounts, it also counts education as consumption.

$$P = P_c \frac{c}{c+i+g} + P_i \frac{i}{c+i+g} + P_g \frac{g}{c+i+g} \quad (9)$$

This definition of P is slightly different than the definition used to calculate the general price level in the PWT database. The reason is that the definition in equation (9) is concerned with the general price level of domestic absorption ($c+i+g$), while the PWT definition is concerned with the general price level of domestic production. PWT defines the general price level as:

$$P_{(PWT)} = P_c\, c + P_i\, i + P_g\, g + (x-m) \quad (10)$$

where x and m are the shares of exports and imports in GDP. For most countries, the two measures of the general price level are very similar. They are slightly different in the case of countries with large trade surpluses or deficits.

This study uses the information on prices in PWT in a different way than previous studies have done. Because all prices in PWT are calculated in PPP current dollars, many studies have used them as measures of real exchange rates. This use involves a cross-country comparison of the price levels (either of the aggregate price level P, or of the prices P_c, P_i and P_g). In contrast, this study compares, across countries, not prices, but relative prices. In particular, it compares across countries the key variable used throughout this paper, P/P_i (the ratio between the general price level and the price of the investment goods basket).

The main feature of the aggregate price level, P, is its positive correlation with income. 1/ But this positive correlation is caused mainly by the prices of private consumption and government consumption, not by the prices of investment. 2/ As a result, the price ratio P/P_i is positively correlated with income. Appendix II explores the effects of income on the different prices. Because income has different effects on different prices, the relative prices are correlated with the income level. In this case, it becomes important to control for the level of income in the growth regressions that include the relative prices as an explanatory variable.

1/ This was noted by Balassa (1964) and by many others. According to Barro (1991), "This relation presumably reflects the relatively low prices of services and some other nontraded goods in low-income countries".

2/ This fact was noted also by Summers and Heston (1991). They mention that "investment goods are relatively expensive in low-income countries" and speculate that "The major explanation for this price pattern undoubtedly lies in the area of public policy". Barro (1991) views the deviation of local investment prices from world investment prices as proxy for market distortions.

V. The Empirical Evidence on Relative Prices and Economic Growth

This section is the central piece of this study. It presents empirical evidence regarding the effects of relative price of investment on long-run growth. The empirical tests include different regression specifications and are applied to different samples of observations. The empirical results identify relative prices in the economy as a key factor affecting growth.

In order to estimate the reduced forms of the model presented in Section III, we need to use period averages of the relevant variables. The price ratio P/P_i is derived from the PWT 5.6a database, according to the method described in Section IV. The same database provides data on output per person, population and investment rates. The price ratio P/P_i during a period $[q,q+t]$ is defined as the simple average of the price ratio for the t observations that start at q and end at $q+t-1$; the investment rate is defined in a similar way; and the growth rates of output per person and of population are defined as the average logarithmic rates of change during the t-year period:

$$(\frac{P}{P_i})[q,q+t] = \frac{1}{t} \Sigma_{j=q}^{q+t-1} \frac{P_{(j)}}{P_{i(j)}} \tag{11}$$

$$s[q,q+t] = \frac{1}{t} \Sigma_{j=q}^{q+t-1} s_{(j)} \tag{12}$$

$$growth_{[q,q+t]} = \frac{\log [y_{(q+t)}] - \log [y_{(q)}]}{t} \tag{13}$$

$$n_{[q,q+t]} = \frac{\log [N_{(q+t)}] - \log [N_{(q)}]}{t} \tag{14}$$

1. The growth rate

Tables 1-7 demonstrate the strong effect of relative prices on economic growth. Each of these tables includes five regressions. Regression 1 is a basic cross-country regression, for the period 1960-90. Regression 2 is a panel regression that uses for each country six nonoverlapping 5-year periods. Regression 3 is identical to Regression 2, except for the fact that it includes five period dummies (for each period except the first). Regression 4 is a panel regression that uses all available observations (thirty years of data for each country). Regression 5 does the same, but it also includes twenty nine year dummies (for every year except the first).

Table 1 contains the basic empirical tests. Each one of the regressions in this table uses as explanatory variables the log of initial income per person ($log\ (y_{(0)})$), the growth rate of population (n), and the

Table 1. Growth Regressions on Relative Prices

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.298	0.0972	0.182	0.0470	0.0819
constant	0.0478 (2.56)	0.0532 (3.95)	0.0384 (2.94)	0.0542 (5.25)	0.0376 (3.27)
log (y)	-0.00630 (-2.66)	-0.00592 (-3.35)	-0.00261 (-1.49)	-0.00565 (-3.93)	-0.00279 (-1.90)
n	-0.498 (-2.37)	-0.632 (-4.69)	-0.588 (-4.56)	-0.742 (-9.08)	-0.702 (-8.65)
P/P_i	0.0372 (5.01)	0.0324 (5.44)	0.0248 (4.25)	0.0315 (6.45)	0.0252 (5.12)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 104, period is 1960-90. (4) t-statistics in parentheses.

mean price ratio P/P_i. The terms n and P/P_i appear in the reduced form for the growth rate that was derived in the model presented in Section III. The term $log\ (y_{(0)})$ is included as explanatory variable for two reasons. First, it captures the usual effect of technological catch-up or of conditional convergence, as found in most empirical studies of economic growth. 1/ Second, as discussed in Section IV, the price ratio P/P_i is affected by the level of income. Controlling for $log\ (y_{(0)})$ is an attempt to capture in the coefficient of P/P_i the direct effects of the tax policy and other effects that are not directly related to the income level.

Tables 2 and 3 include additional explanatory variables in the regressions. Table 2 includes the share of government consumption in GDP, while Table 3 includes the log of the general price level (which can also be interpreted as the real exchange rate) as an explanatory variable. This is done in order to exclude the possibility that the relative prices are found to be significant for growth just because they are proxies for the real activity of the government or for the absolute prices, and also to test the robustness of the estimated parameters.

1/ See, for example, Barro and Sala-i-Martin (1995).

Table 2. Growth Regressions on Government Consumption and Relative Prices

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.330	0.128	0.193	0.0541	0.0840
constant	0.0694 (3.41)	0.0799 (5.56)	0.0570 (3.98)	0.0781 (6.87)	0.0522 (4.15)
log (y)	-0.00725 (-3.08)	-0.00670 (-3.84)	-0.00368 (-2.07)	-0.00649 (-4.50)	-0.00370 (-2.46)
n	-0.522 (-2.54)	-0.649 (-4.89)	-0.600 (-4.68)	-0.748 (-9.18)	-0.707 (-8.71)
G	-0.0575 (-2.42)	-0.0822 (-4.76)	-0.0542 (-3.07)	-0.0721 (-4.96)	-0.0431 (-2.84)
P/P_i	0.0320 (4.22)	0.0247 (4.06)	0.0211 (3.57)	0.0256 (5.11)	0.0227 (4.55)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 104, period is 1960-90. (4) t-statistics in parentheses.

Table 3. Growth Regressions on Real Exchange Rate and Relative Prices

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.293	0.101	0.187	0.0484	0.0832
constant	0.0439 (2.20)	0.0425 (2.92)	0.0259 (1.83)	0.0420 (3.66)	0.0258 (2.05)
log (y)	-0.00610 (-2.54)	-0.00536 (-3.00)	-0.00199 (-1.12)	-0.00496 (-3.39)	-0.00216 (-1.45)
n	-0.520 (-2.43)	-0.663 (-4.89)	-0.626 (-4.82)	-0.755 (-9.22)	-0.718 (-8.82)
log (P)	-0.00309 (-0.586)	-0.00730 (-1.87)	-0.00861 (-2.24)	-0.00753 (-2.42)	-0.00735 (-2.29)
P/P_i	0.0390 (4.85)	0.0367 (5.76)	0.0299 (4.79)	0.0359 (6.89)	0.0295 (5.60)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 52, period is 1960-90. (4) t-statistics in parentheses.

Tables 4 and 5 repeat the tests from Table 1, but divide the 104 countries into 52 high-income countries and 52 low-income countries (according to their level of income per person in 1960). 1/ This distinction is made for two reasons. First, the economic structure may be different across countries at different levels of income, and it is interesting to check if the strong results that were revealed in Table 1 hold for both high-income and low-income countries. Second, this division would possibly reveal if the previous results were driven by one or two low-income outliers with serious data problems.

Table 4. Growth Regressions on Relative Prices (High-Income Countries)

	1	2	3	4	5
Number of Observations	52	312	312	1560	1560
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.244	0.0694	0.226	0.0344	0.115
constant	0.0878 (2.81)	0.111 (4.23)	0.0667 (2.70)	0.103 (5.13)	0.0646 (3.12)
log (y)	-0.0103 (-2.72)	-0.0120 (-3.85)	-0.00365 (-1.19)	-0.0110 (-4.53)	-0.00316 (-1.26)
n	-0.593 (-2.35)	-0.611 (-3.38)	-0.644 (-3.88)	-0.683 (-5.84)	-0.688 (-6.07)
P/P_i	0.0306 (2.35)	0.0253 (2.68)	0.0116 (1.31)	0.0265 (3.78)	0.0150 (2.18)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 52, period is 1960-90. (4) t-statistics in parentheses.

1/ The cut-off point is at a 1960 level of output per person of $1575 (measured in PPP 1985 dollars). In case this measure was identical for two countries, they were ordered based on their 1960 level of output per person, measured in PPP current dollars.

Table 5. Growth Regressions on Relative Prices (Low-Income Countries)

	1	2	3	4	5
Number of Observations	52	312	312	1560	1560
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.306	0.130	0.186	0.0583	0.0781
constant	-0.00951 (-0.255)	0.00252 (0.105)	-0.0208 (-0.868)	-0.00964 (-0.456)	-0.0420 (-1.83)
log (y)	0.00323 (0.596)	0.00214 (0.617)	0.00566 (1.59)	0.00365 (1.18)	0.00661 (2.06)
n	-0.898 (-2.09)	-0.984 (-4.59)	-0.925 (-4.41)	-0.909 (-7.70)	-0.863 (-7.26)
P/P_i	0.0428 (4.47)	0.0377 (4.77)	0.0339 (4.37)	0.0372 (5.33)	0.0343 (4.89)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 52, period is 1960-90. (4) t-statistics in parentheses.

Tables 6 and 7 define the key variable P/P_i in a slightly different way. Table 6 concentrates on the private component of consumption. It excludes government consumption from the definition of the variable P/P_i, defining the general price level P as a function of only private consumption and investment. Table 7 uses as an explanatory variable the consumption-investment price ratio (instead of the output/investment price ratio), defining the consumption price level as a weighted average of P_c and P_g. It does this in order to avoid any possible artificial correlation of the investment rate with the price ratio used as explanatory variable.

The results displayed in Tables 1-7 offer strong evidence that the relative price of investment plays a crucial role in determining the long-run rate of economic growth. The estimated coefficients for P/P_i in all regressions are strong, both quantitatively and statistically. Also, the estimated coefficients are remarkably robust across the various regressions.

Table 6. Growth Regressions on Relative Prices (Excluding Government)

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.260	0.0864	0.177	0.0445	0.0809
constant	0.0392 (2.04)	0.0454 (3.39)	0.0323 (2.50)	0.0461 (4.53)	0.0314 (2.76)
log (y)	-0.00466 (-1.99)	-0.00445 (-2.63)	-0.00144 (-0.864)	-0.00427 (-3.13)	-0.00169 (-1.23)
n	-0.542 (-2.52)	-0.660 (-4.87)	-0.606 (-4.70)	-0.756 (-9.25)	-0.711 (-8.77)
P/P_i	0.0328 (4.32)	0.0277 (4.68)	0.0215 (3.77)	0.0277 (5.78)	0.0228 (4.77)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 104, period is 1960-90. (4) t-statistics in parentheses.

Table 7. Growth Regressions on Consumption-Investment Price Ratio

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.267	0.0869	0.174	0.0440	0.0794
constant	0.0497 (2.60)	0.0529 (3.90)	0.0376 (2.86)	0.0537 (5.16)	0.0366 (3.16)
log (y)	-0.00587 (-2.42)	-0.00509 (-2.90)	-0.00175 (-0.999)	-0.00479 (-3.37)	-0.00189 (-1.30)
n	-0.491 (-2.27)	-0.634 (-4.65)	-0.594 (-4.56)	-0.743 (-9.05)	-0.706 (-8.66)
$P_{(c,g)}/P_i$	0.0313 (4.46)	0.0252 (4.72)	0.0180 (3.45)	0.0242 (5.62)	0.0183 (4.21)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 104, period is 1960-90. (4) t-statistics in parentheses.

2. The investment rate

Tables 8 and 9 demonstrate that the empirical evidence is in accord with the predictions of the model presented in Section III regarding the investment rate. In order to test empirically these predictions, the actual variable used is the investment share in GDP (measured in PPP current dollars). 1/ Each table contains five regressions, and they follow the structure of the five regressions described in Tables 1-7. The results presented in the two tables suggest that all the effect of the price ratio P/P_i on economic growth works through the effect of this relative price on the investment rate, just as predicted by the theoretical model.

Table 8 shows the strong effect of P/P_i on the investment rate. However, the information provided by these results is somewhat limited. A potential problem of measurement error bias, that is also mentioned by Barro (1991), exists here. For example, if the measurement of the price P_i is biased upward, the calculated investment rate will be biased downward. This might lead to a positive correlation between the investment rate and the price ratio P/P_i.

Table 8. The Effect of Relative Prices on Investment Rates

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.790	0.685	0.698	0.650	0.664
constant	-0.0611 (-1.29)	-0.170 (-8.09)	-0.175 (-8.32)	-0.197 (-21.4)	-0.195 (-19.1)
log (y)	0.00825 (1.37)	0.0253 (9.17)	0.0242 (8.56)	0.0294 (23.1)	0.0282 (21.6)
n	-0.675 (-1.27)	-0.121 (-0.576)	-0.0956 (-0.461)	0.0337 (0.465)	0.0311 (0.432)
P/P_i	0.243 (12.9)	0.195 (20.9)	0.198 (21.1)	0.182 (42.1)	0.185 (42.5)

Notes: (1) Dependent variable is the average investment rate. (2) Method of estimation is OLS. (3) Number of countries is 104, period is 1960-90. (4) t-statistics in parentheses.

1/ In the model of Section III, the investment rate and the saving rate are identical. In practice, however, they may differ because of imbalances in the current account.

Table 9. Growth Regressions on Investment Rates and Relative Prices

	1	2	3	4	5
Number of Observations	104	624	624	3120	3120
Length of Period	30 Years	5 Years	5 Years	1 Year	1 Year
Period Dummies	No	No	Yes	No	Yes
Adj. R^2	0.391	0.146	0.229	0.0513	0.0865
constant	0.0569 (3.25)	0.0788 (5.73)	0.0649 (4.85)	0.0697 (6.31)	0.0535 (4.41)
log (y)	-0.00753 (-3.38)	-0.00973 (-5.31)	-0.00628 (-3.48)	-0.00796 (-5.13)	-0.00510 (-3.24)
n	-0.397 (-2.02)	-0.614 (-4.68)	-0.573 (-4.58)	-0.745 (-9.13)	-0.705 (-8.70)
I	0.149 (4.05)	0.150 (6.02)	0.152 (6.24)	0.0787 (3.90)	0.0819 (4.04)
P/P_i	0.00114 (0.101)	0.00310 (0.500)	-0.00531 (-0.713)	0.0171 (2.81)	0.00999 (1.62)

Notes: (1) Dependent variable is the average growth rate of output per person. (2) Method of estimation is OLS. (3) Number of countries is 104, period is 1960-90. (4) t-statistics in parentheses.

Table 9 shows that once the investment rate is included as an explanatory variable, the price ratio P/P_i loses much of its power in explaining growth. In most cases its estimated coefficient is now close to zero and statistically nonsignificant.

VI. Summary and Policy Implications

This paper has examined the role of relative prices in economic growth and the possibility that relative prices are (or can be) partly determined by tax policy.

The paper started with a theoretical part, in which it has linked relative prices to tax policy, and has demonstrated that under certain conditions a simple tax policy, that determines the relative price of investment, can affect the investment rate and the permanent growth rate of the economy.

The paper continued with an empirical part, in which it first developed a method to obtain consistent data on relative prices for a large set of countries. Then, using these data, it examined the effect of relative prices in the economy on the rate of economic growth. As a general

framework for the empirical tests, it used the reduced forms derived from the growth model that was presented in the theoretical part. The results of these empirical tests identify the relative prices as a key factor affecting investment and growth.

The theoretical part of the paper provided a possible interpretation of the empirical part, as well as a motivation for this type of empirical work. However, the methodology used to obtain cross-country data on relative prices and the results obtained in the empirical part of the paper are interesting in their own right. They do not necessarily depend on the predictions that were derived or the specific assumptions that were made in the theoretical part. Accordingly, the views presented in the theoretical part are just one possible interpretation of the empirical results, and any policy implications of these views should be treated with extreme caution.

The Growth Model

The technology of production is linear:

$$y = A\,k \tag{A1}$$

From the point of view of the consumer-producer:

$$\frac{P_i}{P_c} = \frac{1-\sigma}{1+\tau} \tag{A2}$$

The consumer-producer faces the following problem:

$$Max \int_0^{\infty} e^{-\rho t}\ \frac{c^{1-\theta}-1}{1-\theta}\ dt \tag{A3}$$

The budget constraint is:

$$\dot{k} = \frac{y - (1+\tau)\ c}{1 - \sigma} - (\delta + n)\ k \tag{A4}$$

The problem can be solved using a Hamiltonian:

$$H = e^{-\rho t}\ \frac{c^{1-\theta}-1}{1-\theta} + \lambda\ [\frac{A\,k - (1+\tau)\ c}{1-\sigma} - (\delta+n)\ k] \tag{A5}$$

The first-order conditions are:

$$H_c = 0: \qquad e^{-\rho t}\ c^{-\theta} = \lambda\ \frac{1+\tau}{1-\sigma} \tag{A6}$$

$$H_k = -\dot{\lambda}: \qquad \frac{A}{1-\sigma} - (\delta+n) = -\frac{\dot{\lambda}}{\lambda} \tag{A7}$$

From equation (A4):

$$\frac{\dot{k}}{k} = \frac{A}{1-\sigma} - \frac{1+\tau}{1-\sigma}\ \frac{c}{k} - (\delta+n) \tag{A8}$$

From equations (A6) and (A7):

$$\frac{\dot{c}}{c} = \frac{1}{\theta}\left[\frac{A}{1-\sigma} - (\delta+n) - \rho\right] \tag{A9}$$

From equations (A8) and (A9):

$$\frac{\dot{c}}{c} - \frac{\dot{k}}{k} = \frac{1}{\theta}\left[(1-\theta)\left(\frac{A}{1-\sigma}-\delta-n\right)-\rho+\frac{\theta\ (1+\tau)}{1-\sigma}\ \frac{c}{k}\right] \tag{A10}$$

Avoiding explosive paths, the consumption/capital ratio must satisfy:

$$\frac{c}{k} = \frac{1-\sigma}{\theta\ (1+\tau)}\left[(\theta-1)\left(\frac{A}{1-\sigma}-\delta-n\right)+\rho\right] \tag{A11}$$

Equation (A11) implies a constant consumption/capital ratio. Therefore, the capital stock grows at the same rate as consumption. From equation (A9):

$$\frac{\dot{k}}{k} = \frac{1}{\theta}\left[\frac{A}{1-\sigma} - \delta - n - \rho\right] \tag{A12}$$

Equation (A1) implies a constant output/capital ratio:

$$\frac{y}{k} = A \tag{A13}$$

Therefore, the output grows at the same rate as the capital stock. Because the growth rates of output, capital and consumption are identical, the economy is always in steady state. From equation (A12):

$$\frac{\dot{y}}{y} = \frac{1}{\theta}\left[\frac{A}{1-\sigma} - \delta - n - \rho\right] \tag{A14}$$

The term $1/(1-\sigma)$ is equal to the ratio between the output price and the investment price (after subsidy). Therefore, equation (A14) can be expressed as a reduced form that can be estimated using data on the rate of population growth and on the relative price of investment:

$$\frac{\dot{y}}{y} = -\frac{\delta+\rho}{\theta} - \frac{1}{\theta}\,n + \frac{A}{\theta}\,\frac{P}{P_i} \tag{A15}$$

In addition to its predictions about the growth rate, the model is also able to make specific projections regarding the investment rate.

Starting from the balanced budget requirement:

$$\tau\, c = \sigma\, i \tag{A16}$$

Rearranging:

$$\frac{\tau}{\sigma} = \frac{i}{c} = \frac{y-c}{c} = \frac{\frac{y}{k}}{\frac{c}{k}} - 1 \tag{A17}$$

Substituting equations (A11) and (A13) into equation (A17):

$$\frac{\tau+\sigma}{\sigma} = \frac{A\,\theta\,\frac{1+\tau}{1-\sigma}}{(\theta-1)\left(\frac{A}{1-\sigma}-\delta-n\right)+\rho} \tag{A18}$$

At this stage, it is useful to define:

$$X = (\theta-1)\left(\frac{A}{1-\sigma}-\delta-n\right)+\rho \tag{A19}$$

Substituting equation (A19) into equation (A18), we derive an expression for the tax rate τ in terms of the subsidy rate σ:

$$\frac{(1+\tau)-(1-\sigma)}{1+\tau} = \frac{\frac{\sigma}{1-\sigma}\,A\,\theta}{X} \tag{A20}$$

$$1 - \frac{\frac{\sigma}{1-\sigma}\,A\,\theta}{X} = \frac{1-\sigma}{1+\tau} \tag{A21}$$

$$1 + \tau = \frac{(1-\sigma)\,X}{X - \frac{\sigma}{1-\sigma}\,A\,\theta} \tag{A22}$$

$$\tau = \frac{\frac{\sigma}{1-\sigma} A\theta - \sigma X}{X - \frac{\sigma}{1-\sigma} A\theta} \tag{A23}$$

The investment rate, s, is defined as:

$$s = \frac{i}{y} \tag{A24}$$

From equation (A17):

$$\frac{\tau}{\sigma} = \frac{i}{c} = \frac{\frac{i}{y}}{\frac{c}{y}} = \frac{\frac{i}{y}}{1 - \frac{i}{y}} = \frac{s}{1-s} \tag{A25}$$

From equation (A23):

$$\frac{\tau}{\sigma} = \frac{A\theta - (1-\sigma) X}{(1-\sigma) X - \sigma A\theta} \tag{A26}$$

From equations (A25) and (A26):

$$\frac{s}{1-s} = \frac{A\theta - (1-\sigma) X}{(1-\sigma) X - \sigma A\theta} \tag{A27}$$

Solving for s:

$$s = \frac{A\theta - (1-\sigma) X}{A\theta (1-\sigma)} \tag{A28}$$

Substituting equation (A19) into equation (A28):

$$s = \frac{A+(\theta-1)(\delta+n)(1-\sigma)-(1-\sigma)\rho}{(1-\sigma) A\theta} \tag{A29}$$

Or:

$$s = \frac{(\theta-1)\delta-\rho}{\theta A} + \frac{\theta-1}{\theta A} n + \frac{1}{\theta} \frac{P}{P_i} \tag{A30}$$

Multiplying by A and rearranging:

$$A\,s = \frac{1}{\theta}\left[\frac{A}{1-\sigma} - \delta - n - \rho\right] + (\delta + n) \tag{A31}$$

Finally, from equations (A14) and (A31), we obtain:

$$\frac{\dot{y}}{y} = A\,s - \delta - n \tag{A32}$$

Income Effects on Different Prices

Tables A1 and A2 explore the effect of income on the different prices, for the years 1960 and 1990. Each table presents five cross-country regressions. The results of these regressions indicate a significant positive effect of income on the general price level (Regression 1), on the price of private consumption (Regression 2) and on the price of government consumption (Regression 3). This positive effect becomes even stronger in 1990, compared to 1960. In the case of the price of investment, however, the results do not indicate the presence of such an effect (Regression 4). In 1960 the effect of income on investment prices is significantly negative, while in 1990 it is close to zero and nonsignificant. As a result, the price ratio P/P_i has a strong positive correlation with income (as shown in Regression 5).

Table A1. The Effect of Income on Prices in 1960

	1	2	3	4	5
Dep. Var.	log (P)	log (P_c)	log (P_g)	log (P_i)	P/P_i
Adj. R^2	0.102	0.0991	0.173	0.0589	0.238
constant	-1.55 (-5.45)	-1.64 (-5.32)	-2.78 (-6.07)	0.758 (2.08)	-0.581 (-2.39)
log (y)	0.136 (3.57)	0.145 (3.51)	0.292 (4.75)	-0.133 (-2.73)	0.188 (5.77)

Notes: (1) Method of estimation is OLS. (2) The number of observations is 104. (3) t-statistics in parentheses.

Table A2. The Effect of Income on Prices in 1990

	1	2	3	4	5
Dep. Var.	log (P)	log (P_c)	log (P_g)	log (P_i)	P/P_i
Adj. R^2	0.408	0.352	0.589	-0.00975	0.633
constant	-3.16 (-10.2)	-2.96 (-9.21)	-6.08 (-14.0)	-0.219 (-0.678)	-0.995 (-7.48)
log (y)	0.325 (8.48)	0.301 (7.54)	0.656 (12.2)	0.00301 (0.0751)	0.220 (13.4)

Notes: (1) Method of estimation is OLS. (2) The number of observations is 104. (3) t-statistics in parentheses.

References

Bahl, Roy W., Chuk Kyo Kim and Chong-gi Pak (1986), *Public Finances During the Korean Modernization Process*, Harvard University Press.

Balassa, Bela A. (1964), "The Purchasing-Power Parity Doctrine: a Reappraisal", *Journal of Political Economy*, Vol. 72, (December), pp. 584-96.

Barro, Robert J. (1990), "Government Spending in a Simple Model of Endogenous Growth", *Journal of Political Economy*, Vol. 98, (October), pp. S103-25.

——— (1991), "Economic Growth in a Cross Section of Countries", *Quarterly Journal of Economics*, Vol. 106, (May), pp. 407-43.

——— and Xavier Sala-i-Martin (1992), "Public Finance in Models of Economic Growth", *Review of Economic Studies*, Vol. 59, pp. 645-61.

———, ——— (1995), *Economic Growth*, McGraw-Hill.

De Long, J. Bradford and Lawrence H. Summers (1991), "Equipment Investment and Economic Growth", *Quarterly Journal of Economics*, Vol. 106, (May), pp. 445-502.

Easterly, William and Sergio Rebelo (1992), "Marginal Income Tax Rates and Economic Growth in Developing Countries", *Banco de Portugal-Working Paper*, (November), pp. 20-92.

Milesi-Ferretti, Gian Maria and Nouriel Roubini (1995), "Growth Effects of Income and Consumption Taxes: Positive and Normative Analysis", *IMF Working Paper 95/62*, (June).

Pai, Patrick P. (1991), "Tax Policy and Economic Development in the Republic of China", *Industry of Free China*, Vol. 76-6, (December), pp. 47-56.

Rebelo, Sergio (1991), "Long-Run Policy Analysis and Long-Run Growth", *Journal of Political Economy*, Vol. 99, (June), pp. 500-21.

Summers, Robert and Alan Heston (1991), "The Penn World Table (Mark 5): an Expanded Set of International Comparisons, 1950-88", *Quarterly Journal of Economics*, Vol. 106, (May), pp. 327-68.