The Price of Capital Goods, Investment, and Labor: Micro-Evidence from a Trade Liberalization *

Sergii Meleshchuk † Yannick Timmer‡

Abstract

In this paper, we show that a reduction in capital goods prices induced by trade policies can stimulate both investment and labor. We exploit a quasi-natural experiment in the form of a trade reform in Colombia to study how firms with differential exposure to reductions in capital goods tariffs react in terms of their investment and labor decision. Firms that see a larger decline in the input tariff for capital goods increase investment and labor for production, as well as their labor share. Reductions in input tariffs are passed through to input prices for all goods. However, only lower prices for capital, not for other goods, translate into more investment and employment of production workers.

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†International Monetary Fund. Email: smeleshchuk@imf.org

‡Federal Reserve Board. Email: yannick.timmer@frb.gov

1 Introduction

Economists have long argued that the relative price of capital goods, especially machinery and equipment, is one of the key determinants of economic performance and capital deepening (De Long and Summers, 1991, 1992, 1993; Restuccia and Urrutia, 2001; Jones, 1994). One prominent explanation for why developing countries tend to have higher relative prices of capital goods is due to their low efficiency in producing investment goods instead of differences in trade policy (Hsieh and Klenow, 2007).

In this paper, we provide empirical evidence that a trade reform reducing tariffs on capital goods can lower the price of capital goods and increase both investment and employment. We employ an event-study approach around a 2011 tariff reform in Colombia and leverage the various exposures to tariff cuts across firms in different manufacturing sectors. The reduction in tariffs on capital goods that firms use as inputs has an economically strong and statistically significant effect on investment rates. Conversely, there is virtually no effect on investment from a reduction in tariffs on non-capital inputs or tariffs on goods similar to those that firms produce.

These results suggest that a reduction in the price of capital goods can significantly boost investment. However, the reduction in the price of capital goods may incentivize firms to substitute away from labor because of its higher relative price (Karabarbounis and Neiman, 2013). While the total welfare effects of trade liberalization, in this case, can still be positive, there can be substantial distributional asymmetries of the gains. To understand the distributional consequences of trade liberalization, we augment our analysis of investment by examining how a reduction in tariffs affects firm-level employment and the labor share. We do not find evidence in support of the hypothesis that a reduction in the price of capital goods decreases employment and the labor share. In contrast, we find that firms more exposed to a reduction in capital good input tariffs increase employment of production workers and their labor share rises, while employment of administrative workers remains constant.

We further inspect the mechanism through which capital good input tariffs, but not other tariffs, affect investment and labor. One channel is that changes in tariffs are passed through differentially into prices for capital goods than for other goods. For instance, because capital goods are more difficult to obtain domestically, the price elasticities of demand may differ. We estimate product-level pass-through regressions from tariff changes to price changes around the tariff reform and test for heterogeneity in the tariff pass-through. We find evidence of strong pass-through from tariffs to prices, both for capital and non-capital goods, and do not detect significant heterogeneity in the extent of the pass-through. This result further suggests that the *price* of capital goods (rather than differential pass-through) is driving the investment and labor effects.

To further corroborate that the decrease in the price of capital induced by the reduction in tariffs on capital goods is responsible for higher investment rates, more hiring of production workers, and an increase in the labor share, we exploit variation in the capital goods input price change around the trade reform instead of the tariff changes and confirm our results. While the changes in input prices may be more likely confounded by other factors, this piece of evidence points directly to the reduction in the price of capital goods as the force behind stronger investment and employment. To mitigate the concern that the price is endogenous to the amount invested, we turn to instrumental variable (IV) regressions, where we instrument the capital good input price change with the capital goods input tariff change. These IV regressions confirm our main finding.

The way that tariff reductions on different types of goods affect investment is not clear cut from a theoretical perspective. First, consider tariffs on goods that are close substitutes to firms' output. The fall in these output tariffs is likely to increase competition, and the effect of higher competition on firm-level investments can be ambiguous. On the one hand, higher competition can reduce a firm's market share, implying a lower optimal scale of production and lower investment rates. On the other hand, a more competitive environment can stimulate firms to invest in more efficient types of capital to escape competition.[1] In addition, trade liberalization that improves firm-level productivity (Amiti and Konings, 2007; Topalova and Khandelwal, 2011) may encourage firms to invest more. Finally, Gutiérrez and Philippon (2017) argue that lower competition has led to lower investment rates in the United States. We find no effect of output tariffs on investment.

Second, consider tariffs on the goods that firms use as capital or intermediate inputs in production. From this perspective, a reduction in tariffs decreases the price of capital or the price of intermediate inputs that the firm faces. A lower price on capital goods should, in principle, stimulate investment (Restuccia and Urrutia, 2001). Depending on the substitutability of capital and intermediate inputs in production, the response of investment to cuts in tariffs on intermediate inputs may vary. For example, if intermediate inputs and capital are substitutes, firms may cut their investment if the price of intermediate inputs falls. The effect will be the

[1] This effect can be viewed as isomorphic to the "escaping competition" effect in Aghion et al. (2005).

opposite if capital and intermediate inputs are complements in production.

Empirically, we find a strong positive effect of a reduction in capital goods input tariffs on investment, but a null effect of changes in other input tariffs. Economically, a 1 percentage point reduction in capital goods import tariffs spurs firms' investment rates by 0.4 percentage point. Abstracting from general equilibrium effects and assuming that a firm that did not face a reduction in capital goods tariffs did not change its investment rate because of the tariff reform we can calculate the overall effects of the tariff reform. Our results suggest that the average firm increased its investment rate by 0.4 percentage points in 2011 which translates to a 7% increase in investment due to the reduction in capital goods tariffs. Similarly, a 1 percentage point reduction in capital good input tariffs increases the employment growth of production labor by around 1 percentage point, while not affecting the employment of administrative labor.

These results are remarkably similar across various specifications with different sets of firm-level controls, robust to different measures of the exposure to tariff reduction, as well as in IV regressions. For the IV regressions, we lever the fact that the tariff reform was targeted to harmonize the level of tariffs across goods so that goods that had a higher pre-reform tariff –which was determined by historical decisisions on tariffs– level were reduced more relative to tariffs on goods that were already low.

The Colombian 2011 tariff reform is arguably a natural experiment that allows us to study the effects of a fall in tariffs on the performance of firms across various sectors. According to the Colombia Ministry of Commerce, Industry, and Tourism (MCIT), the objectives of the reform were to "reduce tariff dispersion, simplify customs administration, speed up economic growth, generate more employment and reduce poverty."[2] Consequently, from 2010 to 2011, the average tariff rate on imported goods declined by 30% in 2011.[3]

The reform was aimed at reducing the level and dispersion of import tariffs on a broad range of goods and was designed to boost economic activity in general, rather than in particular manufacturing sectors. The latter feature of the reform is crucial for our identification strategy which relies on the assumption that the change in sectoral tariffs was orthogonal to other sectoral shocks in 2011. The goods-specific reduction in tariffs in 2011 was highly correlated with the initial level of the tariffs before the reform. This correlation confirms that the reform was directly targeted to reduce the dispersion in tariffs for all goods rather than to boost investment

[2]See Torres and Romero (2013) for a detailed description of the reform.

[3]While Colombia also entered a Free Trade Agreement with the United States in 2012, the variation in tariffs is almost exclusively driven by the unilateral tariff reform.

in specific sectors.

We observe substantial heterogeneity across firms in terms of their investment response to a decline in capital goods input tariffs. We find the effect of the reduction in the capital goods input tariffs to be strongest for firms that in the third quartile of the size distribution. These results can be generalized through the prism of models in which access to imported capital goods requires firms to incur some fixed costs. The largest firms in this environment are the ones willing to incur the cost even before the reduction in tariffs, and so they mostly benefit along the intensive margin, while medium-sized firms find it profitable to incur the cost right after the reform and thus benefit on the extensive margin of access to imported capital goods.[4] Consistent with this idea, we also provide evidence that the firms more exposed to the reduction in capital goods input tariffs are more likely to start importing.

Related Literature

This paper contributes to the literature on how the price of capital goods affects investment and growth. Economists have long hypothesized that the relative price of capital goods is one of the main determinants of investment rates and therefore economic development (De Long and Summers, 1991, 1993; Hsieh and Klenow, 2007; Lian et al., 2020).

Because capital goods production is concentrated in only a few countries, many emerging markets and developing economies rely on importing capital from abroad which can be associated with major distortions (Eaton and Kortum, 2001).[5]

Jones (1994) demonstrates a strong negative link between economic growth and the relative price of capital goods in a cross-country growth regression. He argues that a reduction in tariffs results in increases in investment and in capital accumulation. However, disentangling the effect of the reduction in the relative price of capital from other factors in a cross-country growth regression is difficult. Moreover, various factors may drive the variation in the relative price of capital goods, such as the productivity of the capital goods-producing sector (Lian et al., 2020; Hsieh and Klenow, 2007), trade costs, or trade policies.

In this paper, we zero in on how trade policies for capital arguably the most easily adapt-

[4]These models are similar in spirit to the Melitz (2003) model of exporting and Antras et al. (2017) model of importing intermediate inputs

[5]Estevadeordal and Taylor (2013) demonstrate a positive link between trade liberalization and growth in a cross-country setting. Capital goods imports have become an increasing source of growth for the U.S. economy (Cavallo and Landry, 2018, 2010).

able by policymakers can shape macroeconomic outcomes, such as capital and labor. In this alternative empirical approach (relative to the previous literature relying solely on macrodata), we test for the importance of capital good prices for investment by using a quasi-natural experiment in the form of a trade reform. Then we exploit variation in the exposure to this reform to study the effects of trade policy-induced changes in the price of capital goods on investment and labor. By using firm-level data and arguably exogenous exposure to a reduction in capital goods tariffs, we can interpret our results as the effect of a reduction in the price of capital goods on investment more causally. To the best of our knowledge, we are the first to provide firm-level evidence on the role of capital goods for firms' outcomes.

Empirically, this paper therefore most closely relates to the literature on the effect of trade liberalization on firm productivity. Amiti and Konings (2007) and Topalova and Khandelwal (2011) show that lower output and input tariffs can increase productivity for Indonesia and India, respectively. Pavcnik (2002) uses Chilean data to study the effect of the reduction of output tariffs on productivity. For Brazil, Muendler (2004) shows that a reduction in inward trade barriers positively affected productivity. Fernandes (2007) uses an earlier trade liberalization episode in Colombia (1977–1991) to show that exposure to foreign competition increases productivity.[6] In contrast to Fernandes (2007) who studies all types of tariffs jointly, we decompose output tariffs, and various types of input tariffs to study the role of capital goods separately. Moreover, we focus on investment and labor instead of productivity.[7]

Interestingly, the effects of trade liberalization on firm investment have not been well studied. One notable exception is Pierce and Schott (2018), who find that US firms decrease investment in response to the threat of substantial U.S. import tariff increases on Chinese goods.[8] While Pierce and Schott (2018) focus mainly on the competition aspect of trade liberalization, our analysis also focuses on the reduction of the cost of importing, in particular capital goods.

The rest of the paper is structured as follows. Section 2 describes the institutional background under which the trade reform took place. Section 3 describes the data we use in the

[6] Using data from Argentina Bustos (2011) provides a link between a regional free trade agreement and technology upgrading.

[7] Ibarra (1995) and Wacziarg and Welch (2008) study the effect of trade policy reforms on investment in a cross-country and industry setting.

[8] Gutiérrez and Philippon (2017) show that increased competition from China leads to a rise in capital stock for firms with high market-to-book values. Recently, Kandilov et al. (2021) measure tariffs on inputs, capital goods, and output and investigate the effects of reduced tariffs on investments in both foreign and domestic capital goods in India. Bas and Berthou (2017) show that reductions in tariffs on intermediate inputs increase the probability of importing capital goods. Kandilov and Leblebicioğlu (2012) study the effect of trade liberalization on firm investment in Mexico.

analysis. Sections 4 and 5 report the main results regarding the reaction of investment rate and employment in response to tariff cuts. Section 6 focuses on the effect of input prices rather than on tariffs. Section 7 concludes.

2 Institutional Background

In the early 2010's, Colombia's macroeconomic landscape was undergoing a solid recovery from the Global Financial Crisis. Juan Manuel Santos, a liberal economist and a previous minister of defense of Colombia, was appointed president in 2010, bringing new macroeconomic policies that sought to accelerate the economic recovery, and seeking to increase Colombia's competitiveness in international markets by providing trade liberalization, and simpler trading laws. The Andean Trade Preference Act of 1991 (between Bolivia, Colombia, Ecuador, and Peru) sets tariffs for certain protected goods in the agricultural and motor vehicles industries. However, these tariffs are not set for all goods in these industries, which increases the tariff dispersion.

The MCIT proposed to generate a structural tariff reform as a priority among other public policies on inequality, innovation, and government reduction. The reform was intended to reduce tariff dispersion, simplifying customs administration; accelerate economic growth; decrease unemployment; and ultimately reduce, poverty. The Structural Tariff reform took place in two stages. The first stage was given in November 2010, and the second in March 2011, following confusion on the tariff system. The first edition of the draft that proposed these changes of structural tariff reforms, in its early stages, was formally dated July 2010.

During the second half of 2010, the Colombian national government evaluated different alternatives for modifying the national tariff structure. After the government considered several possible structures, this reform was carried out in two step and had two general rules: (1) Neither products with 0% tariffs are affected nor are any other tariffs raised; and (2) no tariffs are reduced by more than 10 percentage points.

The second rule sought to prevent nominally highly protected sectors from being severely affected by the reform, which could threaten the destruction of sources of production. Following these two general rules, the structure was applied to a subset of the universe of products classified in Colombian tariff subheadings. To classify the goods by their function in the production chain, the Classification of Goods by Use or Economic Destination (CUODE) was used. To differentiate between agricultural and agricultural and industrial goods, the World Trade Organization definition was used. Within this group of products, agricultural goods tariff rates were not modified given previously negotiated trade deferrals in the Free Trade Agreement with the United States and "protected goods" in the Andean Trade Preference Act. Additionally, two products were included at discretion: cocoa and potatoes (only trading products). However, differential treatment was given to wheat, raw sugar, and white sugar. Within these products, those that had a tariff of 20% were treated as final goods and the tariff was reduced to 15%. Finally, the 10% tariff on cotton was reduced to 5%.

Some sectors expressed their disagreement with the proposed changes to the Colombian tariff. This disagreement was due to (1) disagreement with the CUODE classification, (2) lack of detailed elaboration, (3) inconvenience of the reform, (4) asymmetries in the treatment of agricultural inputs used in production chains, (5) omission of the criterion of national production to make a differential reform on raw materials and capital goods not produced in the country, and (6) failure to take into account previous agreements with the private sector.

Likewise, some sectors, represented by the Ministry of Information Technologies and Communications and the Ministry of Agriculture and Rural Development requested the reduction of tariffs on some products to help implement the policy and support the agricultural industry.

As a result of these requests, the national government implemented an adjustment to the reform. This adjustment adopted two new rules: (1) No product will have its pre-reform tariff reinstated, and (2) the adjustment will not increase the average nominal tariff obtained with the first stage of the reform. Additionally, some rules were formulated to make a differential adjustment on the mining franchise, large-scale mining, and some of the sectors that expressed their disagreement with the reform, usin the code of large economic categories in addition to the previous product classifications. These adjustments were put into effect by decree 492 of February 23, 2011; decree 511 of February 24, 2011; and decree 562 of March 2, 2011.

This paper focuses on Colombian manufacturing firms. Based on the institutional design of the reform, we did not find evidence that it was aimed at bolstering specific sectors within Colombian manufacturing, and hence we will use the heterogeneity in tariff reductions across sectors as arguably an exogenous shock and will trace its effects on investment and employment.

3 Data

3.1 Firm-Level Data

Firm-level data come from the 2008-15 waves of the Colombian Annual Survey of Manufacturers (*Encuesta Annual Manufacturera*). The survey is conducted annually among virtually all firms in the manufacturing industry with at least 10 employees.[9] The survey has information on firm-level expenditures on different types of capital, sales, employment, and fixed assets, as well as the four-digit ISIC industry code. We construct investment as a sum of expenditures on new and used machinery and office equipment and calculate investment rates as a ratio of investment to fixed assets. Our main variable of interest is the change in the investment rate from 2011 to 2010 and we trim the firm-level variable at the 1st and 99th percentiles within each sector.[10]

Table A1 shows the summary statistics. The sample consists of 9,110 firms. $Investment$ refers to investment in machinery and equipment divided by total fixed assets. $\Delta Investment$ is the change in $Investment$ between 2011 and 2010. The average change in the investment rate was negative 0.3 percentage point with a standard deviation of 12.12.[11] The distribution of the change in the investment rate is relatively symmetric. The log of sales and fixed assets in pesos is relatively symmetrically distributed with a mean of 14.47 and 13.42, respectively. In 2010, 22% of firms were importers. This ratio dropped to 21% in 2011 but still 4% of the firms became importers in 2011.

Figure A1 and Figure A2 plot the investment rate and the change in the investment rate over time for the median firm, the firm at the 75th percentile, and the firm at the 25th percentile. The variation around the median is quite large, with the median firm having an investment rate of around 1% over the time horizon but with the 25th percentile having a zero investment rate. The change in the investment rate is zero across all years, but there is a large variation across firms, too. The interquartile range is around 3 percentage points across time.

3.2 Tariff Measures

The data on tariffs come from Teti (2020).[12] We use the Harmonized System (HS) six-digit level most-favored-nation (MFN) tariffs for Colombia and aggregate them to construct several mea-

[9] See, for example, Kugler and Verhoogen (2011), who use a confidential version of the same survey.
[10] We ignore investment into structures, buildings, and land.
[11] The decline in investment rate reflects a more general long-term trend of decline in Colombian manufacturing.
[12] See also Felbermayr et al. (2018)

sures of exposure to the reduction in input tariffs at the sectoral level.[13] First, we calculate output tariffs T_s^O for each manufacturing sector s, as follows:

$$T_{s,t}^{O} = \frac{1}{N_s} \sum_{hs \in S} T_{hs,t}, \tag{1}$$

where hs indexes a particular hs good, $T_{hs,t}$ is the MFN tariff rate for that good in year t, S is the set of hs goods produced by sector s, and N_s is the total number of hs goods produced by sector s[14]. In other words, output tariff for a given sector is a simple average of tariffs for HS six-digit goods that are produced in that sector. Similarly, for each sector s, we compute average tariffs for capital goods, $T_{s,t}^{O,C}$, and other goods, $T_{s,t}^{O,\neg C}$:

$$T_{s,t}^{O,C} = \frac{1}{N_s^C} \sum_{hs \in S^C} T_{hs,t}, \tag{2}$$

$$T_{s,t}^{O,\neg C} = \frac{1}{N_s^{\neg C}} \sum_{hs \in S^{\neg C}} T_{hs,t}, \tag{3}$$

where S^C ($S^{\neg C}$) is the set of HS six-digit capital goods (all other goods) according to the Broad Economic Categories (BEC) classification produced in sector s and $N_s^C = |S^C|$, $N_s^{\neg C} = |S^{\neg C}|$.

To construct input tariffs, we closely follow Amiti and Konings (2007) and construct input tariffs for all goods, capital goods, and other goods ($T_{s,t}^I$, $T_{s,t}^{I,C}$, $T_{s,t}^{I,\neg C}$ respectively) in the following manner:

$$T_{s,t}^{I} = \sum_{s'} w_{s,s'} T_{s,t}^{O} \tag{4}$$

$$T_{s,t}^{I,C} = \sum_{s'} w_{s,s'} T_{s,t}^{O,C} \tag{5}$$

$$T_{s,t}^{I,\neg C} = \sum_{s'} w_{s,s'} T_{s,t}^{O,\neg C}, \tag{6}$$

where $w_{s,s'}$ is the share of expenditures in sector s on inputs from sector s' in total expenditures on intermediate inputs in sector s' taken from the 2008 input-output table for Colombia.[15] In other words, our measures of sectoral input tariffs are weighted averages of output tariffs where

[13] We define 33 sectors analogously to the way they are defined in the 2008 OECD input-output table for Colombia. Input and output tariffs are calculated for 16 tradable manufacturing sectors.

[14] $N_s = |S|$

[15] We use shares of expenditures on intermediate inputs rather than capital originating in different sectors because, to our knowledge, sectoral capital expenditure shares are unavailable for Colombia. As a robustness check, we use alternative measures of exposure to tariff shock using trade-level microdata.

the weights are expenditure shares on inputs from different sectors taken from the aggregate input-output table. The input tariff variables capture the effect of access to cheaper inputs. Unlike earlier studies, we allow for a differential investment response to cuts in the tariffs of capital goods versus other inputs.

Figure 1 plots the tariff rate for the most and least exposed sectors. The most exposed sector (in red) faced a tariff rate of 12% on its inputs between 2008 and 2010; in 2011, the rate dropped to 8%. The least exposed sector experienced almost no change in its input tariff rate in 2011.

We use the trade reform in 2011 that induced the reduction in tariff rates as a natural experiment and study the effect in a differences-in-differences setting. The difference-in-differences setting relies on the assumption that, in the absence of treatment, the difference between firms exposed to the tariff reform and those less affected is constant over time. While this assumption cannot be directly tested we argue that if the sectors were not different before the trade reform in terms of various observed characteristics, the sectors are also less likely in terms of unobservable characteristics. This test helps, for instance, mitigate the concern that the reform was not for example targeted at specific sectors that were lagging behind economically.

As a benchmark to study the correlation between important characteristics and tariff reductions we follow Topalova and Khandelwal (2011) and analyze the Indian trade liberalization of the 1990s who include characteristics such as employment, output, average wage, growth of output, and share of production workers. Table A2 shows that there is no correlation between sectoral exposure to tariff reductions and any of these pre-existing variables before the trade reform was implemented.

Table 1 shows summary statistics on the sector exposure to the tariff reform. The average sector faced a reduction of 3.14 percentage points. The average reduction in capital goods tariffs was 1.03 percentage points with a standard deviation of 1.23. The sector at the 10th percentile of the capital goods tariff change faced a reduction in capital goods tariffs of 2.92 percentage points. The least exposed sector only saw its capital goods tariffs reduced by only 0.04 percentage point. The average reduction in tariffs on other inputs was 3.1 percentage points, and the average reduction in output tariffs was 4.59 percentage points.

3.3 Alternative Input Tariff Measures

As a robustness check, we recompute average tariffs using the very detailed data on Colombian import transactions provided by the Colombian statistical authority (the National Administrative Department of Statistics, or DANE).[16] This dataset covers the universe of import transactions at the importer-HS10 good-origin-month level. Each importer can be matched to one of the particular ISIC four-digits. For each year and each of the 131 four-digit manufacturing sectors $\widetilde{s}$ we observe in the manufacturing survey, we calculate import expenditure shares on each of the HS six-digit goods (in total import expenditures of that sector), denote them by $sh^{\widetilde{s}}_{hs,t}$, and then calculate measures of input tariffs in the following way:

$$\widetilde{T}^{I}_{\widetilde{s},t} = \sum_{hs \in \Omega} sh^{\widetilde{s}}_{hs,t} T_{hs,t}, \tag{7}$$

$$\widetilde{T}^{I,C}_{\widetilde{s},t} = \sum_{hs \in \Omega^C} sh^{\widetilde{s}}_{hs,t} T_{hs,t}, \tag{8}$$

$$\widetilde{T}^{I,\neg C}_{\widetilde{s},t} = \sum_{hs \in \Omega^{\neg C}} sh^{\widetilde{s}}_{hs,t} T_{hs,t}, \tag{9}$$

where $\Omega, \Omega^C, \Omega^{\neg C}$ is the universe of all HS six-digit goods, six-digit capital goods, and all other (i.e. non-capital) goods respectively.

Table 2 shows summary statistics for the alternative measure of tariffs. The alternative measure of change in tariffs in 2011 is positively correlated with the baseline measure: The correlation coefficient ranges from 0.15 for all goods to 0.5 for capital goods. According to the Organisation for Economic Co-operation and Development (OECD), the share of imported inputs in gross fixed capital formation in Colombia hovers around 75%.

4 Trade Liberalization and Investment Rates

4.1 Baseline

The empirical approach relates the change in the firm-level investment rate before and after the tariff 2011 reform to the change in the input and output tariff rate in percentage points. We turn toward dynamic regression in the next section where we evaluate the persistence of the effects and test for pre-trends.

[16] According to OECD supply-use indicators, the share of imported inputs in the gross fixed capital formation of Colombian manufacturing firms is around 75%.

In particular, we estimate the following equation:

$$\Delta Investment_i = \alpha + \beta_1 \Delta T^{I}_{s(i)} + \mathbf{X}\gamma_1 + \epsilon_i, \tag{10}$$

where $Investment_i$ is defined as investment over total fixed assets for a given firm i in a sector $s(i)$, ΔT is the change in variable $\widetilde{T}$ and $\mathbf{X}$ is a vector of controls including lagged logs of fixed assets and sales.

Next, we estimate the equation above again but split the change in input tariffs into the change in capital goods input tariffs and other input tariffs defined in subsection 3.2 and subsection 3.3. First, we re-estimate the equation by replacing input tariffs with capital goods input tariffs. Second, we successively add other input tariffs and output tariffs. Third, we estimate the following equation:

$$\Delta Investment_i = \alpha + \beta_1 \Delta T^{I,C}_{s(i),t} + \beta_2 \Delta T^{I,\neg C}_{s(i),t} + \beta_3 \Delta T^{O}_{s(i),t} + \mathbf{X}\gamma_1 + \epsilon_i, \tag{11}$$

for $t = 2011$

Table 3 reports our baseline specification. Column (1) shows the effect of the exposure to overall input on the change in the investment rate. A 1 percentage point stronger exposure to the reduction in overall tariffs is associated with a 0.12 percentage point increase in the investment rate, but the coefficient is not statistically significant at conventional levels.

Column (2) only includes the exposure to capital goods input tariffs as a regressor. The regression shows that a 1 percentage point stronger exposure to a capital goods input tariff reduction is associated with a 0.377 percentage points stronger increase in the investment rate. For the average firm, for which the investment rate in 2010 was 5.75% (Table A1), a 1 percentage point stronger reduction in capital good input tariffs would increase its investment rate to 6.127 %, a 6.6 percent %.

The sector with the largest exposure to the change in capital goods tariffs in 2011 faced a reduction in its capital goods tariffs by 3.03 percentage points, while the least affected sector faced almost no reduction in its capital goods input tariffs (a 0.03 percentage point decline). Based on our regression results, firms in the sector with the highest exposure, therefore, increased their investment by around 1.14 percentage points in 2011 because of their higher exposure to the reform. For the average firm that would be reflected in an increase in its investment rate from 5.75 to 6.89, an almost 20% increase.

Column (3) adds the change in other input tariffs as an independent variable. We find the effect of the change in other input tariffs on investment to be negative but not statistically significant. The effect of the reduction in other input tariffs on investment is not obvious from a theoretical perspective. If capital goods and other inputs are complements, a reduction in tariffs on other goods can increase investment. However, if both types of goods are substitutes a reduction in other input tariffs would lead to a decrease in investment. The negative effect of the change in tariffs on investment is consistent with recent papers that suggest that factors of production are complements, at least in the short-run (Atalay, 2017; Baqaee and Farhi, 2017; Bøler et al., 2015; Peter and Ruane, 2017). However, the economically small statistically insignificant effect suggests that complementarities are not large enough to boost investment dramatically.

The effect of a reduction of output tariffs on investment is also ambiguous. While a reduction in output tariffs can increase productivity by inducing competition (Amiti and Konings, 2007; Topalova and Khandelwal, 2011), foreign competition can induce firms to shrink and crowd out investment of domestic firms (Autor et al., 2013; Gutiérrez and Philippon, 2017). Column (4) shows that a decline in output tariffs indeed decreases the investment rate of domestic firms, consistent with the crowding out effect, but the effect is not statistically significant and is economically tiny.

Across columns (2)to (4) the coefficient on the change in capital good input tariffs remains remarkably stable and ranges only from negative 0.377 to negative 0.370. The stability of the coefficient suggests that the change in the capital good import tariffs is uncorrelated with both observed and unobserved variables that could bias our regression results (Altonji et al., 2005; Oster, 2019).

To further confirm that our results are not driven by other omitted variables, we implement an instrumental variable approach. As discussed before, the main idea of the trade reform was to harmonize tariff rates. Therefore, the magnitude of the tariff reduction was determined by the level of the tariff rate in 2010. As this level was determined many years before the trade liberalization (as discussed in section 2) it should not affect investment in 2011 through other factors, so we can instrument the change in the tariff rate with its level in 2010.

Table 4 displays the results of an ordinary least square (OLS) regression of the investment rate on the *level* of the capital goods tariff rate, the baseline OLS regression with the change in the capital goods tariff rate, and the IV regression where we instrument the reduction in the tariff rate with the level of the tariff rate in 2010. The level of the tariff rate in 2010 strongly affects the change in the investment rate between 2011 and 2010. A one percentage point larger tariff rate in 2010 raised the investment rate by 0.19 percentage points in 2011. In the instrumental variable regression, where we instrument the change in the tariff reduction with the level in 2010, the IV coefficient is very similar and not statistically different from the baseline coefficient in column (2). The F-statistic of the first-stage regression is 24.54 and therefore exceeds the Stock and Yogo weak instrument test. As the OLS and the IV regression coefficients are statistically not different, we proceed with the OLS regression because it is more efficient.

4.2 Dynamic Effects

Figure 2 displays the coefficient of the capital goods input coefficient (β_1)and the 95% and 99% confidence intervals from the following cross-sectional regressions:

$$Investment_{i,t} - Investment_{i,2010} = \alpha + \beta_1 \Delta T^{I,C}_{s(i),2011} + \beta_2 \Delta T^{I,\neg C}_{s(i),2011} + \beta_3 \Delta T^{O}_{s(i),2011} + \mathbf{X}\gamma_1 + \epsilon_i, \tag{12}$$

where t takes 2008, 2009, 2011, 2012, 2013, 2014, 2015, and 2016. $\Delta T^{I,C}_{s(i),2011}$, $\Delta T^{I,\neg C}_{s(i),2011}$ and $\Delta T^{O}_{s(i),2011}$ are the changes in the tariffs between 2011 and 2010. The change in the investment rate between 2008 and 2010, as well as 2009 and 2010, is not significantly associated with the exposure to the capital goods input tariffs. This result can serve as a placebo test. One concern of the estimated regression could be that the exposure to the capital goods tariff reduction is correlated with factors that affect the change in the investment rate between 2011 and 2010. The result that changes in firms' investment rates before the reform are not significantly correlated with exposure to the capital goods reduction provides reassurance that firms do not postpone their investment until they know the reform comes in. If that were the case, we would overestimate the causal effect of a reduction in tariffs on investment. Because we do not see that firms more exposed to the tariff reform invested less in 2010 than in 2009 or 2008, this finding suggests that firms do not postpone their investment in 2010 to benefit from the effects of the reform in 2011.

The estimated coefficient from Equation 12 also sheds light on how persistent the effect of the reduction in capital goods tariffs is on investment. As shown in Table 3, the coefficient equals negative 0.37 for the change in the investment rate between 2011 and 2010. The coefficient remains negative for 2012 and 2013 but is no longer statistically significant in 2013. After 2013 the effect of the reduction in capital goods input tariffs on the change in the investment rate relative to 2010 fluctuates around 0.

One potential concern could be that investment that would have occurred later simply got pulled forward by the trade liberalization. While the coefficient in 2014 and 2015 turns positive (although not statistically significant), it is significantly smaller in absolute values than the coefficient in 2011 and 2012, suggesting that the trade reform did not simply shift investment toward earlier years.

The results suggest that firms more exposed to the decline in capital goods tariffs increased their capital stock more than other firms, leading to capital deepening.

In Figure A3, we show the dynamic effect for capital goods input tariffs, for other input tariffs, and for output tariffs, separately. The dynamic results confirm the baseline results. The effect of capital goods input tariffs dwarfs quantitatively the effect of other input tariffs and output tariffs, whose effects are also statistically insignificant.

4.3 Heterogeneity across Firms

The results in the previous section suggest that firms more exposed to the reduction in capital goods input tariffs have significantly increased their investment rates relative to other firms. In this subsection, we shed light on the heterogeneity across firms in terms of their investment response given their exposure to the capital goods tariff cut. Production of capital goods is highly concentrated in a few countries. Many countries, especially in emerging markets, rely on importing capital goods from abroad, which can be costly. Larger firms are more likely to self-select into importing markets because it is less burdensome for them to incur the fixed costs (Bernard et al., 2018). A reduction in tariffs can decrease the variable costs of importing and incentivize firms to start importing, as profits from doing so would outweigh the fixed costs (Halpern et al., 2015; Goldberg et al., 2010).

Therefore, we estimate the differential effects of the tariff reduction for firms of different sizes. We regress the change in the investment rate on the change in the capital goods tariffs, three dummies for the size of the firm, and the interaction between the dummies and the change in the capital goods tariffs. We split firms into four quartiles and estimate the coefficient on the interaction with four quartiles $\mathbb{I}_q,\ q \in= \{1,2,3,4\}$, where $\mathbb{I}_1$ and $\mathbb{I}_4$ denote the quartiles with the smallest and largest firms respectively.

We estimate the following regression equation:

$$\Delta Investment_i = \alpha + \beta_1 \Delta T^{I,C}_{s(i),t} + \sum_{q=2}^{4} \mathbb{I}_q \times \beta_2^q \Delta T^{I,C}_{s(i),t} + \beta_3^q \sum_{q=2}^{4} \mathbb{I}_q + \mathbf{X}\gamma_1 + \epsilon_i, \qquad (13)$$

for $t = 2011$. Here β_1 estimates the effect of the change of capital goods tariffs for the smallest quartile of firms within each sector. β_2^2, β_2^3, and β_2^4 reflect the additional effect on the change in investment for medium-small, medium-large, and large firms, respectively. The effect of a change in capital goods input tariffs on the change in investment is negative for small firms in terms of both sales and employment, but only statistically significant for small firms if sales are used as an indicator of size.

Firms in the second quartile of the employee distribution benefit more from the tariff reduction, but the effect is not statistically significant. Medium-large firms benefit the most from the reduction in capital goods input tariffs. The largest firms also benefit more than small firms, but the additional effect is smaller than for medium-large firms. For a firm in the third quartile of the employment distribution exposed to a 1 percentage point decline in capital goods input tariffs, investment increases by 0.66 percentage point more. This outcome compares with a 0.02 percentage point increase in investment for a firm that is exposed to the same reduction in input tariffs but in the first quartile of the employment distribution.

The results are similar when sales are used to assign firms into size bins. While the second quartile of firms benefits less than the first quartile, the effect is again the strongest for firms in the third quartile of the sales distribution. A firm in the first quartile of the sales distribution increases investment by 0.367 percentage point more in response to a 1 percentage point decline in capital goods tariffs. In contrast, a medium-large firm exposed to the same reduction in capital goods tariffs increased investment by 0.781 percentage point. The firms in the fourth quartile of the sales distribution do not seem to benefit more from the tariff reduction than the smallest firms.

In sum, we find that firms in the third quartile of the size distribution i.e., medium-large firms benefit the most from the reduction in capital goods input tariffs. This result suggests that the reduction in the costs of importing makes the benefits of importing exceed the fixed costs.

4.4 Import Entry

In this subsection, we test whether firms that have been more exposed to the reduction in capital goods input tariffs are more likely to start importing.

To shed light on the extensive margin of firms importing, we estimate a probit regression. We regress the dummy $Import\ Entry$ on the changes in tariffs. The dummy $Import\ Entry$ takes the value one if the firm is not importing in 2010 but starts importing in 2011, and zero otherwise. Column (1) of Table 6 shows that a reduction in overall input tariffs increases the probability to start importing in 2011, but the coefficient is not statistically significant. When we split the general tariff change into the change in capital goods tariffs and other input tariffs, we find that firms exposed to a stronger reduction in capital goods tariffs are more likely to start importing. We do not find this effect for the change in input tariffs for other goods.

However, we also find that firms more exposed to a reduction in output tariffs are more likely to become importers. This result is consistent with the idea that output tariffs can raise productivity (Pavcnik, 2002) and increasess firms' tendency to import, potentially offshoring the production of low-quality varieties, thereby freeing up domestic resources for the development, production, and marketing of higher-quality varieties (Bernard et al., 2020).

The effect of capital goods input tariffs remains economically similar and statistically significant after adding output tariffs as controls. Economically, the average marginal effect of a one percentage point reduction in capital goods input tariffs on the probability of a positive outcome is 0.005.

4.5 Robustness

In this subsection, we conduct two types of robustness tests. First, we add additional firm-level controls to our baseline specification. Second, we use an alternative measure of tariffs.

In Table 7, we successively add controls. In column (1), we confirm that our results hold when no controls are included. Column (2) adds only the lagged log of fixed assets, and column (3) adds lagged log of sales and lagged log of total factor productivity. Finally, column (4) adds the change in the log of fixed assets and sales between 2011 and 2010 as additional controls, following Kalemli-Ozcan et al. (2018). Because many of our firms are private, we do not have information on Tobin's Q. In addition, the firm-level data we are using does not provide information on the leverage of the firm. Our base result is confirmed in all of the specifications and the coefficient only varies from negative 0.372 to negative 0.376. As adding additional firm controls only affects the coefficient marginally, other controls, such as Tobin's or Leverage, are unlikely to affect our baseline result significantly. In addition, because our main variable of interest seems to be uncorrelated with the observed firm-level characteristics, the change in capital goods input tariffs is also likely to be uncorrelated with unobserved characteristics that could bias our result.

In Table 8, we use an alternative measure of input tariffs. We obtain data from DANE to construct input tariffs based on previous import volumes. See subsection 3.3 for a detailed description of the construction of the alternative tariff measure. We can confirm our baseline result. Firms exposed to a stronger decline in overall input tariffs, non-capital goods input tariffs, and output tariffs do not significantly change their investment rate more than other firms. However, a larger exposure to capital goods input tariff cuts has a statistically and economically strong effect on the change in the investment rate.

Table A3 shows that the results are virtually the same for the balanced sample when we fill the missing observations with a zero investment share. In columns (3) and (4) we analyze entry and exit but do not find evidence that sectors more exposed to the reduction in capital goods tariffs are more likely to enter or exit.

We also show the results on output in Table A4. The results are similar to those for investment. We find that stronger exposure to a capital goods tariff reduction increases output, but this is not the case for other types of tariffs. Unfortunately, the dataset does not contain information on exports, which would indeed be an interesting margin to explore.

5 Trade Liberalization and Labor

In this section, we analyze the labor effects of trade liberalization. The relationship between capital goods prices and labor is not clear-cut from a theoretical perspective. From the perspective of the Heckscher-Ohlin model, the effect of a tariff reduction on the returns on labor and capital will depend on which factor is used more intensively in sectors that face steeper tariff declines. Using a trade reform in Colombia in the 1980s and 1990s, Attanasio et al. (2004) find results that are inconsistent with the prediction from the Heckscher-Ohlin model. They show that a decline in output tariffs is not associated with a re-allocation of labor but with declines in industry wage premiums. Although employment remained stable across sectors in response to the trade reform, one could conclude that trade liberalization is associated with a decrease in the labor share because the wage premium falls for more exposed sectors.

However, output tariffs are not the only factor affected by the trade reform. In addition to facing tougher competition from abroad induced by lower output tariffs, firms may also be able to use the same inputs from abroad at lower prices due to lower input tariffs. The fall in input tariffs may affect the within-firm substitution between labor and capital, and the sign of the effect will depend on whether labor and capital or intermediate inputs are substitutes or complements in the production.

We employ the same estimation strategy as in our baseline to analyze the effect of the trade liberalization on labor. We test whether firms more exposed to the reduction in different types of tariffs have different responses in terms of the number of employees, and then we move directly to the labor share.

Column (1) of Table 9 shows that a larger exposure to the decline in input tariffs is associated with a reduction in workers between 2010 and 2011. However, as for the response in the investment rate, this result masks significant heterogeneity depending on the types of goods. A reduction in non-capital goods input tariffs leads to a decline in the number of workers. In contrast, a reduction in capital goods tariffs is associated with an increase in the number of employees.

In Table 10, we examine the effect on manual and administrative workers separately. The coefficient capital goods tariffs is around 50% higher than for administrative workers, for which it is not statistically significant.

Next, we examine how persistent the effect of capital goods prices is on employment. We estimate the same regression as in Equation 12 but replace the change in investment with the change in log production employees. Figure 3 shows that the increase in production workers remains significant for four years in the sectors more exposed to the reduction in capital goods tariffs. After four years, the difference between more and less exposed sectors is not statistically significant anymore.

The combination of results on investment and employment demonstrates that in response to a reduction in tariffs on capital goods, firms increase investment as well as employment, which by itself could mean that the firm-level labor share increased, decreased, or remained constant, depending on what happened to employment relative to capital as well as the price of labor.

Next, we test the implications of a lower price of capital goods on the labor share directly. The substitutability between labor and other inputs in production has been studied intensively in the literature. For instance, Karabarbounis and Neiman (2013) show that labor and capital are substitutes.[17] They conclude that the decline in the price of capital has led to a substitution away from labor to capital and therefore to a decline in the labor share. In contrast, Chirinko (2008) surveys the literature on the elasticity of substitution and finds that most estimates are below one but are usually smaller in the short run than in the long run. Grossman et al. (2017) and Raval (2014) are more recent studies that also find an elasticity of below unity for the United States. Oberfield and Raval (2014) show that the substitution between labor and capital is 0.84 for the average manufacturing sector in Colombia.

Chan (2017) and Hummels et al. (2014) study the substitutability between labor and intermediate inputs. They show that intermediate inputs and labor are substitutes, as lower intermediate good prices induce firms to reduce in-house production of intermediate inputs. By contrast, intermediate inputs and labor may be complements if firms need workers to process intermediate goods. Because there is substantial disagreement on the overall effects of trade liberalization and the decline in factor prices on employment, we test firms' labor responses to a decline in (1) output tariffs (2) capital good input tariffs, and (3) non-capital goods input tariffs. In addition, we shed light on the persistence of these effects and whether they are more pronounced for manual or administrative workers.

To test directly how the labor share responds to a reduction in tariffs on capital goods, we leverage detailed data on the wage bill of the firms. The wage bill data report the total compensation for both production and administrative workers, which allows us to compute the labor share for all employees, for only production workers, and for only administrative workers by dividing the respective wage bill by total sales.

We estimate the dynamic regression with the labor share as the outcome variable. We find that the labor share for firms more exposed to the capital goods tariff reduction increases (Figure 4). This increase is driven by production workers (Table 11 and Figure 5). The labor share for administration workers consistent with the labor effects remains constant for firms with stronger exposure (Figure 6). The production worker labor share results are also confirmed in Table 11.[18]

[17] Grigoli et al. (2020) show significant negative effects of automation on the participation rates of prime-age men and women.

[18] If labor and capital are complements in the short run but substitutes in the long run, we would expect our

Our results are consistent with models in which the elasticity between labor and capital is lower than unity i.e., labor and capital are complements. One possible explanation for this result is that manual workers are necessary to use the newly purchased machines. This result is in contrast with Karabarbounis and Neiman (2013) who argue that the decline in the price of capital is associated with a decline in the labor share as labor and capital are substitutes.

6 Tariffs and Prices

So far, the differential effect of tariffs on capital relative to other types of goods can be rationalized through two different mechanisms.

Either the effect of prices on investment rates is similar for all goods, but the pass-through of tariffs to prices is very small for all but capital goods, or the pass-through of tariffs to prices is similar for all goods, but the effect of prices on investment rates is positive for capital goods and insignificant for all other inputs.

In this section, we analyze the pass-through of tariffs to import prices around the trade reform. We rely on customs-level data to proxy prices by unit values that we construct by dividing the nominal value (free of board but including tariff) of the imported good by its quantity. Being equipped with both the price and the tariff level before and after the 2011 trade reform, allows us to estimate price pass-through regressions at the product level. We estimate the following pass-through regression between 2011 and 2010 at the HS six-digit level:

$$\Delta Price_{hs} = \alpha + \beta_1 \Delta Tariff_{hs} + \epsilon_{hs} \tag{14}$$

where $\Delta Price_{hs}$ is the percentage change in the price between 2011 and 2010 and $\Delta Tariff_{hs}$ is the percentage point change in the tariff rate.

We complement the regression with an interaction term between a dummy that is one if the good is a capital good and zero otherwise:

$$\Delta Price_{hs} = \alpha + \beta_1 \Delta Tariff_{hs} + \beta_2 \Delta Tariff_{hs} \times CapitalGood_{hs} + \beta_3 CapitalGood_{hs} + \epsilon_{hs} \tag{15}$$

The results are demonstrated in Table 12 and Figure 7. We find evidence of a 50% pass-

effect to be only temporary.

through from tariffs to prices at the goods level.[19] When testing for differences in the pass-through, we do not find evidence in favor of a stronger pass-through of capital goods tariffs to capital goods prices than for other goods, suggesting that the elasticity of investment with respect to the price of capital goods, rather than differential pass-through from tariffs to prices, is responsible for the stronger investment response.

This hypothesis can be tested more formally by replacing the change in tariffs with the change in the price (proxied by unit values) in our baseline specification.

First, we calculate output prices P_s^O for each manufacturing sector s, as follows:

$$P_{s,t}^{O} = \frac{1}{N_s} \sum_{hs \in S} T_{hs,t}, \tag{16}$$

where hs indexes a particular hs good, $P_{hs,t}$ is the unit value for that good in year t, S is the set of hs goods produced by sector s, and N_s is the total number of hs goods produced by sector s[20]. In other words, the output price for a given sector is a simple average of unit values for HS six-digit goods produced in that sector. Similarly, for each sector s, we compute the average price for capital goods, $T_{s,t}^{O,C}$, and other goods, $T_{s,t}^{O,\neg C}$:

$$P_{s,t}^{O,C} = \frac{1}{N_s^C} \sum_{hs \in S^C} T_{hs,t}, \tag{17}$$

$$P_{s,t}^{O,\neg C} = \frac{1}{N_s^{\neg C}} \sum_{hs \in S^{\neg C}} T_{hs,t}, \tag{18}$$

where S^C ($S^{\neg C}$) is the set of HS six-digit capital goods (all other goods) according to the BEC classification produced in sector s and $N_s^C = |S^C|$, $N_s^{\neg C} = |S^{\neg C}|$.

We construct sector-level input prices ($P_{s,t}^{I,C}, P_{s,t}^{I,\neg C}$, respectively) in the spirit of constructing input tariffs:

$$P_{s,t}^{I,C} = \sum_{s'} w_{s,s'} P_{s,t}^{O,C} \tag{19}$$

$$P_{s,t}^{I,\neg C} = \sum_{s'} w_{s,s'} P_{s,t}^{O,\neg C}, \tag{20}$$

where $w_{s,s'}$ is the share of expenditures in sector s on inputs from sector s' in total expenditures

[19] These estimates are somewhat lower than the complete pass-through documented for the 2018 hike in U.S. tariffs on imports from China (Fajgelbaum et al., 2020; Cavallo et al., 2021) or the India tariff liberalization (De Loecker et al., 2016) and are in line with some of the estimates in Feenstra (1989).

[20] $N_s = |S|$

on intermediate inputs in sector s' taken from the 2008 input-output table for Colombia.

Now we can replace the change in the tariffs with the percentage change in the prices $P^{I,C}_{s,t}$ and $P^{I,\neg C}_{s,t}$ between 2011 and 2010.

Columns (1) to (3) of Table 13 show how the investment rate, the labor share, and the labor share for production workers respond to changes in the price of capital inputs and other inputs. As for tariffs, the capital input price coefficient is negative and statistically significant. In contrast, the coefficient on the other input price is positive. The negative coefficient for the capital goods prices indicates that firms whose capital input price fell most around the trade liberalization increased their investment and labor share (especially for the production workers) the most.

Using prices instead of tariffs in investment and labor share regression raises several endogeneity concerns. For instance, large investment demand could raise prices for capital goods, inducing a spurious positive correlation between prices and quantities.

We use the quasi-experimental exposure of firms to the tariff reduction in 2011 as a price shifter and instrument the change in prices. The IV regressions in columns (4) to (6) confirm the negative and statistically significant coefficient on the price of capital goods for investment and the production labor share. Consistent with an upward bias in the reduced form coefficients in columns (1) to (3) due to the spurious positive correlation of demand and prices, the coefficients are more negative in the IV specification than in the reduced form. The F-statistic of the first-stage regressions is around 23, well above the weak instrument rule-of-thumb threshold of 10. The coefficients on the price of other input prices are positive but statistically insignificant.

Quantitatively, a 10 percentage point larger price decline to the tariff reform is associated with a 73 basis point stronger increase in the investment rate and a 25 basis point stronger increase in the production labor share. Consider two firms that both have investment rates of 6% and 5% labor share of production workers. Firm A is exposed to a reduction in the price of capital goods of 10%. Firm B's price of capital goods remains constant. According to our estimates, firm A would invest 6.73% and raise its production labor share to 5.25%. Firm B would still invest 6% and have a labor share of 5% after the trade reform, all else constant.

7 Conclusion

In this paper, we have exploited a quasi-natural trade reform in Colombia to study how a reduction in the price of capital shapes macroeconomic outcomes. To the best of our knowledge, we are the first to study firm-level evidence on how the price of capital goods affects firms' investment and labor decisions.

Consistent with a simple investment model, the reduction in the price of capital goods increases investment of firms. Moreover, the reduction in the price of capital goods also boosts the labor share through an increase in employment for production labor but not administrative labor, thus also having distributional consequences.

Our results have important policy implications and indicate that trade liberalizations have very nuanced consequences, some of which were overlooked by previous studies. The effect of a reduction on tariffs depends largely on which kind of tariffs are cut. Reducing tariffs across the board and not considering the input-output matrix of firms can lead to unexpected consequences. While output tariffs have no significant effect on investment, a decline in the capital goods tariffs may substantially boost investment. Firm-level data on employment paint an even more complex picture, as a a reduction in capital goods tariffs is associated with a higher level of employment of production workers, whereas a reduction in input tariffs on non-capital goods has the opposite effect. While a reduction in capital goods tariffs can significantly stimulate investment, a reduction in tariffs on other inputs and output tariffs does not have effects on investment.

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Tables

Table 1: Descriptive Statistics – Reduction in Tariffs

	mean	p10	p25	p50	p75	p90	sd
ΔT^{I}_{2011}	-0.942	-2.007	-1.449	-0.783	-0.300	-0.0170	0.849
$\Delta T^{I,C}_{2011}$	-0.296	-0.820	-0.143	-0.0336	-0.00439	-0.000347	0.727
$\Delta T^{I,\neg C}_{2011}$	-0.830	-1.834	-1.274	-0.589	-0.250	-0.0110	0.857
ΔT^{O}_{2011}	-4.416	-7.364	-6.391	-3.735	-2.781	-1.900	2.094
Observations	132						

Note: the table reports descriptive statistics of the changes in input and output tariffs constructed in subsection 3.2

Table 2: Descriptive Statistics – Reduction in Tariffs (Alternative Measure)

	mean	p10	p25	p50	p75	p90	sd
$\Delta \widetilde{T}^{I}_{2011}$	-4.511	-7.597	-5.030	-4.463	-3.563	-2.516	1.668
$\Delta \widetilde{T}^{I,C}_{2011}$	-0.436	-0.861	-0.531	-0.249	-0.140	-0.0319	0.497
$\Delta \widetilde{T}^{I,\neg C}_{2011}$	-4.106	-7.565	-4.658	-3.444	-2.999	-2.262	1.818
Observations	110						

Note: The table reports descriptive statistics of the changes in input and output tariffs constructed in subsection 3.3

Table 3: Baseline

	(1)	(2)	(3)	(4)
Dependent variable:		Δ Investment		
Δ Input Tariffs	-0.116			
	(0.119)			
Δ Capital Input Tariffs		-0.377***	-0.371***	-0.370***
		(0.055)	(0.052)	(0.051)
Δ Other Input Tariffs			-0.0478	-0.0547
			(0.036)	(0.055)
Δ Output Tariffs				0.00553
				(0.040)
Observations	9110	9110	9110	9110
Controls	Yes	Yes	Yes	Yes

Note: The table represents the estimated coefficients of the regression of changes in the investment rate of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.2. Column (1) reports the results for the overall change in tariffs; column (2) reports the results when exposure is calculated based on changes in capital goods tariffs only; column (3) shows the results for the tariffs on capital and other goods; and column (4) also controls for the changes in output tariffs. All regressions include lagged values of log fixed assets and sales as controls. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 4: Instrumental Variable Regression

	(1)	(2)	(3)
	OLS	OLS	IV
Dependent variable:		Δ Investment	
Δ Capital Input Tariffs	0.193***		
	(0.055)		
Δ Capital Input Tariffs		-0.386***	-0.373***
		(0.056)	(0.079)
Observations	9110	9110	9110

Note: The table represents the estimated coefficients of the regression of changes in the investment rate of Colombian manufacturing firms in 2011 on different measures of the exposure to tariff reduction. Column (1) reports the results for the level of capital goods tariffs in 2010; column (2) reports the results when exposure is the change in capital goods tariffs between 2011 and 2010; and column (3) shows the results for an IV regression, where the change in capital goods tariffs between 2011 and 2010 is instrumented with its level in 2010. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 5: Interaction with Size Quartiles

	(1)	(2)
Dependent variable:	Δ Investment	
Interaction:	Employees	Sales
Δ Capital Input Tariffs	-0.0155	-0.367***
	(0.141)	(0.123)
2nd quartile × Δ Capital Input Tariffs	-0.384	0.342
	(0.261)	(0.408)
3rd quartile × Δ Capital Input Tariffs	-0.648**	-0.421**
	(0.285)	(0.170)
4th quartile × Δ Capital Input Tariffs	-0.429**	-0.0617
	(0.160)	(0.122)
Observations	9110	9110
Controls	Yes	Yes

Note: The table represents the estimated coefficients of the regression of changes in the investment rate of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.2 and interacted with the indicators for quartiles of total employment and sales. The quartiles were calculated across firms within broad ISIC sectors. All regressions include lagged values of log fixed assets and sales. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 6: Import Entry - Probit Regression

	(1)	(2)	(3)	(4)
Dependent variable:		Import Entry		
Δ Input Tariffs	-0.0206			
	(0.032)			
Δ Capital Input Tariffs		-0.0560*	-0.0546**	-0.0597*
		(0.029)	(0.026)	(0.032)
Δ Other Input Tariffs			-0.00964	0.0329
			(0.028)	(0.028)
Δ Output Tariffs				-0.0361**
				(0.018)
Observations	9110	9110	9110	9110
Controls	Yes	Yes	Yes	Yes

Note: The table represents the estimated coefficients from a probit regression of a dummy that equals to one if a firm changes status from non-importer in 2010 to importer in 2011. Column (1) reports the results for the overall change in tariffs; column (2) reports the results when exposure is calculated based on changes in capital goods tariffs only; column (3) shows the results for the tariffs on capital and other goods; and column (4) also controls for the changes in output tariffs. All regressions include lagged values of log fixed investment and sales as controls. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 7: Baseline with Additional Controls

	(1)	(2)	(3)	(4)
Dependent variable:		Δ Investment		
Δ Capital Input Tariffs	-0.375***	-0.372***	-0.373***	-0.376***
	(0.049)	(0.050)	(0.051)	(0.050)
Δ Other Input Tariffs	-0.0918**	-0.0544	-0.0493	-0.0755
	(0.042)	(0.053)	(0.055)	(0.056)
Δ Output Tariffs	0.00478	0.00516	0.00807	0.0144
	(0.037)	(0.038)	(0.041)	(0.040)
lagged $\ln(Fixed\ Assets)$		-0.0806	-0.138	-0.0364
		(0.061)	(0.152)	(0.146)
lagged $\ln(Sales)$			0.0806	0.00820
			(0.153)	(0.149)
lagged $\ln(TFP)$			-0.157	-0.143
			(0.146)	(0.146)
$\Delta\ln(Fixed\ Assets)$				0.907***
				(0.225)
$\Delta\ln(Sales)$				-0.0465
				(0.209)
Observations	9105	9105	9105	9105

Note: The table represents the estimated coefficients of the regression of changes in the investment rate of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.2 Column (1) reports the results for the overall change in tariffs; column (2) reports the results when exposure is calculated based on changes in capital goods tariffs only; column (3) shows the results for the tariffs on capital and other goods; and column (4) also controls for the changes in output tariffs. All regressions include lagged values of log fixed assets and sales as controls, as in Table 3, but also lagged logs of revenue TFP, change in log fixed assets, and change in log sales, as in Kalemli-Ozcan et al. (2018). Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 8: Baseline Regression Using Alternative Tariff Measures

	(1)	(2)	(3)	(4)
Dependent variable:		Δ Investment		
Δ Input Tariffs	0.0515			
	(0.038)			
Δ Capital Input Tariff		-0.587***	-0.536***	-0.572***
		(0.169)	(0.171)	(0.179)
Δ Other Input Tariffs			0.0421	0.0789
			(0.045)	(0.060)
Δ Output Tariffs				-0.0840
				(0.065)
Observations	8849	8849	8849	8849
Controls	Yes	Yes	Yes	Yes

Note: The table represents the estimated coefficients of the regression of changes in the investment rate of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.3 (input tariffs) and subsection 3.2 (output tariff). Column (1) reports the results for the overall change in tariffs; column (2) reports the results when exposure is calculated based on changes in capital goods tariffs only; column (3) shows the results for the tariffs on capital and other goods; and column (4) also controls for the changes in output tariffs. All regressions include lagged values of log fixed assets and sales as controls. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 9: The Effect of Tariffs on Employment

	(1)	(2)	(3)	(4)
Dependent variable:		Δ Employment		
Δ Tariffs	1.258***			
	(0.426)			
Δ Capital Input Tariffs		-0.666	-0.847***	-0.877***
		(0.401)	(0.218)	(0.243)
Δ Other Input Tariffs			1.428***	1.718***
			(0.359)	(0.424)
Δ Output Tariffs				-0.233
				(0.164)
Observations	8954	8954	8954	8954
Controls	Yes	Yes	Yes	Yes

Note: The table represents the estimated coefficients of the regression of changes in the log of employment of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.2 Column (1) reports the results for the overall change in tariffs; column (2) reports the results when exposure is calculated based on changes in capital goods tariffs only; column (3) shows the results for the tariffs on capital and other goods; and column (4) also controls for the changes in output tariffs. All regressions include lagged values of log fixed assets and sales as controls, as in Table 3, but also lagged logs of revenue TFP, change in log fixed assets, change in log sales, as in Kalemli-Ozcan et al. (2018). Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 10: The Effect of Tariffs on Employment of Production and Administrative Workers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	Δ Employment							
	Production	Admin	Production	Admin	Production	Admin	Production	Admin
Δ Tariffs	1.244^{**}	0.934^{**}						
	(0.478)	(0.320)						
Δ Capital Input Tariffs			-0.829^{*}	-0.516	-1.011^{***}	-0.652	-1.051^{***}	-0.664
			(0.411)	(0.495)	(0.243)	(0.416)	(0.267)	(0.383)
Δ Other Input Tariffs					1.439^{***}	1.065^{***}	1.824^{***}	1.183^{**}
					(0.353)	(0.310)	(0.398)	(0.413)
Δ Output Tariffs							-0.308^{*}	-0.0938
							(0.166)	(0.185)
Observations	8960	8961	8960	8961	8960	8961	8960	8961
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table represents the estimated coefficients of the regression of changes in the log of employment (divided into the employment of production and administrative personnel) of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.2 Columns (1) and (2) report the results for the overall change in tariffs; columns (3) and (4) report the results when exposure is calculated based on changes in capital goods tariffs only; columns (5), (6) shows the results for the tariffs on capital and other goods; and columns (7) and (8) also control for the changes in output tariffs. All regressions include lagged values of log fixed assets and sales as controls, as in Table 3, but also lagged logs of revenue TFP, change in log fixed assets, and change in log sales, as in Kalemli-Ozcan et al. (2018). Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 11: Labor Share Regression

	(1)	(2)	(3)	(4)
Dependent variable:	Δ Labor Share Production Workers			
Δ Tariffs	-0.000724			
	(0.000)			
Δ Capital Input Tariffs		-0.000693*	-0.000614*	-0.000616*
		(0.000)	(0.000)	(0.000)
Δ Other Input Tariffs			-0.000602*	-0.000581
			(0.000)	(0.000)
Δ Output Tariffs				-0.0000170
				(0.000)
Observations	8784	8784	8784	8784
Controls	Yes	Yes	Yes	Yes

Note: The table represents the estimated coefficients of the regression of changes in the investment rate in columns (1) and (3), the labor share in columns (2) and (5), and the labor of production workers in columns (3) and (6) the change in capital goods prices and other input prices between 2011 and 2010. Columns (1)-(3) are OLS regressions, and columns (4) to (6) are instrumental variable regressions, where the change in capital goods prices is instrumented with the tariff change. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table 12: Price Pass-through

	(1)	(2)	(3)	(4)
Dependent variable:		Δ Price		
Δ Tariff	0.518***	0.498***	0.567**	0.498***
	(0.098)	(0.105)	(0.279)	(0.105)
Capital Good		-0.0300*		
		(0.018)		
Δ Tariff × Capital Good		0.0689		
		(0.298)		
Goods Type	All	All	Capital	Non-Capital
Observations	5543	5543	768	4775

Note: The table represents the estimated coefficients of the regression of changes in the import price between 2011 and 2010 on the charge in tariff of the same good, a dummy for whether the good is a capital good and its interaction. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

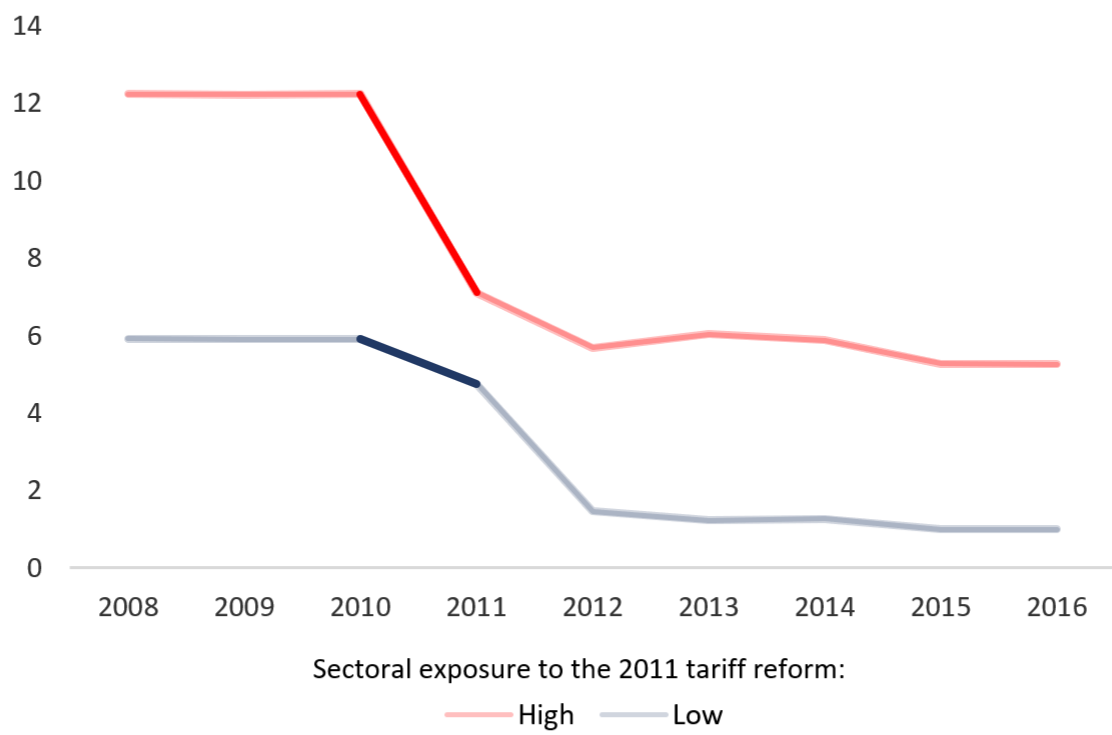
Table 13: Price Regression

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ Investment	Δ Labor Share	Δ Labor Share Prod.	Δ Investment	Δ Labor Share	Δ Labor Share Prod.
Change Capital Input Price	-2.557***	-0.0136***	-0.0145***	-7.339**	-0.0284	-0.0246*
	(0.747)	(0.003)	(0.003)	(3.478)	(0.018)	(0.013)
Change Other Input Price	1.667	0.0328***	0.0286***	39.71	0.157	0.124
	(1.351)	(0.008)	(0.008)	(35.923)	(0.153)	(0.115)
Observations	8580	8406	8465	8580	8406	8465
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-stat				23.16	23.28	23.26
Specification	OLS	OLS	OLS	IV	IV	IV

Note: The table represents the estimated coefficients of the regression of changes in the investment rate in columns (1) and (3), the labor share in columns (2) and (5), and the labor of production workers in columns (3) and (6) of the change in capital goods prices and other input prices between 2011 and 2010. Columns (1)-(3) are OLS regressions and columns (4) to (6) are instrumental variable regressions, where the change in capital goods prices is instrumented with the tariff change. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

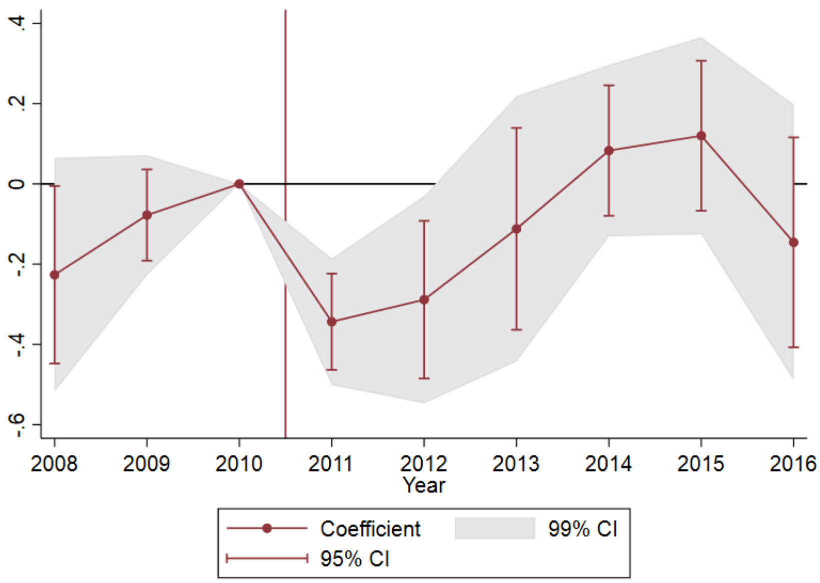
Figures

Figure 1: Evolution of Input Tariffs Over Time



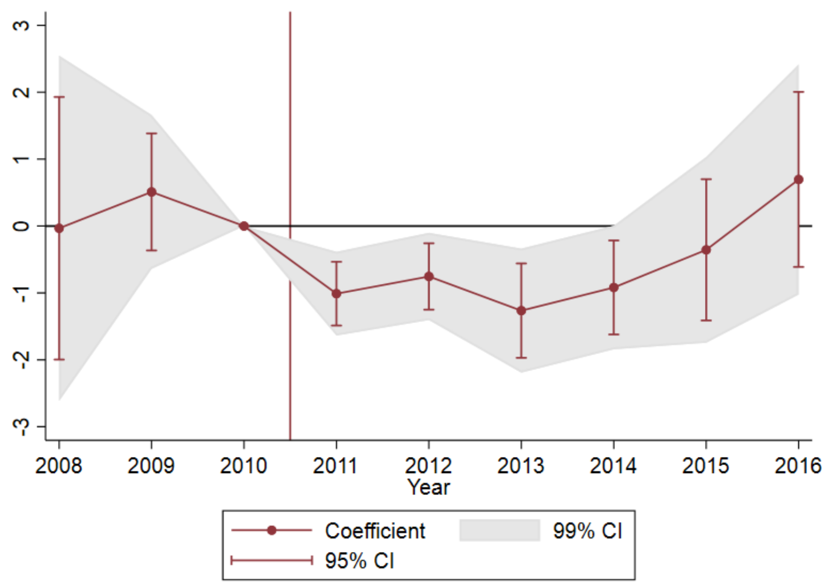
Note: This figure plots the evolution of input tariffs defined in subsection 3.2 over time for two sectors. The high-exposure sector experienced the biggest reduction in input tariffs in 2011, while the low-exposure sector experienced the lowest decline. Source: Teti (2020).

Figure 2: Dynamic Response of Investments to Capital Goods Input Tariffs Cut



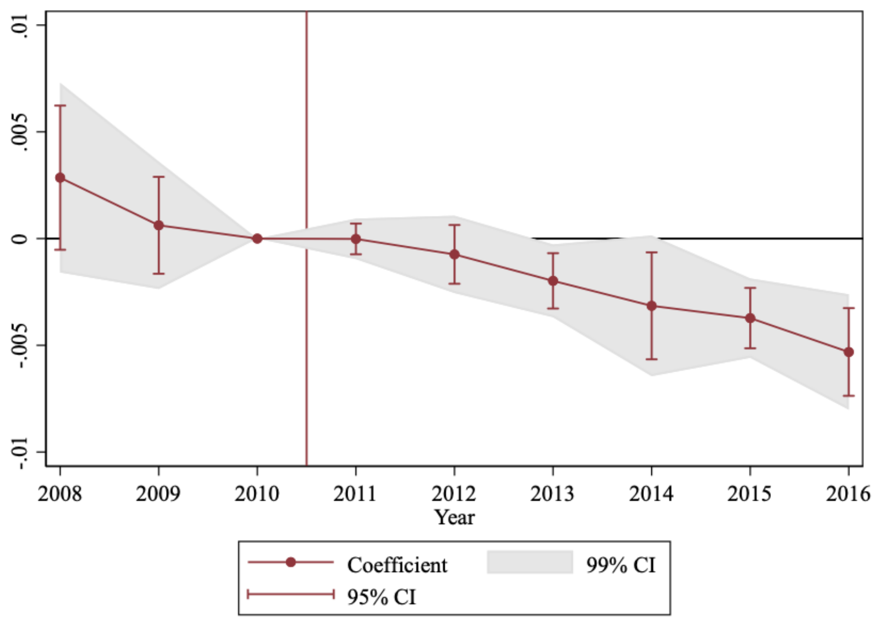
Note: This figure plots the estimated coefficients of a regression equation (Equation 12). The left-hand side variable is the difference between investment rates in year t plotted on the horizontal axis and investment rate in 2010. The variable of interest on the right-hand side is the measure of reduction in capital goods input tariffs in 2011, defined in subsection 3.2

Figure 3: Dynamic Response of Production Workers to Capital Goods Input Tariffs Cut



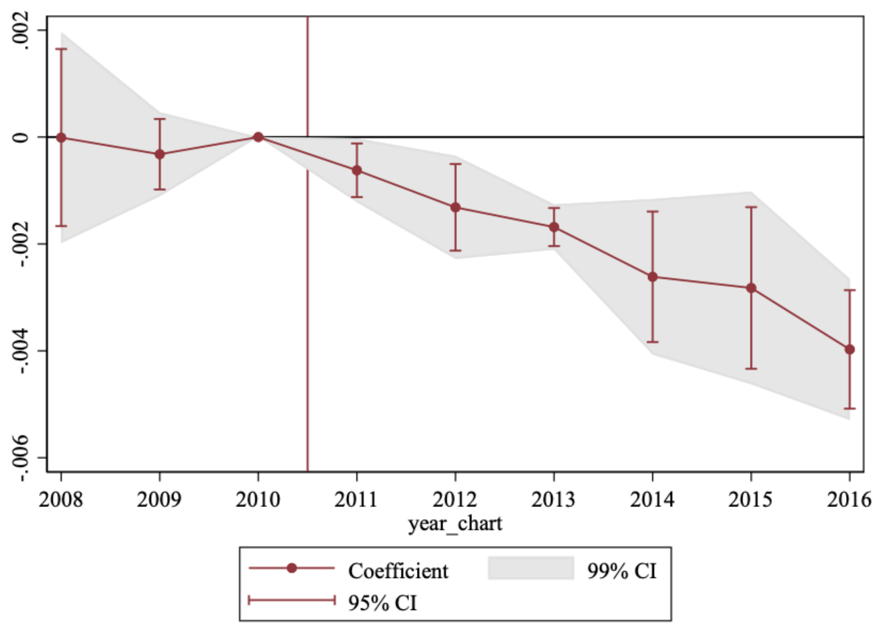
Note: This figure plots the estimated coefficients of a regression equation (Equation 12) but the left-hand side variable is the difference between the log number of production workers in year t plotted on the horizontal axis and the log number of production workers in 2010. The variable of interest on the right-hand side is the measure of reduction in capital goods input tariffs in 2011, defined in subsection 3.2

Figure 4: Labor Share



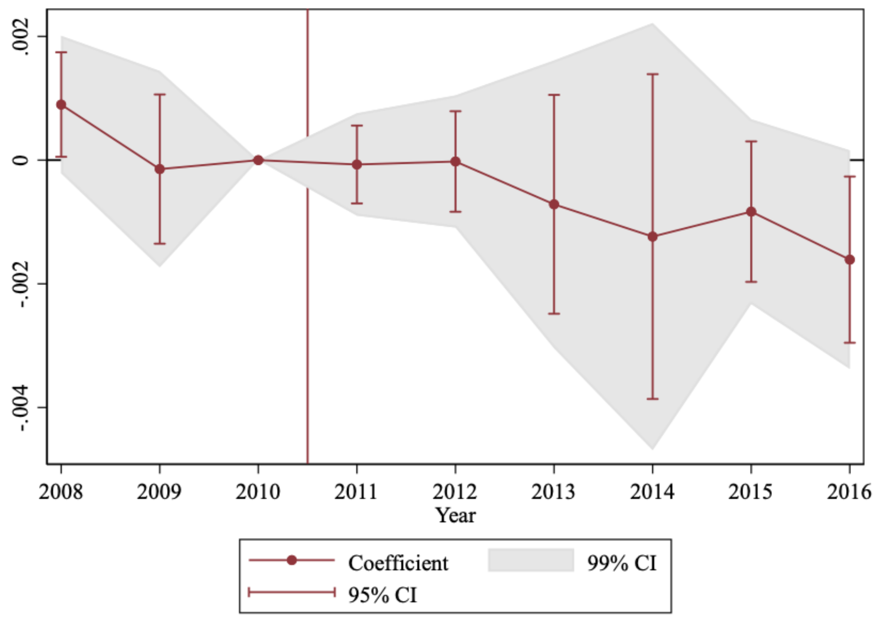
Note: This figure plots the estimated coefficients of a regression equation (Equation 12) but the left-hand side variable is the labor share in year t. The variable of interest on the right-hand side is the measure of reduction in capital goods input tariffs in 2011, defined in subsection 3.2

Figure 5: Labor Share Production Workers



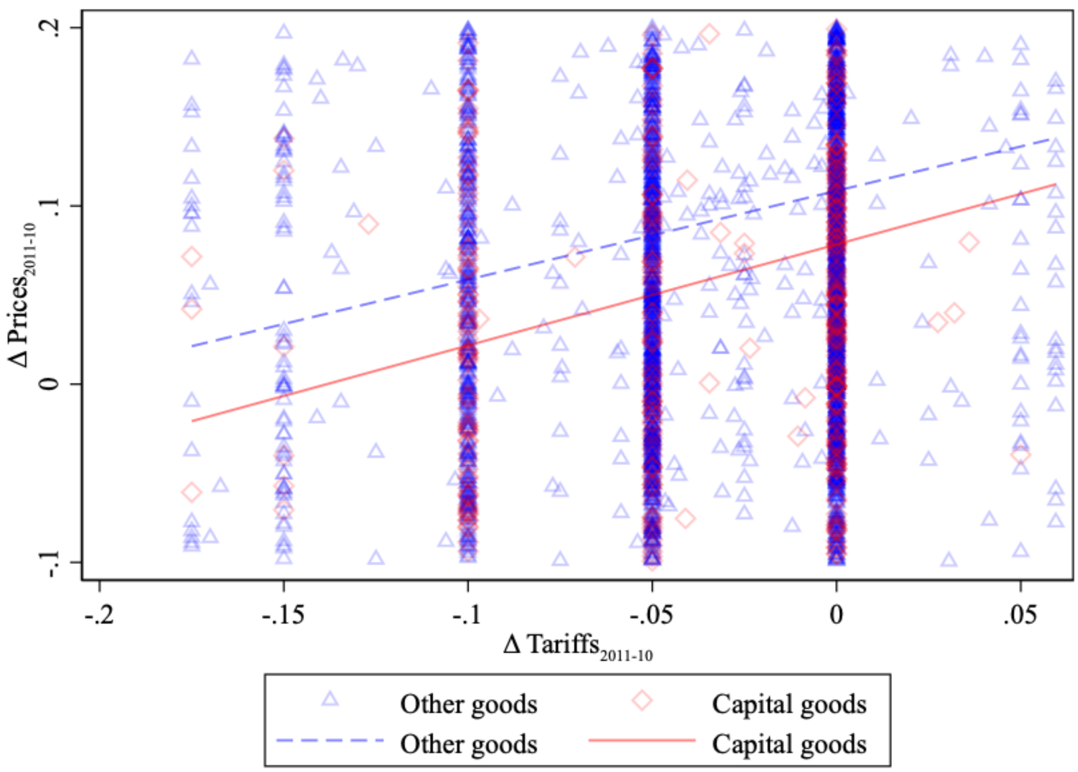
Note: This figure plots the estimated coefficients of a regression equation (Equation 12) but the left-hand side variable is the labor share of production workers in year t. The variable of interest on the right-hand side is the measure of reduction in capital goods input tariffs in 2011, defined in subsection 3.2

Figure 6: Labor Share Administrative Workers



Note: This figure plots the estimated coefficients of a regression equation (Equation 12) but the left-hand side variable is the labor share of administrative workers in year t. The variable of interest on the right-hand side is the measure of reduction in capital goods input tariffs in 2011, defined in subsection 3.2

Figure 7: Price Pass-through



Note: This figure plots the change in import prices between 2011 and 2010 on the y-axis against the change in tariffs between 2011 and 2010 on the x-axis for capital goods in red and other goods in blue.

Appendix

Table A1: Descriptive Statistics

	mean	p50	p25	p75	sd
Δ Investment	-0.00230	0	-0.0210	0.0172	0.122
investment_2010	0.0571	0.0116	0	0.0629	0.109
investment_2011	0.0548	0.0121	0	0.0619	0.103
employees	75.46	25	12	70	148.9
ln_sales	14.78	14.46	13.48	15.80	1.745
ln_fixed_assets	13.68	13.41	12.27	14.89	2.096
importer_2010	0.221	0	0	0	0.415
importer_2011	0.206	0	0	0	0.405
import_entry	0.0393	0	0	0	0.194
Observations	8498				

Note: The table reports descriptive statistics of the selected variables from the 2011 Colombian Annual Survey of Manufacturers . The description of the data can be found in subsection 3.1.

Table A2: Balance Table

	(1) VA	(2) Log(Sales)	(3) $\Delta Log(Sales)$	(4) Employees	(5) Labor Share Prod.
Δ Capital Input Tariffs	32.72	40.11	4.398	1868.2	0.538
	(33.772)	(36.886)	(6.203)	(3378.766)	(0.873)
Δ Other Input Tariffs	-1.504	-2.562	0.0102	35.47	0.105
	(1.617)	(1.803)	(0.163)	(224.709)	(0.073)
Δ Output Tariffs	-0.00827	0.0102	0.000460	0.380	-0.00211
	(0.039)	(0.046)	(0.005)	(2.296)	(0.002)
Observations	16	16	16	16	16

Note: The table represents the estimated coefficients of the regression of various firm-level characteristics in 2011 on the measure of the exposure of changes in tariffs on capital input goods, other input goods, and output goods, constructed in subsection 3.2. The left-hand side is value added (VA) in column (1), log(sales) in column (2), change in log sales in column (3), number of employees in column (4), and the labor share of production workers in column (5). Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table A3: Balanced Sample

	(1) Δ Investment	(2) exit	(3) entry
Δ Capital input tariffs	-0.371***	-0.000758	-0.00517
	(0.053)	(0.001)	(0.006)
Observations	9929	9929	9929

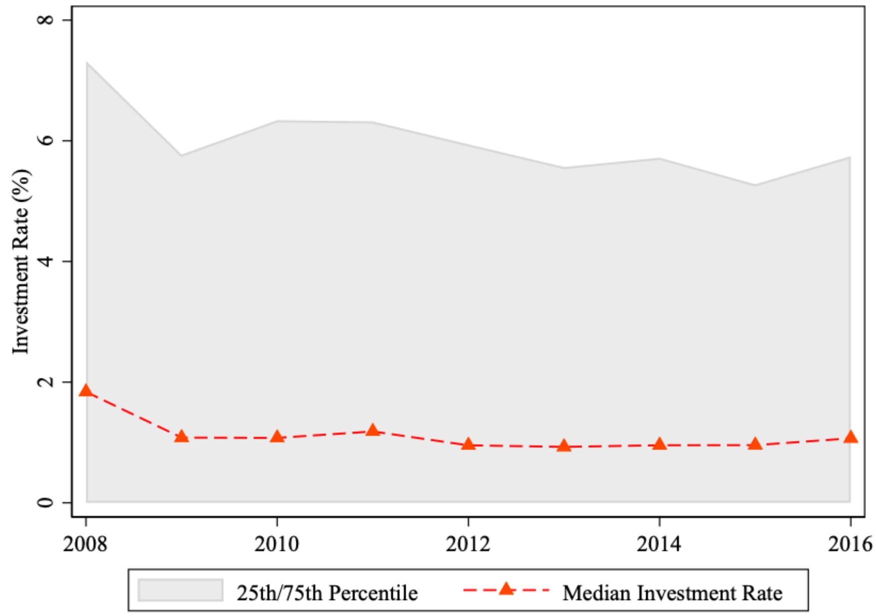
Note: The table represents the estimated coefficients of the regression in a balanced sample of firms of changes in investment rate of Colombian manufacturing firms in 2011, a dummy whether a firm enters the sample, or a dummy whether the firm exits the dummy on the measure of the exposure to tariff reduction, constructed in subsection 3.2. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Table A4: Output

	(1)	(2)	(3)	(4)
	Dependent Variable: Δ Log Sales			
Δ Tariffs	0.0115*			
	(0.006)			
Δ Capital Input Tariffs		-0.00688*	-0.00872*	-0.00924**
		(0.004)	(0.004)	(0.004)
Δ Other Input Tariffs			0.0133	0.0189**
			(0.008)	(0.008)
Δ Output Tariffs				-0.00440*
				(0.002)
Observations	9106	9106	9106	9106

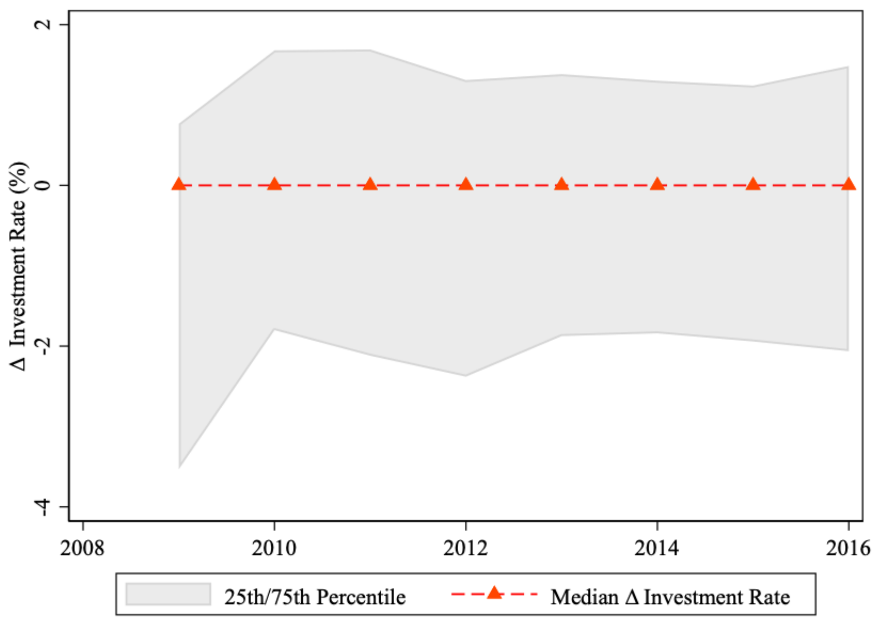
Note: The table represents the estimated coefficients of the regression of changes in log sales of Colombian manufacturing firms in 2011 on the measure of the exposure to tariff reduction, constructed in subsection 3.2. Column (1) reports the results for the overall change in tariffs; column (2) reports the results when exposure is calculated based on changes in capital goods tariffs only; column (3) shows the results for the tariffs on capital and other goods; and column (4) also controls for the changes in output tariffs. Standard errors are clustered at the sector level and reported in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

Figure A1: Investment Rate



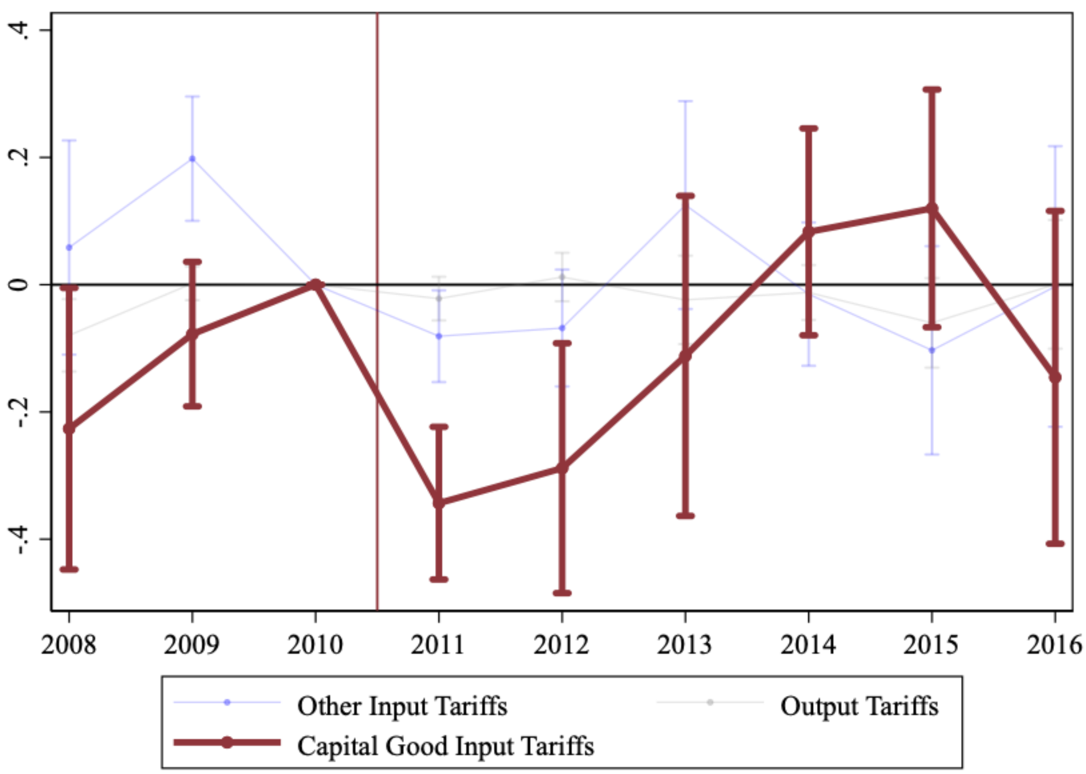
Note: This figure plots the estimated median investment rate across firms and their interquartile range between 2008 and 2016.

Figure A2: Δ Investment Rate



Note: This figure plots the estimated median change in the investment rate across firms and their interquartile range between 2008 and 2016.

Figure A3: All Tariffs



Note: This figure plots the estimated coefficients of a regression equation (Equation 12). The left-hand side variable is the difference between and investment rates in year t plotted on the horizontal axis and investment rate in 2010. The variables of interest on the right-hand side are the measures of reduction in different types of tariffs in 2011, defined in subsection 3.2

B1 Model

To illustrate how our empirical findings can be viewed from a theoretical perspective, we construct a simple theoretical model of firm behavior with capital adjustment costs and two types of labor that can be freely adjusted –production and administrative workers. The model is formulated in a continuous time, and at each instance, the firm chooses how much to invest, and how many workers to hire conditional on the level of capital. Note that because there are no labor adjustment costs, the problem of hiring is static, and does not depend on past or future realizations of capital stock, whereas the investment problem is dynamic in nature because of adjustment costs. The firm maximizes the lifetime discounted value of profits. We will solve the model in two steps. Under standard assumptions on the production function, a solution to the static problem will imply that profits are increasing in the level of capital. Hence, we will first solve a dynamic problem and characterize the path of investment. Second, we will solve a static problem to characterize the co-movement between capital and labor inputs.

B1.1 Model Setup

Consider the following model along the lines of Hayashi (1982). A firm that uses capital in continuous time. In this section, we abstract from labor inputs, as they are being solved for in a static model. Every instance t firms produce $f(K_t)$ units of output, where K_t indicates capital and input with $f_K > 0$ and $f_{KK} < 0$. In the static model below, we show that this condition is satisfied even if we allow for labor inputs in a static model. We assume that firm output is a numeraire and the price of capital is given by p_t^K. A firm maximizes the discounted stream of profits using the discount rate r_t. Capital K_t depreciates at a rate δ and is subject to the following law of motion:

$$\dot{K}_t = I_t - \delta K_t, \tag{21}$$

where I_t is investment. In other words, at period t a firm chooses a level of capital K_t that is going to enter production next period. Investment is subject to convex adjustment costs $\phi(I_t/K_t)$ with $\phi(I_t/K_t) \geq 0$, $\phi''(I_t/K_t) > 0$, $\phi(0) = \phi'(0) = 0$. The adjustment costs are homogenous in investment and capital.

Assume for simplicity that the discount rate is time-invariant. The firm faces the following problem:

$$V(K_t) = \max_{\{I_s, L_s\}_t^\infty} \int_t^\infty e^{-rs} \left(f(K_s) - p_{K,s} I_s (1 + \phi(I_s/K_s)) \right) ds, \tag{22}$$

$$s.t. \quad \dot{K}_s = I_s - \delta K_s. \tag{23}$$

The current-value Hamiltonian of this problem is given by

$$H(I_s, L_s, \lambda_s) = f(K_s) - p_{K,s} I_s (1 + \phi(I_s/K_s)) + \lambda_s (I_s - \delta K_s). \tag{24}$$

And the optimality conditions are given by

$$I_s p_{K,s} (1 + \phi(I_s/K_s) + \frac{I_s}{K_s} \phi'(I_s/K_s)) = \lambda_s, \tag{25}$$

$$f_K(K_s, L_s) + p_{K,s} I_s \frac{I_s}{K_s^2} \phi'(I_s/K_s) - \lambda_s \delta_s = r\lambda_s - \dot{\lambda}_s. \tag{26}$$

$$\lim_{s \to \infty} K_s \lambda_s e^{-rs} \leq 0 \tag{27}$$

The first equation above is the optimality condition with respect to capital, the second equation is the co-state equation; and the third equation is the transversality condition. Let $q \equiv \frac{\lambda}{p_K}$. Note that from the optimality condition for capital, we have

$$q_s = \frac{I_s}{K_s} (1 + \phi(I_s/K_s) + \frac{I_s}{K_s} \phi'(I_s/K_s)), \tag{28}$$

or we can invert $I_s/K_s = \psi(q_s)$ with $\psi'(q_s) > 0$.

B1.2 Dynamic Problem

Note that we can express the dynamics of the model in a two-dimensional (K, q) space. The first equation that we need is the law of motion of capital:

$$\dot{K}_s = I_s - \delta K_s \tag{29}$$

$$= \psi(q_s) K_s - \delta K_s \tag{30}$$

$$= (\psi(q_s) - \delta) K_s \tag{31}$$

The locus of points such that $\dot{K}_s = 0$ is given by $\psi(\bar{q}) = \delta$ with $\bar{q} > 1$.

The law of motion of the costate variable is given by

$$\dot{q}_s = (r+\delta)q_s - f_K(K_s) + \left(\frac{I_s}{K_s}\right)^2 \phi'\left(\frac{I_s}{K_s}\right) \tag{32}$$

$$= (r+\delta)q_s - f_K(K_s) + \psi^2(q_s)\phi'\left(\frac{I_s}{K_s}\right) \tag{33}$$

The locus of points $\dot{q}_s = 0$ is implicitly given by

$$0 = (r+\delta)q_s - f_K(K_s) + p_{K_s}\psi^2(q_s)\phi'\left(\psi(q_s)\right) \tag{34}$$

And it is a downward-sloping curve in the q, K space (the right-hand side of the previous equation increases in both q and K). When we have a decrease in the price of capital $p_{K,s}$, the $\dot{q}_s = 0$ curve shifts to the right i.e., for every value of K_s, we need a higher value of q_s. The equilibrium of this system of differential equations will either be in a steady state or on the saddle path which is also downward sloping. When the price of capital goods falls and assuming the firm was initially in a steady state, the shadow price of capital q_s jumps to the new saddle path and the firm starts slowly accumulating more capital until the investment rate converges to δ. This process is depicted in **??**: A firm starts in the steady state A. The shock pushes the saddle path and the $\dot{q}_s = 0$ locus to the right. On impact, the equilibrium shifts to point B on the new saddle path with higher q and hence higher investment. Over time, the firm converges to steady state C with the investment rate converging to δ from above.

B1.3 Static Problem

Consider the following static problem of a firm that tries to maximize its profits given the level of capital by choosing optimal levels of labor– production (P) and administrative workers (A). This problem is given by

$$f(K) \equiv \max_{P,A} F(A,P,K) - w^P P - w^A A \tag{35}$$

The production function $F()$ is increasing in its arguments; is strictly concave; is twice differentiable; has diminishing returns to capital, production, and administrative workers; and is homogenous of degree 1.[21] In particular, we assume

$$F_P > 0; \quad F_K > 0; \quad f_A > 0, \tag{36}$$

$$F_{KK} < 0, \quad F_{PP} < 0, \quad F_{AA} < 0. \tag{37}$$

And strict concavity yields $F_{AA}F_{PP} > F_{PA}^2$. The previous assumptions also imply that the F function is also concave in A, P conditional on K. Note that according to the Maximum Theorem, $f(K)$ will be increasing and concave – hence, satisfying the assumption on the $f(K)$ function in the dynamic model. Two First order conditions (FOCs) of the static problem are given by

$$F_P = w^P \tag{38}$$

$$F_A = w^A, \tag{39}$$

where the underscripts denote partial derivatives and the arguments of the function f were suppressed for brevity. Taking full differential, we get

$$F_{PK}dK + F_{PP}dP + F_{PA}dA = 0 \tag{40}$$

$$F_{AK}dK + F_{PA}dP + F_{AA}dA = 0 \tag{41}$$

From the first equation, we get

$$dA = -\frac{F_{PK}dK + F_{PP}dP}{F_{PA}} \tag{42}$$

Plug this equation into the second equation to get

$$F_{AK}dK + F_{PA}dP - F_{AA}\frac{F_{PK}dK + F_{PP}dP}{F_{PA}} = 0 \tag{43}$$

$$dP\left(F_{PA} - \frac{F_{AA}F_{PP}}{F_{PA}}\right) + dK\left(F_{AK} - \frac{F_{AA}F_{PK}}{F_{PA}}\right) = 0 \tag{44}$$

As a result,

$$dP = -dK\frac{F_{AK}F_{PA} - F_{AA}F_{PK}}{F_{PA}^2 - F_{AA}F_{PP}} \tag{45}$$

[21] We need these assumptions for the production function to be well-behaved and have a unique solution. See, for example, Christensen et al. (1973) for a discussion.

Similarly,

$$dA = -dK \frac{F_{PK}F_{PA} - F_{PP}F_{AK}}{F_{PA}^2 - F_{AA}F_{PP}} \tag{46}$$

Let $dK > 0$, which may result from a decrease in the price of capital goods, as we showed in the dynamic model. Because F is concave down in P, A, the denominators are both positive. Assume that production labor and capital affect each other's marginal productivity much more than that of administrative workers. In other words, let $F_{KL} > 0$ and $F_{AK}, F_{AP} \approx 0$. As a result, $dP > 0$ and $dA \approx 0$ i.e., production labor will positively react to an increase in capital much more so than administrative labor. Note that the path of production labor in this case will mimic the path of capital because there is a monotonous relationship between P and K in this model.

We can now derive implications for the labor share. Note that the labor share that goes to production workers is given by:

$$\alpha^P = \frac{w^P P}{F(A, P, K)} \tag{47}$$

The homogeneity assumption implies that:

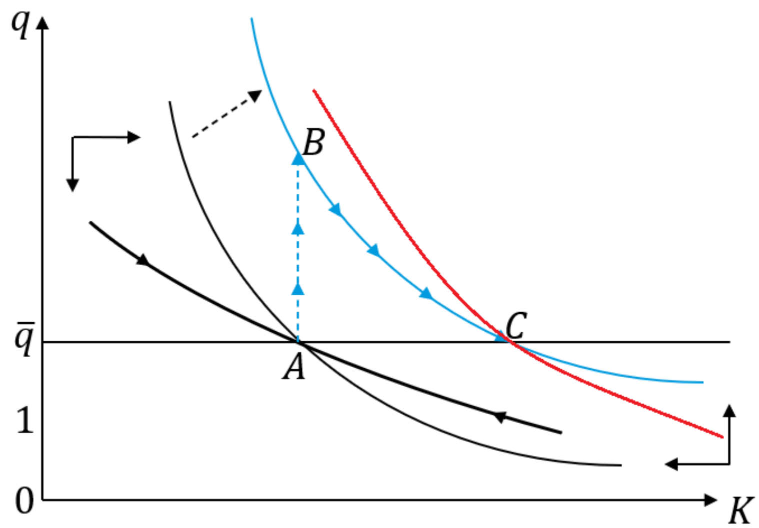
$$F(A, K, P) = KF_K + PF_P + AF_A \tag{48}$$

Plugging this equation into the previous expression, we get

$$\alpha^P = \frac{w^P P}{KF_K + w^P P + w^A A} \tag{49}$$

where we use the FOCs instead of F_P and F_A. Note that under the additional assumptions we impose on cross-derivatives, when K increases, we show that A does not move much and P increases. The numerator of the labor share increases as a result of a decline in the price of capital, but so does the denominator. Since, by assumption, $w^A A$ does change dramatically, the labor share may go up.

Figure A4: Phase Diagram



Note: This chart plots a phase diagram of the dynamic model and illustrates qualitatively what happens when the price of capital goods increases. The initial state of the system is described by two loci in the (K, q) space: the $\dot{K}_s = 0$, which is a thin horizontal line, a $\dot{q}_s = 0$ which is a downward-sloping thin black line, and a saddle path, which is a thick black line. The firm starts in the steady state A and a decrease of the price of capital goods shifts the $\dot{q}_s = 0$ locus to the right (red line), as well as the saddle path (blue line).