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

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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 31% fall thereafter. GDP per effective labor was 3% lower in 1991 compared to 1981 due to import restrictions on capital goods. Their removal and a 71 percentage point reduction in tariff rates raised GDP per effective labor permanently by 20%.

JEL: O11; E17; E2
Keywords: Relative price of investment; Policy reform in India

I. Introduction

The behavior of the relative price of investment (RPI) in India stands in fascinating contrast to its well known fall in the developed world in recent decades (Greenwood, Hercowitz and Krusell, 1997).[1] Figure I displays RPI for India and the USA relative to the Penn World Table benchmark world index RPI (Feen-

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[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).

stra, 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 whereas the path of USA RPI shows short term fluctuations around an almost flat trend. Clearly the US displays roughly the same path as the benchmark index for the world while India displays large decade long deviations.

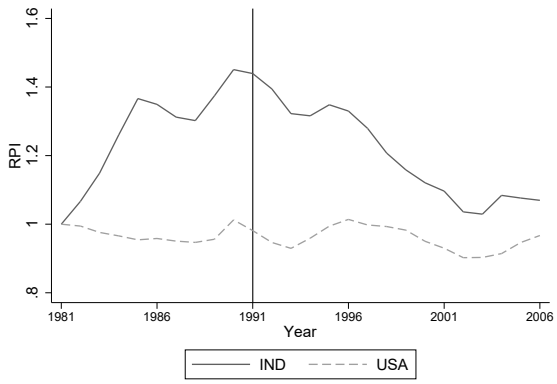

Figure 1. RPI in USA and India from 1981 to 2006

Note: The vertical line denotes the year 1991 when capital import reform begins. Both RPI are normalized to unity in 1981. *Source:* The Penn World Table 9.0.

To contextualize and appreciate 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 RPI 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. Within the historical US context, the RPI data peaks in 1956 which is 33 percent higher than its value in 2006.

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 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 US and other G7 nations (see next section)? 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 USA, 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, 2018). 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 78 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 78 percent to 7 percent by 2006 in a series of steps. Moreover, import licensing was removed from a number of capital good categories that quickly expanded

[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).

such that they became freely importable by 1993.[3]

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.[4] 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.[5] 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.[6] This policy-induced scarcity created a wedge between domestic and world prices of capital good imports, over and above the already high tariff rates. The following quote from the Seventh Five Year Plan, India Planning Commission (1985), section 7.112 illustrates this point. "***The relatively high cost of production of our indigenous machinery as compared to the imported one is due to a variety of factors including***

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

[4]Our model assumes that the price of consumption goods is fixed so all the action must come from the price of investment goods. This assumption is consistent with the price of consumption between 1981 and 1990 which fluctuates around 0.26 over this period but not subsequently. The fall in this price in the reform period contributes to tempering the fall in RPI, a feature our model is unable to capture.

[5]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).

[6]The following quote from the Sixth Five Year Plan (1980 – 1985), India Planning Commission (1981), illustrates the point: "As a result of the policy of import substitution followed in the past and the emphasis on the creation of heavy machine building capacity, a strong base has been established in the country to produce a wide range of heavy and light engineering goods. The bulk of our requirements of equipment for the various sectors of the economy such as power, steel, fertilizers, cement, mining and irrigation are now being met from indigenous sources. The entire requirements of construction machinery, agricultural tractors, diesel engines, pumps, railway rolling stocks and commercial vehicles are being met from domestic production."

the high cost of input raw materials and the cascading effect of duties and taxes." 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. The quote above suggests that policy makers understood that import substitution policies were at least partially responsible for the high cost of investment goods in India even if they did not understand the dynamic effects of this policy.

In order to quantitatively explore the contribution of these import substitution 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 Rupee 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, in real terms, further and further behind demand. During the reform period, this cap is removed so that capital goods can be freely imported 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 its ability to account for both the rise and subsequent fall in the relative price of investment.

In the pre-reform phase, we ask, how much does the relative price of investment increase in the model when we embed three exogenous forces on the economy: the actual growth in productivity, the observed growth in employment and the observed fall in the real exchange rate experienced by India from 1981 to 1991.[7] 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 31 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 3 percent lower in 1991 compared to a decade earlier, purely due to the rising distortion caused by import restrictions on capital goods. In addition, the 71 percentage point reduction in capital import tariff rates and removal of quantity restrictions raised GDP per worker permanently by 20.2 percent. Turning to the transitional dynamics induced by the reduction in capital import tariff rates, they alone account for 18 percent 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. To our knowledge, this is the first paper that provides an endogenous explanation for

[7] 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.

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 induced scarcity of foreign machines. As a result the model has no sectoral differences in productivity trends.[9] 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. Samaniego and Sun (2020) study trends in the relative price of capital across nations and show that cross-country differences in the composition of consumption and capital sectors combined with exogenous trends in investment specific technological progress can account for these facts. We share an interest in exploring the quantitative im-

[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).

[9]Between 1981 and 1991 productivity grew slightly slower in the investment sector than in the consumption sector by 0.1% per year. As such this cannot be the source of the large rise in RPI. Productivity grew faster in investment goods than in consumption goods in the post reform period. The ratio of investment sector TFP to consumption sector TFP was 55% higher in 2006 compared to 1991. In our benchmark model modified to add investment productivity growth, this would by itself, imply a lower RPI in 2006 than in 1991. The model would consequently overshoot the decline in RPI. Clearly other unexplored factors that influence either the price of consumption or investment are at play reducing the observed decline in RPI in India.

plications 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 II looks at RPI in an international context and also explores the underlying Indian data in more detail. Section III presents the model while section IV discusses the data used in the study as well as the calibration of model parameters. Section V presents quantitative results from the benchmark calibration as well as some sensitivity analysis. Section VI discusses the impact of two extensions to the model. Concluding remarks are followed by an appendix that outlines the mapping of our model quantities to the Penn World Table 9.0 (PWT) and the solution methods used in our paper.

II. RPI: international and sectoral comparisons

Since the PWT expresses prices relative to the world benchmark index which is heavily weighted towards G7 nations, it is useful to take a look at the behavior of the RPI over the same period calculated from the national account of each country. Figure 2 shows the path of RPI of all G7 nations where the label RPI-NA refers to the calculation of RPI from national accounts data so that it is not measured relative to the world benchmark. It clearly shows a declining price path as expected. While this figure strongly suggests that the world benchmark index is also declining, it may be useful to express India's RPI relative to a well known observable object, namely the RPI in the US. We obtain this series by dividing India's RPI by USA's RPI, both of which were calculated from the PWT. This series is shown in each panel of Figure 3 which we discuss next.

The dashed lines in Figure 3 display the same dramatic rise and fall in the relative price of investment in India relative to the relative price of investment in the US that characterized Figure I. In order to ascertain if this phenomenon is commonly seen in other developing nations that share similarities to India, we plot the RPI of several nations relative to the RPI of the US. We divide this exploration

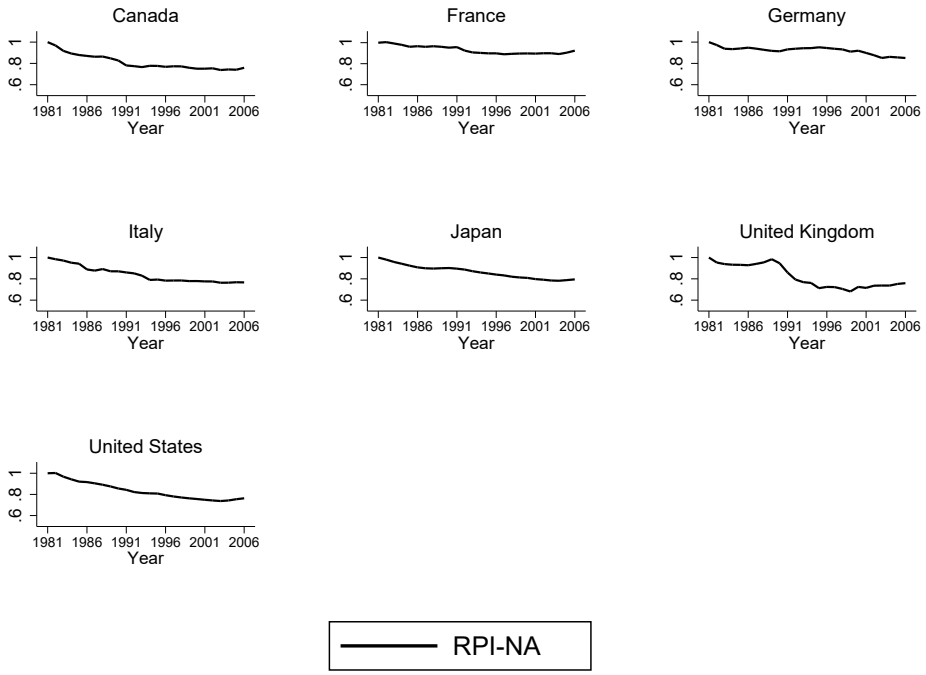

Figure 2. RPI: G7 Nations

into two groups. The first group of four nations have a much larger capital import share than India suggesting that capital import substitution is unlikely to be a dominant policy in those countries. In choosing these nations we made no attempt to be comprehensive. In addition to looking for large capital import shares, we also exclude any major oil producing countries since they readily have access to foreign exchange and rarely follow import substitution policies in order to preserve foreign exchange. Finally, we exclude all Latin American countries that tend to have recurrent debt crises and very high inflation episodes since this is unlike the development path of India. The four nations that we focus on are Israel, Malaysia, Philippines and Taiwan. The capital import share of these nations in 1981 is shown in Table 1 along with India for comparison.

Figure 3 shows the RPI (normalized to USA RPI) of these four nations along

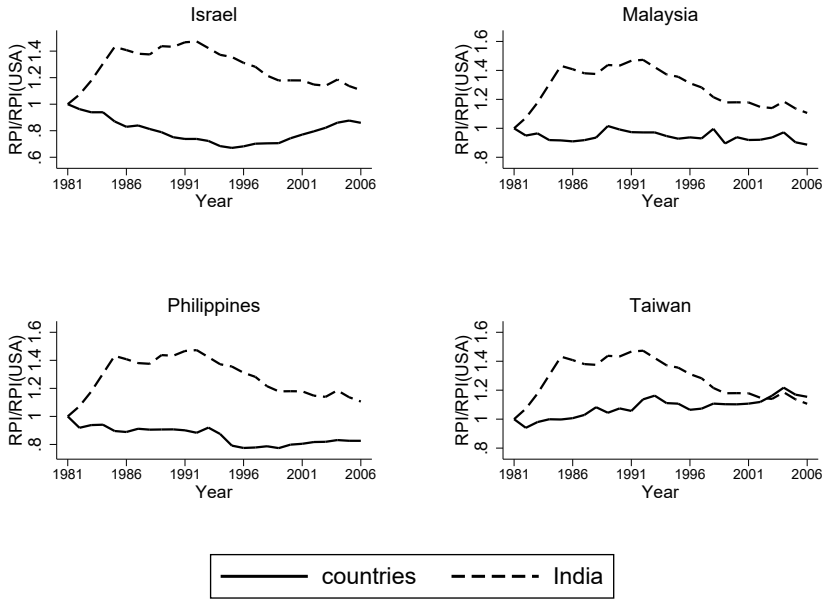

Figure 3. RPI: selected countries vs. India

with the RPI of India for comparison. Clearly the RPI graph of these nations looks very different from that of India. Next, we look at two nations with a history of tinkering with import substitution policies, though, perhaps not at the same scale as India.

Brazil. — The history of trade policy reform in Brazil is a tale of one step forward and two steps back. We provide a short description based on Hudson (1997) which shows that Brazil has historically experimented with import substitution policies but trade reform has also been on the agenda for a long time. In the 1960s Brazil eliminated some existing restrictions on exports and provided special incentives for exporters of manufacturing goods in terms of import restrictions. In the late 1960s imports increased due to tariff reforms however in the 1970s Brazil returned to imposing restrictions on imports due to a high trade deficit at the time. In the mid 1970s, import financing was suspended for many products and tariff rates

Table 1—Capital import shares

Country	Capital import share
India	0.037
Israel	0.247
Malaysia	0.238
Philippines	0.137
Taiwan	0.285

doubled for more than 900 items. Some non-tariff impediments to imports were also imposed. Nonetheless, Brazil ran a trade deficit for most of the 1970s. More relevant for our comparison with India, in the early 1980s import controls were introduced and all foreign exchange transaction were centralized by the Central Bank. A negative list of items was expanded and import financing was restricted. Next, from 1984 to 1986, Brazil reduced direct controls on imports which resulted in a large increase in imports. In late 1986, the government reintroduced an import control policy. Like India, trade reforms occurred in 1991 which resulted in lower average tariff rates from 50% to 40%. Although import licenses were not abolished, the licensing procedure became easier and less time consuming (see http://countrystudies.us/brazil/80.htm).

We conclude that the 1991 Brazilian reforms were similar to India in that it led to reduced import protection but neither the scale of protection nor of the reform was as dramatic as it was in India. The back and forth in import controls likely accounts for the RPI showing an early decline followed by a short lived rise in the half decade leading up to the 1991 reforms. Some direct evidence for the scale difference compared to India can be seen in the following table which shows the simple (weighted) tariff rates just before and during the reform period for capital imports.

In the graph showing RPI for Brazil, the rise in RPI begins in 1986 and the fall is more or less over by 1996 by which time most of the tariff reductions had been completed. Like India, this reform eliminated non-tariff barriers and various

Table 2—Tariff rate on capital good imports in Brazil

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Tariff rate (%)	41.54	33.61	27.98	25.25	18.68	18.64	14.89	14.53	14.08
Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
Tariff rate (%)	16.41	15.59	14.95	10.31	11.79	11.72	11.15	10.33	9.41

export incentives, as well as a significant reform of the institutional structure responsible for foreign trade policy.

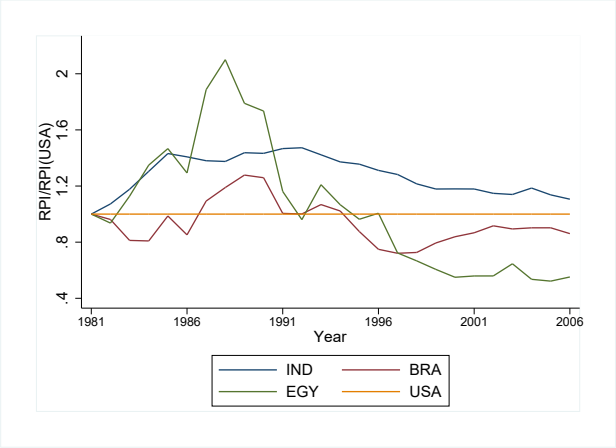

Figure 4. RPI relative to USA from 1981: four nations

Egypt. — Egypt has flirted with trade liberalization for a long time but the desire to control the foreign trade sector has competed with the imperative to liberalize since the nationalization of the Egyptian economy. In the 1960s, most foreign trade transactions occurred through centralized control and was conducted by state owned commercial entities. This began to change in the 1970s. Slowly the number of goods that could be freely imported by the private sector increased, especially since the middle of the 1970s. The advent of the "open-door policy" eased many restrictions on the use of foreign exchange for imports as well. Re-

forms of the tariff structure began at this time and continued in the early part of 1980s, nonetheless, the average tariff rate was quite high in 1986, with an average value of 47.5 percent.

Despite a slow liberalization of the trade sector, Egypt's balance of trade worsened considerably over the 1970s and especially from mid 1980s. A primary driver of this may have been the decline in oil revenue due to the fall in the price of petroleum at the time as well as declining Suez Canal revenue due to a global decline in trade. In response to this, trade policy reversed direction, especially around non-tariff barriers. In addition, to high tariff rates, Egypt employed import bans on a large number of goods. Kheir-El-Din and El-Shawarby (2000) reports that these applied to 548 commodities and more were added in 1987 and as late as 1989. The weakening external condition led to Egypt being one of the most indebted nations in the world in 1989, which culminated in a crisis leading to the introduction of a structural adjustment program by the IMF in 1991. As part of this program, Egypt underwent major reform of the foreign trade sector including a reduction in the average tariff rate as well as a decrease in the dispersion of tariff rates applied to different goods. Between 1991 and 1998 the number of commodities under these bans was reduced to 15, leading to a slow but substantial reduction in import protection. It would appear that the brief hump in the RPI around a generally declining trend may be explained by the rise in trade barriers in response to a deteriorating balance of payments situation in the mid 1980s which was reversed in 1991 by the reform package.

We conclude from this brief look at Brazil and Egypt that our story for India may have resonance for other emerging economies.

A. Digging into the RPI data

Consumption vs. investment price. — So far our explanation for the pre-reform rise in the relative price of investment centres around a rise in the price of investment due to a scarcity of foreign capital goods. It is possible, however,

that the rise in RPI occurs at least partially due to movements in the price of consumption goods. Figure 5 explores this issue by plotting three series: RPI, the price of consumption and the price of investment over the period of interest. We note that all these prices are expressed relative to the corresponding world benchmark indices. The price of investment rises between 1981 and 1991 by roughly the same magnitude as RPI but falls in the reform period much faster than RPI. Movement in the price of consumption influences the path of the relative price of investment primarily after reform. From 1981 to 1990, the non-normalized price of consumption fluctuates around a flat line equal to 0.26 displaying no trend. This fluctuation makes the pre-reform path of RPI less smooth than the path of the price of investment. Since we are not attempting to match short term fluctuations in RPI, our model will keep the price of consumption constant. During the reform period, the behavior of the price of consumption is multi-directional. Initially, it falls, which causes RPI to fall less than the price of investment. This contributes to the model overshooting the fall in RPI. Following a lengthy period without a trend, the price of consumption rises sharply in the mid 2000s. This causes RPI to move more than the price of investment. One limitation of our model results is our choice to ignore this factor in the benchmark model.[10] The impact of exogenous movements in the price of consumption and other factors are explored in the model variant that follows the benchmark model where we match the rise and fall in the RPI exactly (see Figure 9) using both the endogenous and exogenous movements in RPI. The unexplained portion of the movement in RPI in India may also be due to the Balassa-Samuelson effect of changing trade costs explored in Mutreja, Ravikumar and Sposi (2018).

[10]Differences in productivity growth in the consumption versus the investment sector can explain movements in the price of consumption to some extent but these differences in sectoral TFP trends are small in India. Between 1981 and 1991 investment TFP grew slower than consumption TFP by an average of 0.1 percent per year. This implies that over the decade in question, RPI would have been 1.3 percentage points higher than shown by our model if we had taken this difference in trends into account (calculations available from authors). To place this difference in context, the actual rise is 44% and the model delivers 23% over the same decade.

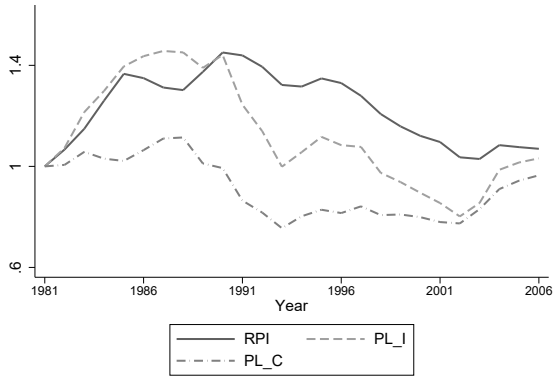

Figure 5. Relative price of investment, price of consumption and price of investment

Equipment and structures. — Since the price of investment is made up of two major component prices, equipment and structures, we disaggregate RPI into the relative price of investment and the relative price of structures. This decomposition will allow us to ascertain if the movement in RPI was primarily driven by changes in equipment prices as opposed to the price of structures which are not traded.

Information on the deflators specific to structures and equipment categories are available from the national accounts part of the PWT. In order to construct the RPI equivalent relative prices for these categories, we divide each by the consumption deflator, also taken from the national accounts. The resulting indexes are further divided by the real exchange rate so that the price of structures and equipment are both expressed relative to foreign consumption in order to be broadly consistent with the way that PWT treats variables (see the accounting section below). Note that the resulting relative price indices of equipment and structures are still quite different from RPI in that they are not constructed as a double relative price (i.e., relative to a world benchmark) so they will behave differently from aggregate RPI. The specific formula used is:

$$RPI\_\text{Machine} = \frac{\frac{Ip\_\text{Mach}}{pl\_c\_na}}{REER},$$

where $pl\_c\_na = \frac{v\_c}{q\_c}$ and v_c refers to household consumption at current national prices and the variable q_c refers to household consumption at constant national 2011 prices. Ip_Mach refers to the investment price index for machinery and non-transport equipment (2011=1). In addition, $REER$ refers to real effective exchange rate (Darvas, 2012). We proceed similarly for the transport equipment index in order to obtain two measures of RPI which are shown in Figure 6.[11] Clearly both measures show a similar rise and fall pattern that was displayed by overall RPI. From 1981 to 1991 the RPI of machines rose 70 percent while that of transport equipment rose 75 percent. Moreover, between 1991 and 2006 the relative price of machine fell by 30%. By contrast, the relative price of structures rose by 130% between 1981 and 1991 and rose again by 13% from 1991 to 2006.[12]

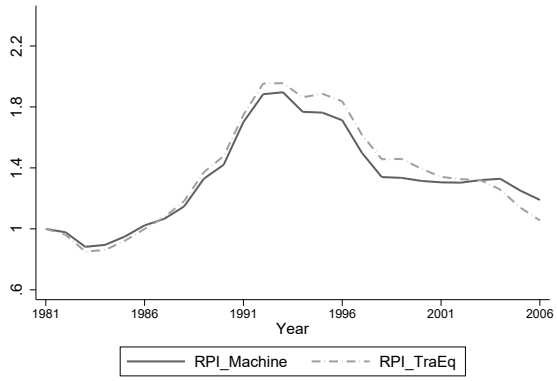

Figure 6. The relative price of machines and of transport equipment in India

[11] $RPI\_\text{TraEq} = \frac{\frac{Ip\_\text{TraEq}}{pl\_c\_na}}{REER}$, where Ip_TraEq refers to the investment price index for transport equipment (2011=1).

[12] $RPI\_\text{Struc} = \frac{\frac{Ip\_\text{Struc}}{pl\_c\_na}}{REER}$, where Ip_Struc refers to the investment price index for residential and non-residential structures (2011=1).

The price of structures displays a rising trend over both the pre-reform and reform period. Our model is not built to account for this as it treats all domestic investment goods as identical. From the lens of the model, both domestic equipment and domestic structures use foreign equipment in the same proportion. Equally, a rise in the domestic price of foreign equipment raises the price of both equipment and structures in equal measure. As such, it cannot separately explain the rising underlying trend in the relative price of structures. It is likely that structure-specific distortions in the Indian context are responsible for the long term rising trend in the price of structures but we think that idea is best explored in a separate paper. What is clear is that the basic stylized fact of the paper survives the exclusion of structures from the RPI calculation so that it may be thought of as describing the unusual path of the relative price of equipment.

III. 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. A detailed mapping of model quantities to PWT series is provided in the Appendix.

A. 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.[13]

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, Π^Y, the investment good producer, Π^I, the importer, Π^{imp}, 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

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

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:

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

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

B. 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.

C. 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).[14] The firm buys M_t from the importer at price p_t^m, and sells the produced investment good, I_t to the household at price q_t. The investment good producer chooses D_t and M_t to maximize its profits given by

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

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 [15]. We also get the following

[14] Robustness analysis is conducted with constant elasticity of substitution technology, see section V.D.

[15] Strictly speaking, the government in the model is substituting foreign capital goods with domestic final goods. The idea of using final goods here is a shorthand to save adding another sector called domestic capital goods. This is similar to a one good model where domestic final goods can be either consumed or invested in physical capital.

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.

D. *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 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 expressed in terms of domestic consumption goods, $\overline{LIC}$. 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. Thinking in terms of foreign capital goods, we can use India's real effective exchange rate, $REER_t$ to convert the domestic consumption equivalent limit into foreign capital goods. As a result, the importing firm is restricted to importing no more than $\bar{M}_t = \overline{LIC} \times REER_t$ units of capital goods into the country in the pre-reform period. In contrast, there is no constraint on the importer after reforms begin so the path of the real exchange rate becomes irrelevant to import policies. In India, import licenses were often expressed in nominal Rupee terms. This meant that periods of rapid depreciation of the Rupee inadvertently made the capital import limit even tighter in physical units of imported capital. Our assumption that $\overline{LIC}$ is constant is equivalent to the assumption that in nominal terms, the

Rupee limit on licenses was being increased at the same rate as inflation.[16] We discuss the calibration of the path of $\bar{M}_t$ in more detail later.[17]

E. 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

[16] We thank the referee for suggesting that we keep the import limit constant in the pre-reform period and use the path of the real exchange rate to calibrate the model.

[17] While India's Five Year Plans provide no conclusive evidence that licenses were issued in Rupee terms, court documents where petitioners laid out the terms of their licenses provide illustrative examples. Licenses were issued by the Chief Controller of Imports and Exports (a subdivision of the Ministry of Commerce) using public notices. Our first case involves public notice 117-ITC (PN)/66. The case involves a license issued for the import of "spare parts for refrigeration and air conditioning machinery other than domestic refrigerators". A license for Rs. 25,000 was issued to the petitioner. By the time the goods arrived in India, the value of the order had increased by Rs. 426 and the goods were confiscated on these grounds by customs agents. We note that the license was expressed in Rupee terms with no mention of the quantity of goods to be purchased and was strictly enforced in nominal terms as well. This can be understood in light of an official obsession with foreign exchange reserves. In our second case, the appellant was issued an import license to import silk yarn worth Rs. 327,841. In both cases, the licenses were for a one time permission to import a specific good with no guarantee of future licenses. These cases were found online from casemine.com. We include links to these two judgments which can be found at `https://www.casemine.com/judgement/in/5608e9bce4b01497111146e7` and `https://www.casemine.com/judgement/in/5609ab50e4b014971140c311`.

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.

All international trade in the economy takes place through the importer who pays for foreign capital goods with the domestic consumption good. The economy maintains balanced trade in all periods.

F. 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 (A2) 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, $C_t + D_t = Y_t$, 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 also constant if the tariff rate is left unchanged, 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 and adjusts to changes in the real exchange rate, 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 $\frac{D_t}{\bar{M}_t}$ falls over time as is clear from (11). In addition the rise in q_t causes the household to save less, lowering the capital stock below the balance growth path levels. Our solution method, discussed in section V.A, provides a terminal period for this scenario after which the economy returns to a balanced growth path.

IV. 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.

A. Data

The PWT 9.0 (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').[18] 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 deflator. To remove these prices, we construct the ratio of capital imports to consumption using:

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

- 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'). [19] To calculate the consumption-output ratio, we use share of gross capital formation at current PPPs ('csh_i'), share of merchandise

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

[19] $Z = \left(\frac{rgdpna/emp}{(rkna/emp)^{1/3}}\right)^{(1/(1-1/3))}$

exports at current PPPs ('csh_x') and share of merchandise imports at current PPPs ('csh_m').[20] To calculate the capital-output ratio, we use capital stock at current PPPs ('ck') and real GDP at current PPPs ('cgdpe').

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)[21] [22] This series is available from 1990. Zsolt (2012) provides annual REER data for 67 countries from 1960 to 2016. [23]

B. Parameters

Our model is calibrated to match several features of the Indian economy in 1981 which is the starting year of our analysis. 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. In solving the model, all growing variables are divided 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. We set the gross growth rate of the labor input, $\gamma_l = 1.036$ to match the annualized growth rate of the employed population in India between 1981 and 1991. We also set the gross growth rate of productivity, $\gamma_z = 1.0214$ to match the observed growth in the labor augmenting productivity for India during the same period.[24] 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 in 1981 to unity.

As discussed earlier, licenses were issued in nominal rupee terms. We assume that the real domestic consumption value of these licenses were fixed over the pre-reform simulation period, rising with inflation. Since the period of 1981 to

[20] $\frac{c}{y} = (1 - \text{csh\_i} - \text{csh\_x} - \text{csh\_m})$.

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

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

[23] The real effective exchange rate (REER) measures the development of the real value of a country's currency against the basket of the trading partners of the country. Zsolt (2012) used data on exchange rates and consumer price indices and the weighting matrix derived by Bayoumi, Lee and Jayanthi (2006) to calculate consumer price index-based REER. The dataset is available at `https://bruegel.org/2012/03/real-effective-exchange-rates-for-178-countries-a-new-database/`.

[24] $\gamma_z = \left(\frac{Z^{1991}}{Z^{1981}}\right)^{1/10} - 1$.

1991 was a time of rapid fall in the real exchange rate (see Figure IV.B), this implies that the foreign consumption value of imported machines was falling over this period as captured by $\bar{M}_t = \overline{LIC} \times RER_t$. The REER declined 44% from 1981 to 1991 (Darvas, 2012)[25]. As a result, in de-trended terms, the import quota, $\bar{m}_t = \frac{\bar{M}_t}{\gamma_l \times \gamma_z}$, declines due to three exogenous sources: employment growth, productivity growth and real exchange rate decline[26].

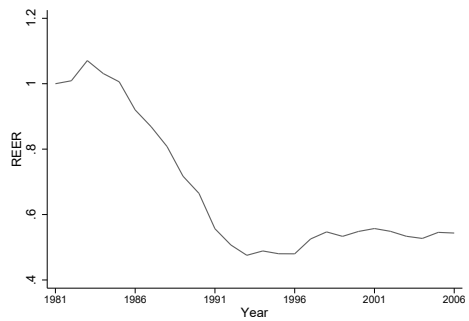

Figure 7. Real effective exchange rate in India

Source: Darvas (2012).

Since our model simulations have an arbitrary start date (1981), we map our model simulations to the Indian data by picking the state vector values in 1981 to match observations in Indian data in 1981. The benchmark model has two elements in the state vector in the initial period, $\bar{m}_{1981}$ and k_{1981} in the pre-reform period. As a result we calibrate these two parameters and the capital import share parameter, η jointly in 1981 using three targets taken from Indian data in 1981 which are the capital to output ratio, the capital import to consumption ratio and the consumption to output ratio.[27] These parameters values are provided in

[25]REER is calculated using weights from all imported goods not just imported capital goods. It is unclear if this overstates or understates the decline.

[26]The current calibration strategy for dealing with the unobserved import quota has limitations in that it relies too much on a large decline in REER. An alternative calibration where the path of the quota was picked to deliver the observed decline in capital imports to consumption over the pre-reform period gives similar results. Indeed there is evidence of limited capital import reforms in the 1980s.

[27]In a previous version of this paper Johri and Rahman (2017), we employed a different calibration

Table 3 along with the target values in 1981. Table 3 also provides a summary of the chosen values of other parameters.

Table 3—Parameters

Parameter	Value	Source
β	0.96	Literature
α	0.33	Literature
δ	0.044	Data
γ_l	1.036	Data
γ_z	1.0214	Data
growth REER	-0.0569	Data
Calibrated Parameters	Value	Target
η	0.78	$\frac{qK}{Y} = 2.5$
K_0	1.345	$\frac{M}{C} = 0.033$
$\bar{M}$	0.029	$\frac{C}{Y} = 0.79$

The value of the depreciation rate, δ, in the capital accumulation equation is 0.044, which is obtained from the average of the annual reported value in the PWT between 1981 and 1991. 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.

The pre-reform tariff rate, θ_t, on imported capital goods is set to 0.78. We use weighted average tariff rates on capital imports from 1991 until 2006, when θ_t falls to 0.07. Since these tariff rates are not available for every year, we assume that the rate was held constant at the last known rate during the periods when data is unavailable. We provide the actual measure of the weighted tariff rate by

strategy with very similar results. The economy was assumed to be in steady state in the first period. In order to discipline the path of $\bar{M}_t$ beyond the initial period we used the ratio of capital imports to consumption obtained from the PWT in 1991 which had a value of 0.014. In the model economy this ratio declined due to labor productivity growth, employment growth and an exogenous change in $\bar{M}_t$. The third factor, was chosen so that the growth rate of $\bar{M}_t$ between 1981 and 1991 was such that the ratio of capital imports to consumption was exactly equal to the data value in 1991 and 1981.

Table 4—Tariff rates on capital imports in India

Year	1990	1992	1996	1997	1999	2000
Tariff rate(%)	78.45	51.85	29.8	21.52	24.53	21.79
Year	2001	2002	2003	2004	2005	2006
Tariff rate(%)	21.85	20.92	19.95	20.88	9.34	6.94

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

year in Table 4. 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.

V. Results

A. *Before reform*

In this section, our goal is to get a quantitative sense of the ability of the calibrated benchmark 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 and other macroeconomic quantities such as the ratios of consumption and investment to output and the ratio of imported capital to consumption which can then be compared to observed values in the Indian data. We begin by assuming that the economy is at an arbitrary state vector in 1981 as explained in the last section.

Since $\frac{\bar{M}_t}{Z_t L_t}$ shrinks every period after 1981, the detrended economy is not in a steady state. To solve the model we assume that agents expect the current policy on capital imports to remain in place (including the tariff rate) for 100 years. In other words, the detrended import limit is expected to keep shrinking for 100

years after which the government adjusts the import limit to keep pace with productivity, employment growth and the real exchange rate changes forever.[28] We compute the transition of the economy from 1981 to 1991 along the perfect foresight path 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 exogenous variables.

Compared to 1981, the simulated domestic price of foreign capital goods, p_t^m, is 158 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 23 percent rise in the relative price of investment over this period. Moreover, annual output per effective unit of labor, y_t, falls on the transition path and is 3 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 and the fall in the real exchange rate, the model would have remained at the 1981 capital output ratio 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

[28] 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.

would have been constant. The first column of Table 5 reports the change in the relative price of investment over the pre-reform period and compares them to the data.

Table 5—Change in q (%)

	Before reform	During reform
Data	44%	-26%
Model	23%	-31%

B. *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. From the pre-reform model we obtain the detrended capital stock chosen in 1991 since after the removal of the import limit, there is only one state variable to keep track of in the model. In addition to the removal of non-tariff barriers, the Indian government reduced tariff rates on capital goods from 78 percent in 1990 to 7 percent in 2006 (see Table 4). 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 seen in 2006.

Transition to the low tariff steady state. — In order to characterize the transition of the economy due to the policy changes outlined above, we calculate the transition path taking as given the 1992 capital stock, k_{1992}, obtained from the pre-reform transition. In addition, we assume that tariff rates follow the path shown in Table 4 while assuming that the rate was constant in between the steps.

We also assume that this policy was fully anticipated by agents in the economy.[29] Overall, between 1991 and 2006, the removal of the capital import limit and the subsequent tariff rate reductions lead to a 31 percent fall in the relative price of investment.

Figure 8 plots the entire transition of the benchmark model economy from 1981 to 2006. The transition path of RPI jumps from 1991 to 1992 as a result of the removal of the capital import limit which causes a drop in the domestic price of foreign capital goods, which, in turn, translates into a drop in the relative price of investment. The figure shows that the benchmark model approximates the medium term trends of key ratios, $\frac{c}{y}$, $\frac{qi}{y}$ and $\frac{m}{c}$, in the data, despite not fully accounting for the rise in Indian RPI.[30] In order to get a better sense of the ability of the model to capture the path of these ratios, later we add an exogenous component to q_t so that the rise and fall of the relative price of investment is exactly matched before and after reform.

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 0.4 percent per annum on average in this period, which suggests that liberalization of capital goods imports may have, on its own, contributed 18 percent 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.

[29] As observed in Table 4, tariff rate reductions occurred in a series of steps of unequal sizes. In a previous version of the paper, we compute the transition path during the reform period by assuming that tariff rates were reduced in three steps. Details can be found in Johri and Rahman (2017). In addition, the role of unexpected tariff jumps was explored there. None of those changes have a material impact on our results so we use a simpler perfect foresight solution algorithm here.

[30] The biggest discrepancy between the model predictions and the data is in the investment rate being too high. The decline in the pre-reform period mirrors that seen in the data but the model is unable to deliver the pick up in the later part of the study period. See also the corresponding figure when RPI is smooth pasted to match the path of the data below.

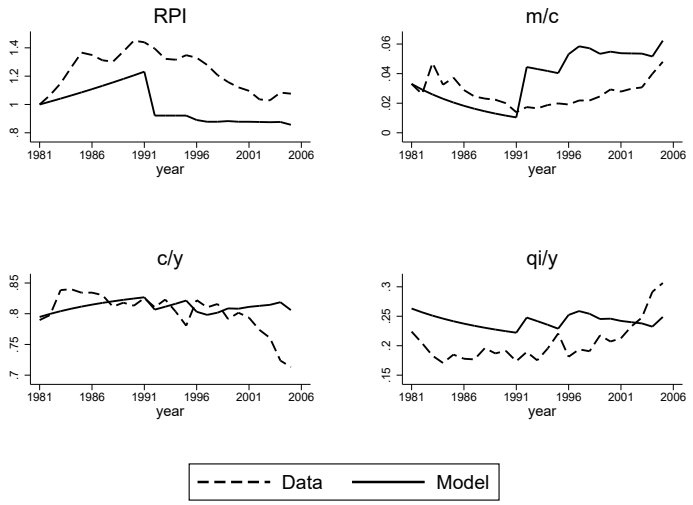

Figure 8. Model performance

In order to separate the contribution of the removal of quantity restrictions from the contribution of tariff rate reductions to the economy, we calculate a hypothetical steady state for 1991 and compare this to the low tariff steady state towards which the economy is transitioning. To obtain the "1991 steady state", we hold p^m fixed at its pre-reform 1991 value. This hypothetical steady state corresponds to a situation where 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 after adjusting for the impact of real exchange rate changes.

Having calculated key variables (y^*_{1991}, c^*_{1991}) in the "1991 steady state", we can compare their values to two other steady states, one in which the quantity restriction is removed but the tariff rate remains at 78 percent and another in which they are further reduced to the 2006 value of 7.6 percent. We will refer to the former hypothetical steady state as the "high tariff steady state" and the latter as the "low tariff steady state". We can then calculate the total change in y and c by comparing the "1991 steady state" to the "low tariff steady state"

and also the pure contribution of tariff rate reductions by comparing the "high tariff steady state" to the "low tariff 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 30.7 percent. Out of this total fall, the tariff rate reduction alone accounts for 11 percent while 22.5 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 "low tariff steady state", $y*$ is 20.2 percent higher than y^*_{1991}. The pure contribution of the tariff rate reduction to this large rise in output per effective unit of labor is 5.8 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 20.2 percent compared to the "1991 steady state".

C. Smooth pasting RPI

The benchmark model is unable to fully capture the observed rise in RPI in India. In this subsection, we introduce an exogenous source of rise and fall in RPI in order to fully match the rise and fall seen in the data so that we can assess how well the rest of the benchmark model does in explaining medium trends in other main macroeconomic quantities.[31] This is accomplished through the variable ε_t which is added to endogenously generated RPI. ε_t encapsulates all the other dynamic distortions missing from our model. For example, our model holds the price of consumption fixed. To the extent that variations in this price cause part of the rise and fall in RPI, our benchmark model would not capture this. Thus,

$$q_t = q_t^{\text{inv}}(1 + \varepsilon_t), \tag{14}$$

[31] We thank our referee for suggesting this exercise.

where q_t refers to the price paid by the household for investment goods while q_t^{inv}

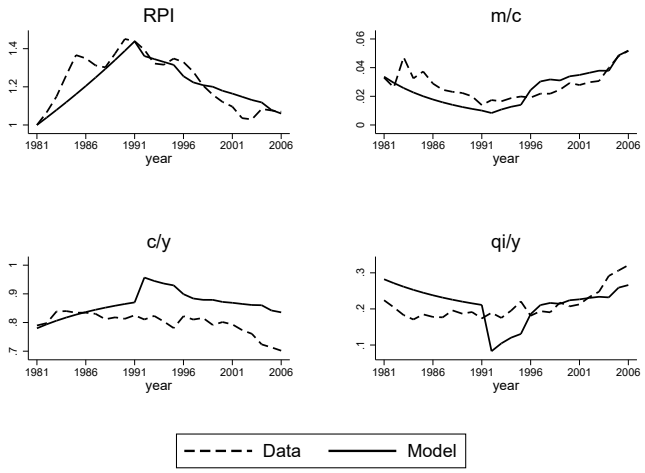

Figure 9. Model with exogenous change in q

refers to the price charged by the investment good producer. The difference in the two prices can be viewed as a tax or subsidy that is fully returned to the household as a lump sum transfer, thus leaving the resource constraint of the economy unchanged. It's sole purpose, then, will be to distort the investment/saving decision of the household, leaving the rest of the benchmark model unchanged. The results of this exercise are displayed in Figure 9.[32] The first panel shows that the rise and fall of q_t is fully matched to the data. Compared to the benchmark model, m/c in Figure 9 no longer rise above the data in the reform period and is quite close to its 2006 observed value. The over all path of investment share is also improved but this comes at the expense of the path of the consumption share (see lower panels in Figure 9). We note that the model does a pretty good job of capturing the broad rise and fall of these variables over a span of two and a half decades. The larger rise in RPI in the pre-reform period compared to the

[32]The model is recalibrated to ensure that the initial point of the system in 1981 is matched to the data as was done for the benchmark model.

benchmark model leads to a bigger decline in output per effective units of labor which falls by 5 percent between 1981 and 1991 compared to 3 percent in the benchmark model.

D. *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 6 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 as elasticities of substitution. As σ is varied, we recalibrate the model to maintain the initial point of the system near the targets as discussed earlier. 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, 2018), 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.

Our ideas regarding the possibilities of substitution between imported capital goods and domestic goods is also influenced by the India specific factors. First, prior to reform, the default policy in place in India was to simply deny any requests to import classes of goods that were already in production in India, with little attention to quality. The import substitution policy was founded on a desire to save foreign exchange as well as a more abstract desire to be "self-sufficient". This is apparent from even a cursory reading of Indian planning documents.

The previously discussed quotes from policy documents help to contextualize these statements. In practice, the policies were gradually weakened as political consensus developed so that it became easier to argue in favor of being allowed to import a specific type of industrial input or machine, even if similar items were produced locally and eventually, the constraint was removed entirely. Our use of a Cobb Douglas function is an attempt to find an elasticity that makes sense in the pre-reform period as well as the reform period.

Evidence regarding the empirical relevance of this attempt to balance out the two periods without losing quantitative discipline (we did not want to use different elasticities in the two periods) can be found using the following simple but imperfect metric. Using our first order condition for the investment good producer in the benchmark model, we can calculate the following average elasticity of the share of imports used in investment, $\frac{M}{I}$ w.r.t the relative price of investment, q, between 1981 and 2006. In the data this elasticity is equal to 2.9, whereas in the calibrated version of the benchmark model this elasticity is given by $\frac{(\frac{\hat{M}}{I})}{\hat{q}} = \frac{\eta}{1-\eta} = 3.55$, where hatted variables refer to percent changes of that variable. We note that this moment is not targeted in our calibration strategy so we view this as suggestive that the elasticity is in the right ballpark.

Table 6—Sensitivity analysis: Change in q (%)

	Data	Model		
		CES (Elasticity)		Cobb-Douglas
		0.80	1.33	
Before reform	44%	37%	13%	23%
During reform	-24%	-46%	-19%	-31%

VI. Model Extensions

In this section, we extend our benchmark model by incorporating two important features into the benchmark model. The first extension allows the accumulation of imported capital by the investment good producer, while the second introduces

trade in international bonds into the benchmark model.

A. Accumulation of foreign capital

Up to this point all foreign capital goods are fully used up in the creation of domestic investment goods. This is quite unrealistic since several capital good categories that we use have a durable component. In this sub section we ask if our results are sensitive to the introduction of an accumulation equation for foreign capital goods by the domestic economy. [33]

The modification is a straightforward extension of the investment good producer problem. The rest of the economy follows from the benchmark model already described above. First, we modify the technology for producing the local investment good to use the accumulated stock of foreign capital which will be referred to as K_t^m instead of current period imports, M_t. The production function may be written as

$$I_t = D_t^{\tau} K_t^{m\,1-\tau}, \tag{15}$$

where D_t refers to domestic final goods as before. Second, we need an accumulation equation for imported capital which is given by

$$K_{t+1}^m = (1-\delta_m)K_t^m + M_t, \tag{16}$$

where M_t refers to units of the imported capital good purchased, and δ_m to the average depreciation rate of this capital stock.

The introduction of equation (16) into the model creates a free parameter, δ_m, which needs to be calibrated. We impose discipline on this parameter choice by calculating the amount of imported capital goods falling into the category of capital goods and the category of transport equipment as a proportion of

[33] We thank a referee for encouraging us to explore this issue.

all four categories of imported capital goods in the PWT. Looking over the pre-reform and post 1991 period together, the proportion of these categories imported into India rises substantially starting from a very small number in 1980. The movement in the number is especially large from 1992 to 2006 once import limits are removed. We respond to this changing value by taking the average over the entire time period, which yields a value of 33 percent. The depreciation rate for capital goods and transportation equipment is set to the value of 14% which was obtained from PWT and is also very similar to the values observed in national accounts. The depreciation rates for the other two categories was set to 100% since these categories include fuels and lubricants and industrial supplies. The final value for δ_m is calculated as a weighted average of the depreciation rate for capital goods and transportation equipment and for other two categories as follows: $\delta_m = 0.33 \times 0.14 + 0.67 \times 1$. Clearly this number over-represents the low depreciation rate categories for the initial half of the sample, but at least this allows us to calibrate the depreciation parameter to a number meaningfully lower than unity which was the value used in the benchmark model.

The investment good producer's maximization problem is now dynamic. He maximizes lifetime discounted profit using the household's endogenous discount factor with the following period profit function

$$\Pi_t^{\mathrm{I}} = q_t D_t^{\tau} K_t^{m\,1-\tau} - D_t - p_t^m M_t, \tag{17}$$

subject to the accumulation equation (16). The new first order condition (for K_{t+1}^m) is

$$p_t^m \frac{1}{C_t} = \beta \frac{1}{C_{t+1}} \left((1-\tau) q_{t+1} D_{t+1}^{\tau} {K_{t+1}^m}^{-\tau} + p_{t+1}^m (1-\delta_m) \right). \tag{18}$$

In addition to the change implied directly by less than 100 percent depreciation of the foreign capital good stock, the new equation captures the forward looking

behavior of the investment good producer who now will care about the rising path of p^m in the pre-reform period while choosing how much to produce. An implication of this is that we lose the simple characterization of the relative price of investment in equations (11) and (12) in the benchmark model as a function of the ratio of domestic goods, D_t to imported capital goods, M_t.

Given the changes to the model, especially the new first order condition that determines q, we recalibrate the model parameters to the targets discussed earlier. The calibrated model delivers a rise in RPI, q_t, of 23% in the pre-reform period and a decrease of 30% during the reform period which is quite similar to the results of the benchmark model. Figure 10 shows the path of model generated variables and data. The presence of two capital stocks introduces an additional margin for adjustment which makes the transition of the economy less smooth.[34]

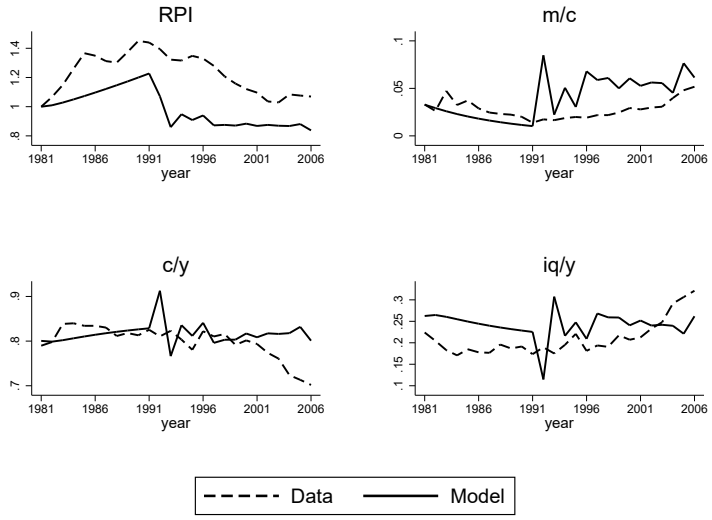

Figure 10. Model with accumulation of imported capital

[34]The addition of a small adjustment cost can return the model dynamics to a smooth path. These results are available from the authors.

B. International bond

In this subsection we address the impact of allowing intertemporal claims to be traded by the household.[35] The budget constraint of the household in the old benchmark model is given by

$$C_t + q_t I_t = w_t L_t + r_t K_t + \Pi_t^{\mathrm{Y}} + \Pi_t^{\mathrm{I}} + \Pi_t^{\mathrm{imp}} + T_t. \tag{19}$$

To incorporate international claims, we modify the household's budget constraint as follows:

$$\begin{aligned} C_t + q_t I_t + B_t(1 + r_t^b) =& B_{t+1} - \frac{\psi}{2}\Big(\frac{B_{t+1}}{B_t} - \gamma\Big)^2 B_t + w_t L_t + r_t K_t \\ &+ \Pi_t^{\mathrm{Y}} + \Pi_t^{\mathrm{I}} + \Pi_t^{\mathrm{imp}} + T_t, \end{aligned} \tag{20}$$

where B_t refers to one period international debt issued by the economy, and r^b refers to the interest rate on foreign borrowing which the small open economy takes as given. The term $\frac{\psi}{2}\big(\frac{B_{t+1}}{B_t} - \gamma\big)^2 B_t$ describes an adjustment cost term which is needed to solve the usual unit root problem when a small open economy must borrow at a given interest rate.

Since steady state debt is not pinned down within the model we need to calibrate it. We impose quantitative discipline on this by matching the debt to GDP ratio in the initial period (1981) to its value in the data, namely 0.12 (World Bank, 1991). The adjustment cost term ψ has no impact on the results given above (recall RPI is a function of the tariff rate in the reform period). Variation in the value mainly influences how quickly the amount of debt adjusts from the initial value to the steady state value. Our simulations assume that after the 1991 reform, the economy will eventually reach steady state. We set the value of debt in this steady state such that the transition path in 2006 passes through the

[35] We thank a referee for encouraging us to explore this issue.

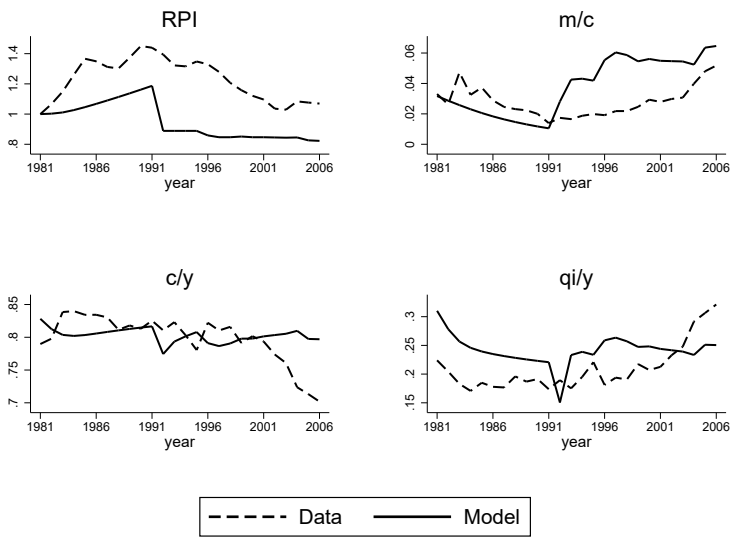

Figure 11. Model with international bonds

observed Debt to GDP ratio of 17%, obtained from (Reserve Bank of India, 2019). We find that the presence of international claims has a small impact relative to our benchmark model results. We find that RPI rises by 19% in pre-reform period and decreases by 31% during the reform period. Figure 11 shows compares the data to model generated variables. The change in output per effective unit of labor on the transition path is also similar to the benchmark model.

VII. 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 PWT 9.0 and use it to account for the dramatic rise and fall of the relative price of investment in India between 1981 and 2006. 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. The model also accounts for a 31 percent fall in the relative price of investment over the subsequent 15 years as tariff rates fell from 78 percent to 7 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 18 percent of the observed increase in GDP per worker in India between 1991 and 2006.

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Appendix

A1. Mapping the Penn World Table Data to the model

We begin by expressing the household budget constraint in terms of local prices in India, all expressed in terms of the GDP deflator and proceed to construct the PWT equivalent prices. We also discuss the resource constraint.

In the budget constraint we have substituted in the following expressions for the profit of the investment producer, the importer and the final good producer, as well as all tariff revenue earned by the government. Let P_t^C and P_t^I refer to the domestic price of the consumption good and the investment good expressed in terms of the numeraire. Then the profit of the investment producer is

$$\Pi_t^{\mathrm{I}} = P_t^I I_t - P_t^C D_t - P_t^m M_t. \tag{A1}$$

Similarly let the profit of the importer be given by

$$\Pi_t^{\mathrm{imp}} = P_t^m M_t - P_t^C \frac{p^w}{RER_t}(1+\theta_t)M_t, \tag{A2}$$

where P_t^M refers to the domestic price of foreign machines in terms of the numeraire and p^w refers to the world price of machines in terms of the world consumption index. Dividing by the real exchange rate , RER_t converts this price into domestic consumption goods which must then be multiplied by P_t^C in order to express it in terms of the numeraire. Also tariffs must be paid to import these machines. The household budget constraint is given by

$$P_t^C C_t + P_t^I I_t = w_t L_t + r_t K_t + \Pi_t^{\mathrm{Y}} + \Pi_t^{\mathrm{I}} + \Pi_t^{\mathrm{imp}} + T_t, \tag{A3}$$

which may be written as

$$P_t^C C_t + P_t^I I_t = P_t^C Y_t + P_t^I I_t - P_t^C D_t - P_t^m M_t + P_t^m M_t - P_t^C \frac{p^w}{RER_t} M_t, \tag{A4}$$

noting that all tariff revenue is remitted to the household in a lumpsum manner.

The PWT expresses all domestic prices in terms of a world benchmark index. These can be obtained by multiplying all prices by the real exchange rate so that they are expressed in terms of the world index.

$$p_t^C C_t + p_t^I I_t = p_t^C Y_t + p_t^I I_t - p_t^C D_t - p_t^m M_t + p_t^m M_t - p_t^C p^w M_t, \tag{A5}$$

where lower case prices indicate that they are expressed relative to the world index.

Dividing through by p_t^C, we can express all prices relative to consumption giving us

$$C_t + q_t^I I_t = Y_t + q_t^I I_t - D_t - q_t^m M_t + q_t^m M_t - p^w M_t \tag{A6}$$

or

$$C_t + D_t = Y_t - p^w M_t, \tag{A7}$$

which can be transformed into the resource constraint of the economy by realizing that the economy has two kinds of resources, domestic final goods and foreign machines. The final good Y_t is used for consumption, as a domestic input in

the production of investment goods and to buy foreign capital goods. Adding the consumption value of these goods $p^w M_t$ to Y_t gives us the total resources available in the economy. Using equation A7 gives us the expression for the resource constraint:

$$C_t + D_t = Y_t. \tag{A8}$$

We note that all trade in the benchmark model is balanced. Foreign machines flow into the economy and are paid for in final goods. This assumption, while unrealistic, is reasonable since the economy was largely closed with very low import and export shares, especially before reforms.

In the PWT, all the prices are expressed relative to an unobserved world benchmark as discussed above. This raises the question about what role movements in the world benchmark play in the relative price movements seen in India. We have shown earlier that by dividing the PWT RPI in India by the PWT RPI in the USA it is possible to obtain a relative price series from which the world index is eliminated. Since the USA RPI can be observed to be falling over time (shown in Figure 2), we can now interpret all movements in India's RPI relative to movements in the US RPI. The rise an fall before and after reforms is evident here as well.

For the model to data comparisons we prefer to work directly with the PWT data. Note that if there were no trade policy frictions, RPI in India would remain constant relative to RPI in the world benchmark indexes. Thus we treat the world price in the model, p^w as constant and express all movements in the model relative to this price.