The Rise and Fall of India's Relative Investment Price: A Tale of Policy Error and Reform

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Abstract

India's relative price of investment rose 44% from 1981 to 1991 and fell 26% from 1991 to 2006. We build a simple DGE model calibrated to Indian data in order to explore the impact of capital import substitution policies and their reform post-1991, in accounting for this rise and fall. Our model delivers a 23% rise before reform and a 28% fall thereafter. GDP per worker was 2.9% lower in 1991 compared to 1981 due to import restrictions on capital goods. Their removal and a 64 percentage point reduction in tariff rates raised GDP per worker permanently by 17.8%.

Keywords: Relative price of investment; Policy reform in India

JEL codes: O11; E17; E2

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1 Introduction

The behavior of the relative price of investment in India stands in fascinating contrast to its well known fall in the US in recent decades (Greenwood, Hercowitz and Krusell, 1997).[1] As seen in Figure 1, relative to the Penn World Table benchmark index (Feenstra, Inklaar and Timmer, 2015), the relative price of investment in India rose 44 percent from 1981 to 1991 and subsequently fell 26 percent from 1991 to 2006. To contextualize the magnitude of this change in relative price, we can look at cross country differences in the relative price of investment in 1991. The average value of the relative price of investment for G7 nations in 1991 was 0.88 while the average for all other nations was 1.38 which is 57 percent higher. Similarly the one decade rise seen in India of 44 percent is equivalent to moving from the United States to nations such as Antigua and Barbuda or Estonia in terms of percent difference in the relative price of investment.

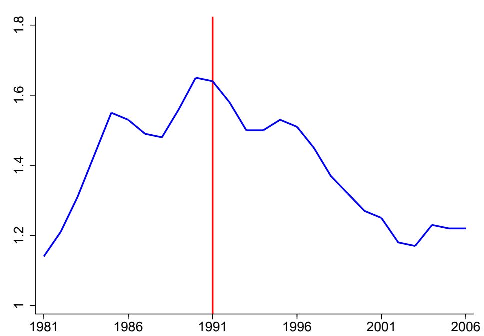

Figure 1: The relative price of investment in India from 1981 to 2006

Note: The vertical line denotes the year 1991 when capital import reform begins. *Source:* The Penn World Table 9.0.

The sudden change in direction in the relative price of investment in India is tantalizingly coincident with a period of rapid economic reform in India and the concomitant increase in the growth rate of Indian GDP. These observations

[1]The decrease in the relative price of investment can also been seen in world indexes starting in the early 1980s (Karabarbounis and Neiman, 2014).

raise a number of questions that we seek to answer in this paper. Why did the relative price of investment rise in India during the 1980s while it fell in the developed world? Did the sudden change in direction in 1991 have something to do with the unexpected change in policies instituted by the Indian state during the reform period beginning in 1991 and beyond.?[2] If so, what was the contribution of these policy shifts to the increase in the growth rate of GDP experienced by India over the next decade and a half?

When thinking about the divergent paths of the relative price of investment goods in India and the world benchmark, it is natural to focus on policy distortions specific to the import of machines into India. This is especially true when the vast majority of capital goods are produced in a few developed nations (Mutreja, Ravikumar and Sposi, 2016). These distortions were large and came from several sources. Before reforms, capital good imports into India faced very high tariff rates — the United Nations Conference on Trade and Development (UNCTAD) calculates the weighted average tariff rate on capital to be 72.7 percent in 1990. Similarly Hasan, Mitra and Ramaswamy (2007) report that in 1988 electrical machinery faced a tariff rate of 143 percent, transport equipment 130 percent, and other machinery 140 percent approximately. In addition, there existed pervasive non-tariff barriers on the import of capital goods which required import licenses to be obtained from the government. Hasan, Mitra and Ramaswamy (2007) report that quantitative restrictions applied to 90 percent of the value added in manufacturing. The coverage rates of non-tariff barriers for the import of goods in the machinery category was 77 percent, while it was 79 percent for the electrical machinery category and an even higher 82 percent for the import of transport equipment. After 1990, tariff rates on imported capital goods fell from a weighted average of 72.7 percent to 7.6 percent by 2006 in a series of steps. Moreover import licensing was removed from a number of capital good categories that quickly expanded such that they became freely importable by 1993.[3]

[2] Most observers agree that the change in policy regime in India around 1991 was unexpected. For example, see Goyal (1996) and Goldberg et al. (2010).

[3] Additional figures and details can be found in Kotwal, Ramaswami and Wadhwa (2011) and the references therein.

In this paper we argue that both the rise in the relative price of investment in the pre-reform period and the fall during the reform period were closely linked to Indian capital import substitution policies and their removal after 1991. The fall in prices seen over the reform period are relatively easy to understand. We would expect the price of investment goods to fall as tariffs on imported machines used in the production of these goods are reduced over time.[4] The rise in the pre-reform decade is a little less obvious. Our explanation is based on the insight that any decade-long endogenous rise in the relative price of investment must come from an increasing relative scarcity of machines. The import substitution policies instituted by the Indian state provide a well documented source of scarcity. Import license requirements were put in place precisely to restrict the amount of capital goods that could be brought into India. This policy-induced scarcity created a wedge between domestic and world prices of capital good imports, over and above the already high tariff rates. Indeed policy makers must have found that the tariff barriers were insufficient to squelch the demand for foreign machines and thus resorted to outright quantity restrictions in the form of licenses. This relative scarcity increased with time as the demand for imported capital goods grew along with the economy in the 1980s, both due to productivity growth (which picked up over this period) and due to rapid population growth while the supply was kept relatively tight by policy. The impact of these policies can be seen in a decline in the ratio of capital imports to output which fell by 28 percent between 1981 and 1991.[5]

In order to quantitatively explore the contribution of these import substi-

[4] A number of studies have established the positive impact of Indian tariff reductions on firm choices and performance, though we are not aware of any that study the impact on the relative price of investment. For example, Topalova and Khandelwal (2011) estimate that the sudden fall in import tariff rates in 1991 had a positive impact on firm level productivity of domestic manufacturing firms. Goldberg et al. (2010) and Goldberg et al. (2009) find that the decline in trade tariff rates led to a large expansion in new products and imported input use by Indian firms. Bollard, Klenow and Sharma (2013) however find that reforms have only a limited ability to explain TFP growth in large existing firms. See also Chamarbagwala and Sharma (2011).

[5] Details about the construction of the capital import share can be found in section 3.1 below.

tution policies to the rise and fall of the relative price of investment in India, we build a simple dynamic general equilibrium model of a small open economy in which foreign capital goods are an input into the production of domestic investment goods. In the pre-reform period, the import of capital goods is capped at a fixed amount each period as specified by the government so that the domestic price paid by firms for foreign capital goods is determined by a market clearing domestic price which can differ from the world price. As demand for foreign capital goods rises, the domestic price of foreign capital goods rises as well, even in the presence of constant tariff rates because the cap on imported capital goods falls further and further behind demand. During the reform period, this cap is removed so that capital goods can be freely imported into the economy, once a tariff is paid to the government. In the absence of a constraint on imports, the wedge between world and domestic prices of foreign capital goods becomes exogenous and is solely determined by tariff rates. We calibrate this model to Indian macroeconomic data and explore two scenarios. First, in the pre-reform phase, we ask, how much does the relative price of investment increase in the model when we embed the actual growth in productivity and employment experienced by India from 1981 to 1991.[6] Next we use observed reductions to tariff rates on imported capital goods from the UNCTAD's Trade Analysis & Information System (TRAINS) database and calculate the implied fall in the relative price of investment in the calibrated model without an import constraint. Our results suggest that we can generate a rise of about 23 percent in the relative price of investment before reforms begin, and thereafter, a decline of roughly 28 percent. This large decline comes from both the removal of quantity restrictions as well as the decline in tariff rates. These movements in the relative price of investment have great significance for the economy. The model implies that GDP per worker was 2.9 percent lower in 1991 compared to a decade earlier purely

[6] We start our analysis in the 1980's because the previous decade was tumultuous, marked by the 1971 war with Pakistan, the OPEC oil price shock of 1973 and the political crisis known as the emergency from 1975 to 1977. Perhaps due to these disturbances, output per worker barely grew in the 1970s and TFP growth was negative (see Rodrik and Subramanian (2005)). Kochhar et al. (2006) also begin their analysis of Indian development in the 1980s.

due to the rising distortion caused by import restrictions on capital goods. In addition, the 64 percentage point reduction in capital import tariff rates and removal of quantity restrictions raised GDP per worker permanently by 17.8 percent. Turning to the transitional dynamics induced by the reduction in capital import tariff rates, they alone account for one fifth of the rise in the growth rate of GDP per worker observed between 1991 and 2006. Bosworth and Collins (2008) report that output per worker growth almost doubled from 2.4 to 4.6 percent per annum in the reform period. Consistent with our story, the authors report that the contribution of physical capital also doubled from 0.9 percent to 1.8 percent.

An interesting feature of our model is an endogenously rising policy distortion in the pre-reform period which increases with the overall size of the economy.[7] To our knowledge, this is the first paper that provides an endogenous explanation for medium term movement in the relative price of investment over time. Our work is related to the literature that explains cross-country differences in the relative price of investment based on exogenous relative productivity differences in the investment versus consumption sector (Hsieh and Klenow, 2007) and especially to exogenous differences in investment distortions. For example Restuccia and Urrutia (2001) establish the large dispersion in the relative price of investment across countries and use an exogenous stochastic process for distortions to investment to account for these facts.[8] Our work differs from these in two ways. First we do not focus on cross-sectional differences in the level of relative prices in, say, India and the United States at a point in time. Instead we explain why the relative price of investment in India increased compared to US for a long period of time. Second, the change in the relative price of investment in our model is driven by a distortion that grows over time with the economy because of a policy

[7]The model also contains exogenous sources of distortion which are discussed more fully later.

[8]Our model is also related to the literature that links the relative price of investment to growth, investment, income and productivity differences across nations. Jones (1994) provides an early link between the relative price of investment and economic growth. See also Armenter and Lahiri (2012) and Restuccia (2004).

induced scarcity of foreign machines. As a result the model has no sectoral differences in productivity trends. To the extent that there were differences in trends in productivity in investment versus consumption good sectors, these would complement our quantitative results. Indeed an additional 21 percent rise in India's relative price of investment remains unaccounted by our calibrated model. Our interest in medium term trends in the relative price of investment is shared by Karabarbounis and Neiman (2014) which links the fall in the relative price of investment to the recent global fall in labor share; however, changes in the relative price of investment are driven by exogenous shocks to the productivity of the investment sector in that study. We share an interest in exploring the quantitative implications of population growth on development with Leukhina and Turnovsky (2016) who study the transition from agriculture to manufacturing in England.

The rest of the paper is structured as follows. Section 2 presents the model while section 3 discusses the data used in the study as well as the calibration of model parameters. Section 4 presents quantitative results from the benchmark calibration as well as some sensitivity analysis. Concluding remarks are followed by an appendix that outlines the solution methods used in our paper.

2 Model

We model a standard small open economy that imports a capital good at a given world price and combines it with a domestic final good to create the domestic investment good used for capital accumulation. There are three type of firms in the economy: a representative final good producer, a representative investment good producer and a representative importer that faces a capital import restriction. All firms behave competitively. In addition, the model has a representative household and government.

2.1 The household's problem

The benevolent head of an infinitely lived representative household of size L_t obtains utility from sequences of total consumption, C_t, of the final good with lifetime utility defined as

$$\mathcal{U} = \sum_{t=0}^{\infty} \beta^t \log C_t \tag{1}$$

where β, $0 < \beta < 1$, is the household's subjective discount factor.[9]

The household supplies one unit of labor per person so that it supplies L_t units of total labor inelastically to the final good producer. In each period it earns a wage equal to w_t per unit of labor. In addition it earns capital income by renting out its capital stock K_t at the rental rate r_t and also receives profits from the final good producer, the investment good producer, the importer and receives lump-sum transfers, T_t, from the government. At the end of each period, the household chooses its total consumption, C_t, (divided equally among members), and buys domestic investment good, I_t, at price, q_t, which will be our notation for the relative price of investment. All prices are expressed in units of the final good. The household budget constraint is

$$C_t + q_t I_t = w_t L_t + r_t K_t + \Pi_t^{\mathrm{Y}} + \Pi_t^{\mathrm{I}} + \Pi_t^{\mathrm{imp}} + T_t \tag{2}$$

and the law of motion for capital is

$$K_{t+1} = (1 - \delta) K_t + I_t \tag{3}$$

where δ is the depreciation rate of capital. The household chooses sequences of C_t, K_{t+1} to maximize (1) subject to (2) and (3), and the initial condition, $K_0 > 0$, which yields the first order condition:

$$\frac{q_t}{C_t} = \beta \frac{1}{C_{t+1}} \left(r_{t+1} + q_{t+1}(1 - \delta) \right) \tag{4}$$

[9]We follow the literature in the use of log preferences. See Restuccia (2004) for example.

2.2 The final good firm's problem

The perfectly competitive final good producer operates a constant returns to scale technology given by

$$Y_t = K_t^{\alpha}(Z_t L_t)^{1-\alpha} \tag{5}$$

where Z_t is productivity that grows at the exogenous rate γ_z. Our notation presupposes market clearing in factor markets, therefore we do not distinguish between quantities supplied and demanded in these markets. As such, since each member of the household inelastically supplies one unit of labor, L_t, measures, not only the hours hired by the firm, but also the size of the working population which grows exogenously according to (6)

$$L_t = \gamma_l L_{t-1}. \tag{6}$$

The firm sells its output in the final good market to the household for consumption, and to the investment good producer as an input in investment good production. Standard efficiency conditions for the producer are omitted for brevity.

2.3 The investment good firm's problem

The representative investment good producer combines units of the imported capital good with units of the domestic final good to produce the domestic investment goods using the following technology :

$$I_t = D_t^{\eta} M_t^{1-\eta} \tag{7}$$

where D_t refers to units of the domestic final good, and M_t to units of the imported capital good purchased. Domestic and foreign capital goods are usually combined using the Cobb-Douglas specification in the literature (see

Boileau (2002) and Hsieh and Klenow (2007) for example).[10] The firm buys M_t from the importer at price p_t^m, and sells the produced investment good, I_t to household at price q_t. The investment good producer chooses D_t and M_t to maximize its profits given by

$$\Pi_t^{\text{I}} = q_t I_t - D_t - p_t^m M_t, \tag{8}$$

yielding the first order conditions:

$$\eta q_t D_t^{\eta-1} M_t^{1-\eta} = 1 \tag{9}$$

$$(1-\eta) q_t D_t^{\eta} M_t^{-\eta} = p_t^m \tag{10}$$

Combining equations (9) and (10), we get a relationship between the intensity of imported capital use in the economy and the domestic price of imported capital goods:

$$\frac{D_t}{M_t} = \frac{\eta}{1-\eta} p_t^m \tag{11}$$

which shows that the government can pursue its pre-reform agenda of import substitution by implementing policies that inflate p_t^m. We also get the following relationship between q_t and p_t^m,

$$q_t = \frac{1}{\eta} \left(\frac{\eta p_t^m}{1-\eta} \right)^{1-\eta} \tag{12}$$

which further clarifies the mechanism by which our model will operate to influence the relative price of investment over time.

2.4 The government

The government plays a limited role in our model. It follows capital import substitution policies by imposing a tariff, θ_t, on each unit of imported capital

[10] Robustness analysis is conducted with constant elasticity of substitution technology, see section 4.3.

goods. This is paid by the importer. We assume the government runs a balanced budget so that all revenues from the import tariff are rebated to the household as a lump-sum transfer, T_t. In addition we interpret the license requirements on imported capital goods as a government set capital import limit, $\bar{M}_t$, that potentially changes with time. We assume the importing firm must obtain one license per unit of imported capital goods so that we can think of the domestic market for imported capital in symmetry with the market for licenses. The importing firm is restricted to importing no more than $\bar{M}_t$ units of capital goods into the country in the pre-reform period whereas there is no constraint on the importer after reforms begin. In practice import licenses were often expressed in nominal terms. This meant that periods of rapid depreciation of the Rupee inadvertently made the capital import limit even tighter in physical units. We discuss this issue in more detail when calibrating the path of $\bar{M}_t$.

2.5 The importing firm's problem

The representative importing firm brings foreign capital goods, M_t, from outside the country, taking as given the world price p^w. In addition it must pay the tariff, θ_t, to the government. The importer then sells M_t units of imported capital goods at the market clearing price, p_t^m. The importer's profits are given by

$$\Pi_t^{\text{imp}} = p_t^m M_t - p^w(1+\theta_t)M_t \tag{13}$$

In the reform period, when the import limit is effectively infinite, the importer maximizes profits by choosing M_t. Before reforms, if the constraint imposed by the government binds, $M_t = \bar{M}_t$, otherwise it is chosen to maximize profits. Efficiency conditions imply that $p_t^m \geq p^w(1+\theta_t)$. When the domestic price of imported capital goods exceeds the cost to the importer, we assume profits are repatriated to the household in a lump sum fashion. After reforms begin, the importer makes zero profits. In India, imports of machines and other inputs were often carried out by central government agencies such that any profits earned flowed into the coffers of the government. Since both tariff revenue and profits from imports flow back to the household, we could easily have pooled the importer into the government without any loss of results. Note that the premium charged by the importer over and above the tariff inclusive price could also be interpreted in terms of bribes paid to bureaucrats in order to obtain a license to import, where the bribe amount is determined by supply of and demand for licenses. Note also that the price, p_t^m, which measures the degree of distortion in the domestic market for foreign capital goods, is determined endogenously in equilibrium in the pre-reform period. During the reform period p_t^m is the sum of two exogenous components, namely the tariff rate and the world price of imported capital goods. The world price of imported capital goods is held constant in the model because we want to generate movements in the relative price of investment in India relative to the world benchmark index for the relative price of investment in the Penn World Table. This ensures that any movement in the relative price solely emerges from domestic sources in India in the model.

2.6 Equilibrium

Definition: Given the initial conditions, the equilibrium of this economy is given by sequences of C_t, I_t, K_{t+1}, D_t, M_t, T_t and prices w_t, r_t, q_t, p^w and p_t^m where $t = \{0, \ldots, \infty\}$ such that (i) given w_t, r_t and q_t the representative household chooses C_t, I_t, K_{t+1} to solve its utility maximization problem using (4); (ii) given w_t and r_t, the final good producing firm chooses K_t, L_t to solve its profit maximization problem; (iii) given p_t^m, the investment good producing firm chooses D_t and M_t to solve its profit maximization problem using (9) and (10); (iv) given p^w, θ_t and the government imposed restriction $\bar{M}_t$, the importer chooses M_t to solve its problem using (13) and; (v) markets for labor, capital, investment goods, foreign capital goods and final goods clear; (vi) the government budget is balanced; and (vii) the aggregate resource constraint, $C_t + D_t = Y_t - p^w M_t$, holds.

At this point it may be useful to discuss the dynamics of the model in two situations, when $\bar{M}_t$ is binding and when it is not. We begin with the latter situation. When $\bar{M}_t$ is not binding, p_t^m is effectively exogenous and only responds to changes in tariff rates. From (12) we can see that in this situation the relative price of investment, q_t, is constant and the economy follows a balanced growth path where all other variables grow at a constant rate given by growth of productivity and employment. When the import constraint is binding, there are two possible scenarios. In the first scenario, $\bar{M}_t$ grows at the same rate as productivity and employment growth, therefore, q_t is still constant and the economy follows a balanced growth path. In the second scenario, the import constraint grows at a slower rate, then p_t^m and q_t both rise and the economy is no longer on a balanced growth path. This occurs because the rise in the price of imported capital goods causes the investment producer to change the optimal mix of domestic and foreign goods used in the production of investment goods. As a result $\frac{D_t}{M_t}$ falls over time as is clear from (11). Our solution method, discussed in section 4.1, provides a terminal period for this scenario after which the economy returns to a balanced growth path.

3 Data definitions and calibration

In this section we describe the data used in our study and discuss how the parameters of our model were chosen.

3.1 Data

The Penn World Table 9.0 (PWT) (Feenstra, Inklaar and Timmer, 2015) provides data on relative levels of income, output, inputs and productivity in 182 countries between 1950 and 2014. Below, the series from the PWT used in our paper are discussed with the series name in parentheses. The price of consumption ('pl_c') and the price of investment ('pl_i') are constructed using both a purchasing power measure and a "reference price" (which we refer to as the world benchmark). The reference price is calculated using the *quantity-weighted average over countries of prices of each good*. The relative price of investment is constructed by taking the ratio of the price of investment and the price of consumption. The aggregate depreciation rate ('delta') is a weighted average of the following categories: structures (residential and non-residential), transport equipment, computers, communication equipment, software and other machinery and assets. To calculate the capital import share, we use import share data measured in current purchasing power parity units on the following categories of merchandise trade: industrial supplies ('csh_m2'), fuels and lubricants ('csh_m3'), capital goods ('csh_m4'), and transport equipment ('csh_m5').[11] These import shares are measured as the ratio of import expenditure by category to nominal GDP at current prices and therefore contain movements in the prices of imports relative to the GDP deflater. To remove these prices, we construct the ratio of capital imports to consumption using:

$$\sum_{i=2}^{5} \frac{csh\_mi}{csh\_c} \times \frac{pl\_mi}{pl\_c}$$

- where ('csh_c') is the consumption share, the various import shares are: industrial supplies ('csh_m2'), fuels and lubricants ('csh_m3'), capital goods ('csh_m4'), and transport equipment ('csh_m5') with corresponding import prices ('pl_mi'), i=2,3,4,5.

To calculate productivity, Z_t, we use real GDP at constant 2011 national prices ('rgdpna'), real capital stock at constant 2011 national prices ('rkna'), number of persons engaged ('emp'). To calculate the consumption-output ratio, we use the series, 'Real consumption at constant 2011 national prices' and divide it by 'Real GDP at constant 2011 national prices'.

The UNCTAD's Trade Analysis & Information System (TRAINS) database provides data on the average tariff rate (UNCTAD method) on capital goods (UNCTAD-SoP4 – Capital goods[12]).[13] This series is available from 1990.

[11] Imported capital categories used in our calibration are also similar to EU-KLEMS database (Jäger, 2016).

[12] UNCTAD-SoP4 is a Harmonized System (HS) classification for capital goods.

[13] Data is accessed through the World Bank: WITS application; see http://wits.worldbank.org.

3.2 Parameters

Our model is calibrated to match several features of the Indian economy in 1981 which is the starting year of our analysis. These parameters values are provided in Table 1. We assume that the economy was on a balanced growth path in 1981. Some evidence in support of this assumption can be seen in the relatively stable investment to output ratio during the decade of the 1970s when this ratio had an average value of 0.20. By contrast the investment output ratio declined in the 1980s and then rose in the 1990s displaying average values of 0.19 and 0.22 respectively (the investment output ratio is obtained from the PWT using the series 'csh_i').

Table 1: Parameters : benchmark calibration.

Parameter		Value	Source
Capital share in final good production	α	0.33	standard
Discount factor	β	0.9255	calibrated
Employment growth	γ_l	1.0326	PWT
Depreciation rate	δ	0.05	PWT
Productivity growth	γ_z	1.0212	PWT
Import share in investment good production	$(1-\eta)$	0.2650	calibrated
Tariff	θ	0.72 & 0.076	UNCTAD's TRAINS

There are two sources of growth in the model, the number of employed people, L_t, and the level of labor augmenting productivity, Z_t. We set the gross growth rate of the labor input, $\gamma_l = 1.0326$ to match the annualized growth rate of the employed population in India between 1981 and 2006. We also set the gross growth rate of productivity, $\gamma_z = 1.0212$ to match the observed growth in the labor augmenting productivity for India during the same period. Since the initial level of L_t and Z_t has no impact on the percentage change in q_t, we normalize the initial values of both to unity. The value of the depreciation rate, δ, in the capital accumulation equation is 0.05, which is obtained from the average of the annual reported value in the PWT.

We calibrate β, the time preference parameter in the household utility function, and η, the share of domestic final goods in the production of investment goods, jointly using the consumption-output ratio in 1981 which is 0.84 and the capital import to consumption ratio in 1981 which is 0.03 in the PWT. We described the construction of this measure in the previous subsection. Turning to the final good production technology, we follow the literature in assuming a constant returns to scale production function of the Cobb-Douglas form. The capital share parameter, α, is set to 0.33, a standard value in the literature (Hsieh and Klenow (2007)) which is also close to the average value seen in this period.

Table 2: Tariff rates on capital imports.

Year	Tariff rate (%)	Step
1990	72.72	-
1992	52.62	Step 1
1996	29.30	Step 2
1997	21.24	Step 2
1999	26.60	Step 2
2000	21.70	Step 2
2001	22.37	Step 2
2002	20.79	Step 2
2003	19.65	Step 2
2004	21.73	Step 2
2005	9.60	Step 3
2006	7.06	Step 3

Note: Tariff rates are calculated using UNCTAD's averaging method. *Source:* UNCTAD's TRAINS database.

The pre-reform period differs crucially from the reform period due to the presence of the import constraint captured by $\bar{M}_t$. Obviously the path of this variable has a strong influence on the domestic price of imported capital goods, p_t^m, and through that on the level of the relative price of investment, q_t. Our approach for disciplining the quantitative analysis is to choose the most conservative level for $\bar{M}_t$ in 1981 while ensuring the constraint is actually binding in equilibrium. This level of imports is obtained when the 1981 price of imported capital goods, p_t^m, is equal to 1.72 which is composed of the world price of capital goods, $p^w = 1$, and the tariff rate of 72 percent. This is equivalent to a situation where the effective distortion caused by the non-tariff barrier is no greater than the actual tariff rate observed in 1990 (see Table 2). Note that our analysis focuses on the percentage change in the relative price of investment and not on the level in any year. The rise in the relative price discussed in the next section is not sensitive to the initial level of $\bar{M}_t$. We demonstrate this by recalculating the change in q_t for a lower value of $\bar{M}_t$ which implies an imported capital good price, $p_t^m = 2$ as opposed to the benchmark value of 1.72.

In order to discipline the path of $\bar{M}_t$ beyond the initial period we use the ratio of capital imports to consumption obtained from the PWT in 1991 which has a value of 0.014. In our model economy this ratio shrinks for three reasons: labor productivity growth, employment growth and a change in $\bar{M}_t$. As discussed above, we measure the growth rate of the former two factors directly from the PWT data. The third factor, which governs the increase or decrease of the capital import limit is not directly observed but can be extracted from model simulations. We pick the growth rate of $\bar{M}_t$ between 1981 and 1991 to be such that the ratio of capital imports to consumption is exactly equal to the data value in 1991 and 1981. Our simulations reveal that $\bar{M}_t$ must shrink at a rate of 3.5 percent each year to meet our target. In order to understand this tightening of import limits one needs to remember that the Rupee depreciated dramatically in the 1980's and this caused nominal import limits expressed in Rupees to shrink in real terms. Our finding of an aggregate tightening of 3.5 percent per annum should be viewed as the net effect of the real depreciation of the Rupee and a slowly liberalizing import policy which was not keeping pace with the falling value of the currency and the rising demand for imported capital goods due to population and productivity growth.

The pre-reform tariff rate, θ_t, on imported capital goods is set to 0.72. We use weighted average tariff rates on capital imports from 1991 until 2006, when θ_t falls to 0.076. Since these tariff rates are not available for every year, we try to capture the falling trend in rates by pooling the reductions into three discrete steps. We provide a table with the actual measure of the weighted tariff rate by year and our steps in Table 2. We stop our analysis of the reform period in 2006 to avoid the impact of of the financial crisis and the US trade collapse (see Ahn, Amiti and Weinstein (2011) for a discussion of the size of the collapse in world trade). Since our measure of the relative price of investment in India is calculated relative to a benchmark relative price of investment for the world, we normalize the world price of imported capital goods to unity.

4 Results

4.1 Before reform

In this section, our goal is to get a quantitative sense of the ability of our calibrated model to produce a rise in the relative price of investment while also obtaining measures of the impact of the import substitution policy on output per worker. We begin our analysis by assuming that the economy is on a balanced growth path until 1981. In order to implement our solution method, we divide all growing variables by effective labor. For example, we define output per effective unit of labor as $y_t = \frac{Y_t}{Z_t L_t}$ and similarly for other variables, giving us an initial steady state in the transformed system. Since $\frac{\bar{M}_t}{Z_t L_t}$ shrinks every period after 1981, the economy is no longer in steady state. To solve the model we assume that agents expect the current policy on tariff rates and a tightening import constraint to remain in place for 50 years after which the government adjusts the import limit to keep pace with productivity and employment growth forever.[14] We compute the transition of the economy from 1981 to 1991 at which point an unexpected change in policy occurs.

We confirm that the pre-reform transition path of the economy is not significantly affected by our choice of terminal year for when the import limit stops shrinking. We obtained similar results with a 20, 50 and 100 years transition since there is little change in the path in the first 10 years. To solve the transition in the pre-reform period, we use the relaxation algorithm for a system of non-linear equations using the forward-looking method proposed by Boucekkine (1995). Key aspects of this algorithm involve a known initial and terminal condition and perfect foresight for agents regarding the path of

[14] An alternative assumption would have been to assume that the current policy remains in place forever, but this seems unreasonable since it would imply that the capital stock is driven to zero in the limit.

exogenous variables.

Compared to 1981, the simulated domestic price of foreign capital goods, p_t^m, is 115 percent higher by 1991. This rise in input costs causes the relative price of investment, q_t, to increase (see equation 12). Our calibrated model delivers a 22.5 percent rise in the relative price of investment over this period. Moreover, annual output per effective unit of labor, y_t, is 2.9 percent lower in 1991 than in 1981. This loss in output arises from the cumulative impact of the rising relative scarcity of foreign capital goods which over time creates an increasing distortion in the production of investment goods. This distortion is reflected in a steep rise in the relative price of investment. If government policy in India had merely increased the number of licenses to keep pace with the rise in productivity and workers, the model would have remained at the 1981 steady state and investment would not have become more expensive to produce over this period. The stability of the price of imported capital goods would have prevented the capital stock from lagging behind other inputs in the economy so that output per effective unit of labor would have been constant. The first column of Table 3 reports the change in the relative price of investment over the pre-reform period and compares them to the data.

Table 3: Change in q (%)

	Before reform	During reform
Data	44%	-26%
Model	23%	-28%

In order to show that this rise in q_t is not sensitive to the 1981 value of $\bar{M}_t$, we redo our quantitative analysis using $\bar{M}_t = 0.0220895$ which implies an initial $p^m = 2$ whereas $p^m = 1.72$ in the benchmark calibration.This change resulted in the model generating a rise in q_t of 22.57 percent instead of 22.54 percent.

4.2 During reform

The Indian government instituted major reforms beginning in 1991 which included a quick dismantling of import controls on capital goods. Our goal is to focus on the impact of these specific reforms using our calibrated model. To implement this reform in our calibrated model, we assume that the restrictions on capital goods imports were fully in place during 1991 and completely removed by 1992. In addition to the removal of non-tariff barriers, the Indian government reduced tariff rates on capital goods from 72.7 percent in 1990 to 7.6 percent in 2006 (see Table 2). We assume for our quantitative analysis that all tariff changes are complete by 2006 and that there are no further changes so that a new steady state can be calculated at the lowest tariff rate in 2006. In order to extract the contribution of the removal of the quantity restrictions from the contribution of the tariff rate reductions to the relative price of investment in 1991, we calculate a hypothetical steady state for 1991. To obtain this steady state, we pick a tariff rate, θ^*, to match p^m to its pre-reform 1991 value, so that $p^{m^*} = p^w(1+\theta^*) = 3.71$, where the world price equals unity as usual. This hypothetical steady state corresponds to a situation where the actual tariff rate is equal to the implied distortion caused by the non-tariff barrier. One interpretation of this steady state is that the government has committed to keep the domestic price of foreign capital goods constant at the 1991 level by increasing licenses at the combined growth rate of productivity and employment. Having calculated key variables (y^*, c^*) in this steady state, we can compare their values to two other steady states, one in which tariff rates are reduced to 72 percent and another in which they are further reduced to the 2006 value of 7.6 percent. We can then calculate the total change in y and c by comparing the hypothetical 1991 steady state to the 2006 steady state and also the pure contribution of tariff rate reductions by comparing the steady state where tariff rates are fixed at the pre-reform weighted average of 72 percent to the 2006 steady state. Comparing the three steady states, we find that the total effect of the policy changes led to a fall in q_t of 28 percent. Out of this total fall, the tariff rate reduction alone accounts for 12 percent while 16 percent comes from the removal of quantity restrictions. The actual fall in the relative price of investment in India was 26 percent. The policy change induced fall in the domestic price of capital imports induces an increase in the import of capital goods used in investment goods creation, more capital accumulation and higher levels of output per unit of effective labor. In the new steady state, y is 17.8 percent higher than y^*. The pure contribution of the tariff rate reduction to this large rise in output per effective unit of labor is 6.5 percent while the remainder comes from the removal of quantity restrictions. Assuming no further declines in the tariff rate on capital goods imports, the policy change implies that consumption per worker is permanently higher by 13.4 percent compared to the hypothetical steady state in 1991.

4.2.1 Transition to the 2006 steady state

While it is clear that the reduction in imported capital goods price lead to a permanently higher level of output and consumption, there could be welfare losses along the transition path as consumption falls in order to accumulate enough capital to reach the new steady state. In order to explore this issue and to further characterize the transition of the economy to the policy changes we calculate the transition path taking as given the 1991 capital stock, k_{1991}, obtained from the pre-reform transition. As observed in Table 2, tariff rate reductions occurred in a series of steps of unequal sizes. In order to deal with this, we compute the transition path during the reform period by assuming that tariff rates were reduced in three steps. These tariff rates for the transition are: i) 52 percent, ii) 23 percent, and iii) 7.6 percent.[15] The policy functions used during the reform period are calculated using the value function iteration (endogenous grid points method) proposed by Carroll (2006) (see Appendix A.1 for details). The transition follows the policy rule corresponding to a 52 percent tariff rate for 4 periods using k_{1991} as the starting value. Thereafter, the economy switches to a new policy rule corresponding to a 23 percent tariff rate for 9 periods using the 4th period capital stock as

[15]The tariff rate falls from 72 percent to 52 percent between 1990 to 1992. It is on average 23 percent from 1993 to 2004. It is 7.6 percent in 2006. Data is not available for all years.

the starting value. After 9 periods the policy rule switches one last time to correspond to a 7.6 percent tariff rate using the existing capital stock in that period as the starting value. The economy follows this policy rule until it reaches the new steady state.

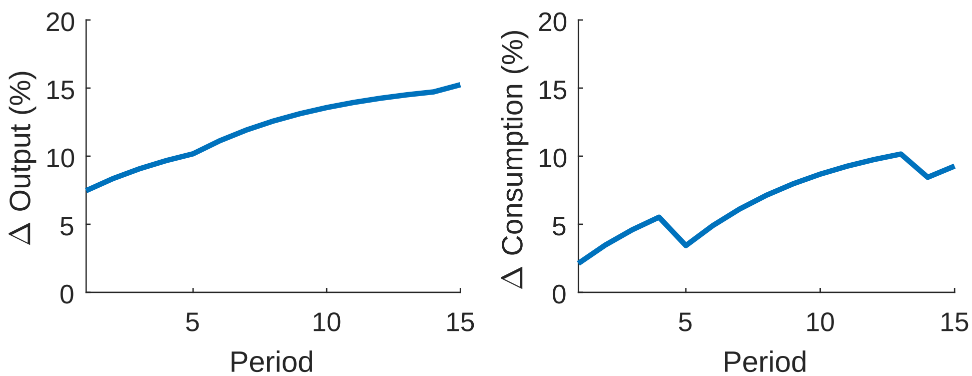

Figure 2: The impact of capital import reform in the benchmark economy

Figure 2 illustrates the first 15 periods of the transition paths for output per effective unit of labor, y_t and consumption per effective unit of labor, c_t expressed in percentage changes relative to the level of y^* and c^* respectively, in the hypothetical 1991 steady state discussed above. Output per effective unit of labor rises steadily with barely perceptible kinks around the shifts in policy rules. In contrast to this steady climb, c_t displays sharp kinks around shifts in policy rules but nonetheless rises relative to the 1991 steady state value. By 2006, y_t is 15.2 percent above and c_t is 9.3 percent respectively above the hypothetical steady state values but are quite far from reaching the 2006 steady state which takes over 60 periods to reach. Adding up the extra consumption in these periods, we find that the economy generates an additional 101 percent of steady state c^* over these 15 years. Similarly, over the 15 years, the economy produces an extra 180 percent of 1991 steady state output per effective unit of labor, y^*. Since output grows faster on the transition path than in the steady state (where all growth comes from exogenous sources) we can use the average growth rate of y_t during these 15 transition years to calculate the contribution of the reform to the observed increase in Indian GDP growth rate in the transition period. We find that y_t grows at 0.49 percent per annum on average in this period, which suggests that liberalization of capital goods imports may have, on its own, contributed one-fifth of the observed 2.2 percent rise in the growth rate of GDP per worker in India. This is interesting in light of the results in Bosworth and Collins (2008) that capital accumulation contributed 39 percent of the 4.6 percent growth in GDP per worker seen during the reform period in India.

4.3 Sensitivity analysis

In this section we use a constant elasticity of substitution specification instead of a Cobb-Douglas specification for the investment good production technology. Table 4 shows the change in the relative price of investment induced by the calibrated model in both the pre-reform period and during the period of reform for different values of the CES parameter σ, expressed in elasticity of substitution. As σ is varied, we recalibrate the model to maintain the capital import to consumption ratio at the 1981 value for India which is 0.03. It shows that as the elasticity of substitution between domestic final goods and foreign capital increases, the responsiveness of the relative price of investment in the model decreases in both periods. The intuition is evident - if the investment goods producer can readily substitute foreign capital goods with domestic final goods, the impact of a rise in the price of imported capital can be mitigated. Given that the vast majority of capital goods are produced in just 10 nations (Mutreja, Ravikumar and Sposi, 2016), these substitution possibilities are likely to be quite limited in practice. As a result we view the benchmark Cobb-Douglas results, reproduced here, on the conservative end of the ability of our model to account for the relative price of investment movements in India.

Table 4: Sensitivity analysis: Change in q (%)

	Data	Model		
		CES (Elasticity)		Cobb-Douglas
		0.80	1.33	
Before reform	44%	28%	16%	23%
During reform	-24%	-32%	-24%	-28%

5 Conclusion

In this paper, we construct a small open economy model where the government uses tariff and non-tariff barriers to limit the import of foreign capital goods. We calibrate the model to India using data from the Penn World Table and use it to account for the dramatic rise and fall of Indian relative price of investment. Our benchmark calibration implies that the model can generate a 23 percent rise in the relative price of investment between 1981 and 1991 due to increasing distortions created by quantitative restrictions on capital goods imports in the face of a growing economy. The model also accounts for a 28 percent fall in the relative price of investment over the subsequent 15 years as tariff rates fell from 72.7 percent to 7.6 percent and quantity restrictions were removed. The model allows us to separate the impact of tariff rate reductions from the impact of the implicit distortions to investment created by quantity restrictions on capital goods imports. We uncover a considerable general equilibrium impact of these price changes on output and consumption per worker and show that the Indian government's import substitution policies exerted a significant drag on the economy prior to reform. Moreover the removal of capital import restrictions and reduction of tariff rates accounts for one fifth of the observed increase in GDP per worker in India between 1991 and 2006.

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A Appendix

A.1 Algorithm for calculating the transition to the 2006 steady state

We use value function iteration - endogenous grid points method (VFI-EGM) proposed by Carroll (2006) to solve the model. The recursive version of the problem is:

$$V(k) = \max_{c,\, k'} \log c + \beta V(k')$$

subject to the household's budget constraint, capital accumulation, all firms' first order conditions, and market clearing conditions. The following steps are used to solve the model and obtain transition to the 2006 steady state:

1. find policy rule corresponding to $\theta = 0.52$ using the following steps:

    - $p^m = p^w(1+\theta)$; p^w is normalized to 1,
    - calculate steady state, obtain k_{ss}, V_{ss}
    - create a fixed grid for $k' = [k'_{min}, k'_{max}] = [0.25 \times k_{ss}, 1.5 \times k_{ss}]$, where size of k' is $[100 \times 1]$
    - guess $\frac{\partial V(k')}{\partial k'} = V^k_{ss}$,
    - calculate q using

    $$q = \frac{1}{\eta}\left(\frac{\eta p^m}{1-\eta}\right)^{1-\eta}$$

    - calculate $\frac{d}{m}$ using

    $$\frac{d}{m} = \frac{\eta}{1-\eta}p^m$$

    - use the Newton method to solve for optimal k (i.e., k^{opt}) in following:

    $$k^\alpha - \left(\frac{\beta}{\gamma_l\gamma_z q}E\frac{\partial V(k')}{\partial k'}\right)^{-1} - \left(\frac{d}{m}+p^w\right)\left(\frac{d}{m}\right)^{-\eta}(\gamma_l\gamma_z k' - (1-\delta)k) = 0$$

    - calculate current period consumption, c^{opt} using

    $$c^{opt} = \left(\frac{\beta}{\gamma_l\gamma_z q}E\frac{\partial V(k')}{\partial k'}\right)^{-1}$$

- get $\frac{\partial V(k^{opt})}{\partial k^{opt}}$ using envelop condition

$$\frac{\partial V(k^{opt})}{\partial k^{opt}} = \frac{1}{c^{opt}}(\alpha k^{opt(\alpha-1)} + q(1-\delta))$$

- interpolate k' to $\frac{\partial V(k')}{\partial k'}$ using the relationship between k^{opt} to $\frac{\partial V(k^{opt})}{\partial k^{opt}}$
- update the guess for $\frac{\partial V(k')}{\partial k'}$
- check convergence of $\frac{\partial V(k')}{\partial k'}$
- the policy rule is $[k', k^{opt}]$.

2. simulate y and c from period 1 to period 4 using k_{1991} as the starting value,
3. calculate the policy rule for using $\theta = 0.23$ following step 1,
4. simulate y and c for next 9 periods, i.e., from period 5 to 13 using the 4th period capital stock as the starting value,
5. calculate the policy rule for using $\theta = 0.076$ by following step 1,
6. simulate y and c next 87 periods using the 13th period capital stock as the starting value.