Time delays at the border: macroeconomic consequences for sub-saharan african economies*†

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Abstract

Time delays to clear imported inputs are longer in sub-saharan African countries than in advanced economies. In some countries, the clearance delays exceed a month on average while it is about five days or less on average in Germany, Greece, Ireland or Thailand. This paper studies the effects of the inputs supply disruptions that result from time delays at the borders on the macroeconomy of some sub-saharan african countries. I develop a dynamic general equilibrium model of heterogeneous firms where inputs motion is subject to a random time delay process. I then calibrate the model, for eah country, to the World Bank Enterprise Surveys data and simulate a counterfactual scenario where the time delays are reduced to one week or less. The results show that the firms would place higher foreign inputs order at a time to self-insure against inputs' breaks. But the negative effects of the implied inputs disruptions take over in the long run. The potential gain from reducing the border delays in terms of production (respectively consumption) in steady state varies across countries from 0.1% (respectively -0.4%) to 10.2% (respectively 6.4%), with a median of 2.7% (respectively 1.7%). The potential gain in terms of employment is also sizeable, higher than 3% in many countries. The gains are driven mainly by substantial increase of foreign inputs use. Thus, long waiting times for inputs clearance at customs in Sub-saharan Africa are a major obstacle to economic growth and development. It is therefore advisable that authorities of these countries take the appropriate measures to simplify the customs' procedures. Reducing waiting times will allow firms to gain efficiency and enhance economic growth.

Key words: Border delays, customs clearance, foreign, inputs, disruption, Sub-saharan, Africa.

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1 Introduction

Firms in most sub-saharan african countries (SSAC hereafter) import a significant proportion (up to 60% on average in some countries) of their inputs. But in the customs clearance process, they undergo red tape and wait long, in some cases up to six times longer than firms do in Germany or Ireland for instance. These delays cause inputs disruptions and affect adversely the ability of firms to produce. This paper studies the macroeconomic effects of the border delays on investment, employment, production and consumption. To this end, I develop a tractable dynamic general equilibrium model where inputs motion is subject to an exogenous waiting time process. After calibration, I simulate the model for a scenario where the average delay is brought down to a week or less, in each country separately. The average border delay of 7 days or less observed in developed countries such as Germany or Ireland motivated this scenario. The results show that the inputs delays trigger higher investment orders by firms because they self-insure against inputs disruption risks by building a buffer. However, the economy accumulates less inputs in steady state. Reducing the delays to one week or less would increase production (respectively consumption) by 0.1% (respectively -0.4%) to 10.2% (respectively 6.4%), with a median of 2.7% (respectively 1.7%) depending on the proportion of foreign inputs used in the country and the relative shares of material and capital goods. The potential gain in terms of employment is also sizeable, exceeding 3% in many cases.

The border delays have gained some attention in the international trade literature. However, they can also affect firms' production capacity. As globalization drives increasing integration between economies, border delays potentially create inputs supply disruptions, thereby restricting economic activities of existing firms. I use data from the World Bank Enterprise Surveys to compute the average time imported inputs remain in customs[1] in SSAC, and in some advanced economies (Germany, Ireland, Greece and Thailand). Figure 1 shows how the result varies accross SSAC. In Germany, Ireland, Greece or Thailand, firms clear customs and can pick up their inputs in five to seven days on average. In Sub-Saharan Africa on the other hand, only few countries – Botswana, Djibouti, Eswatini [2], Lesotho, Namibia, Somalia, and Sudan – show an average border delay of one week or less among 42 countries I consider. In the other countries, firms reported having to wait longer, often more than a month. Sometimes, the process lasts longer than

[1]It includes all clearances required from the moment the goods arrived at their point of entry until the moment they satisfy the requirements of the clearance procedures at the customs office and can be picked up. It does not include time spent on transportation to reach the point of entry but it includes waiting time to enter customs.

[2]The official name of Eswatini was formerly Swaziland.

three months. In Burundi for example, custom clearance takes 32.4 days on average, and a maximum of 90 days.. In South Africa on the other hand, the average of the border delays is 10.7 days, and the $75th$ percentile is 14 days.

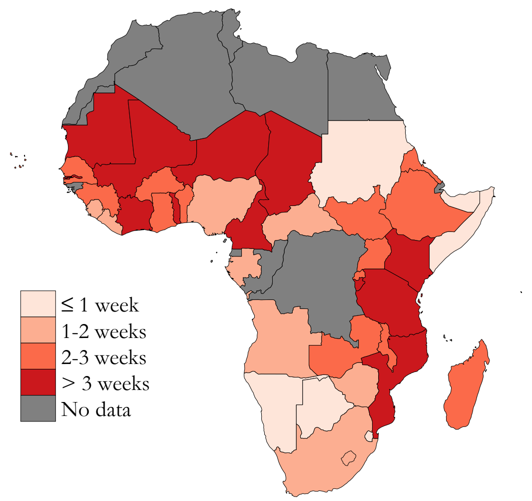

Figure 1: Average border delays (in days) in Sub-saharan Africa. The time imported inputs remain in customs includes all clearances required from the moment the goods arrived at their point of entry until the moment they meet customs requirements and can be picked up. It does not include time spent on transportation to reach the point of entry but it includes waiting time to enter customs.

These waiting times are not only a source of additional costs for businesses, but also a source of uncertainty as the actual waiting time is not known in advance. Figure 2 shows the extent of the variability in waiting times within and across the countries. When referring to the border delays, a nigerian business man complained in *The Business Year* saying: *"As a manufacturer, one of our biggest headache is with the supply chain. We have a situation where we have to order materials three months or six months ahead because of clearing delays"* [3] . In the same vein, many studies identified waiting times resulting from the international movement of goods as a major problem that enterprises are facing in Sub-Saharan Africa [4] (SSA hereafter).

In this paper I study the effects of the border delays on aggregate production, investment, employment and household welfare in SSA. This analysis is valuable for many reasons. First, no paper in my knowledge has examined the effects of the border delays on firms and production process to date. Second, this research is policy relevant as I quantify the gain from achieving better clearance process - that is to catch up with the world's best practices - in terms of output growth in the counterfactual analyses. Third, the anal-

[3]See The Business Year

[4]See OECD (2005); The World Economic Forum (2012); Moïsé and Sorescu (2013); UNECA (2013); Valensisi and Lisinge (2013).

ysis is based on the World Bank Enterprise Surveys (WBES thereafter) data, which have been less exploited in the literature. Finally, although the cause of inputs delays in this paper may not be relevant in other parts of the world (as in developed countries), the framework provides an understanding of the effect of any exogenous time delay process on firms. Many factors can trigger such delay on firms inputs: strike in the transportation, logistics or mail sectors, disruption of supply chains (Meier, 2018), or sanitary threat like the late COVID-19 that hampers international movements of people and goods, thereby interrupting supply chains integration (Bonadio, Huo, Levchenko, and Pandalai-Nayar, 2021).

The paper is related to three strands of the literature. First, it is related to the literature on *time to build* where a new investment takes some time before it becomes productive. It is shown not only that taking into account the *time to build* helps to better match the data, but also that the *time to build* should not be thought of as an adjustment cost (Kydland and Prescott, 1982; Altug, 1989; Rouwenhorst, 1991; Chang, 1995; Christiano and Todd, 1996; Casares, 2006). Conceptually the time delay I consider in this paper is different from the *time to build* by its randomness. The maturity period in the *time to build* models is determined, fixed and known; therefore it is not a direct source of uncertainty [5]. In this paper, time delay does not arise from the *time to build* per see, but from border administration inefficiency, which is beyond firms' control. Meier (2018) studied the effects of stochastic time to build on the business cycle in the US. In his environment, time delays arise from supply chain disruptions in an endogenous search-and-matching setup. In this paper, the mechanism is different because the waiting times are assumed to be exogenous.

Second, My paper is related to the literature on the effects of time delays (including transportation delays) on the international trade (Hoffman, Grater, Schaap, Maree, and Bhero, 2016; Hummels and Schaur, 2013; Plane, 2021). This literature doesn't consider the effect of the delays on firms. Nonetheless, authors have argued that delays of capital and intermediate goods do affect businesses adversely. Valensisi and Lisinge (2013) for example argue that "Africa's disproportionately high transaction costs (due to tariffs and delays at border) hit not only consumers' welfare, but also stem the opportunities resulting from the emergence of global value chains and the associated subdivision of production processes. Notably, by increasing the costs of intermediates and capital goods, they also dampen the prospects for industrialization and structural transformation, hindering value addition and perpetuating Africa's long-standing concentration on primary commodities exports". From this perspective, this paper analyzes the effects of delays on the

[5] When firms have varying stochastic productivity, even the constant fixed *time to build* is source of increasing uncertainty because of imperfect foresight (See Meier (2018)).

internal dynamics of the sub-saharan african economies.

Finally, this paper is also related to the literature on *investment specific technology shocks* (ISTS hereafter) because it models the delay process as a binary exogenous shock to new foreign inputs investment. Papers in this literature emphasize the role of ISTS in explaining the business cycle and growth in the US (Ma, 2018; Chen and Wemy, 2015; Ben Zeev and Khan, 2015; Justiniano, Primiceri, and Tambalotti, 2010; Guerrieri, Henderson, and Kim, 2010; Greenwood, Hercowitz, and Krusell, 2000, 1997), and in developing economies (Dogan, 2019; Araùjo, 2012). However, there is no clear definition or consensus on what an ISTS is, or even how it comes about (Guerrieri et al., 2010). This paper provides a solid and clear motivation for the source of such a shock, and the model is tractable.

The rest of the paper is organized as follows. In section 2 I present some data facts and discuss the possible causes of the border delays in SSAC. Section 3 presents the model, and some analytical results. The calibration strategy and the quantitative results follow in section 4 . The conclusion and recommendations come in the last section.

2 The data

This paper uses data mainly from the World Bank's Enterprise Surveys (WBES). A WBES is a firm-level survey of a representative sample of an economy's formal private sector. The surveys use a global methodology that includes standardized survey instruments and a uniform sampling methodology across all covered countries, and cover a broad range of business environment topics including access to finance, corruption, infrastructure, crime, competition, etc. The unit of observation is an establishment and respondents are business managers. The data are publicly and freely available on the WBES portail. Included variables of interest for this study are the proportion of firms importing material inputs or supplies, the average time material inputs or supplies remain in customs and the proportion of imported material inputs or supplies. The Enterprise Surveys are cross-sectional and repeted for some countries in different years. Therefore, some countries have been surveyed more than once. But I just consider the latest year, and I retain SSAC that have been surveyed from 2009 onwards [6]. Thus 42 countries are under consideration. A complete list of the countries is provided in table 3.

In addition, I use data from the UNCOMTRADE database, which I aggregate along with the classification of Broad Economic Categories (BEC) that classifies imported inputs into capital equipment or materials. This allows me to compute the proportion of capital and materials in the imported inputs. I get some other macro data from the World Bank's

[6] The WBES is better harmonized accross SSACs from 2009 onwards.

World Development Indicator (WDI) database.

2 .1 Long delays at borders for imported inputs in SSA

The WBES reports firm-level average number of days imported inputs remain in customs until they are available to be picked up by the owner. In figure 2 , the border delays feature great variabilities within and across countries. Long border delay is widespread all over SSAC, with a few exceptions including Lesotho, Somalia, Namibia and Botswana. On the other hand, in countries like Burundi and Chad, the average border delay amounts over 30 days. In many countries, the maximum firm's average border delay of inputs is greater than 150 days. Even the *best students* in terms of faster border procedures feature maxima of firm-average border delay of two months or more. For comparison, the average border delay is about 2.6 days in Sweden, 4.7 in Germany and Spain, and 6.5 days in Italy and Thailand.

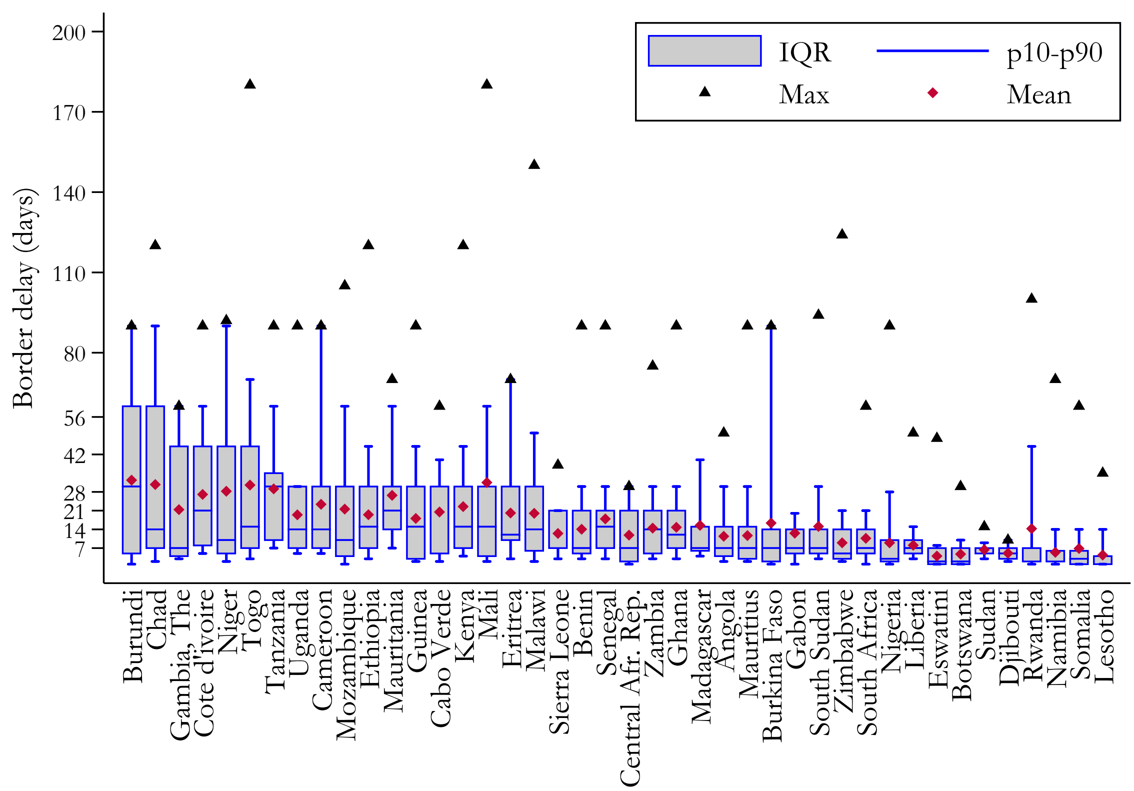

Figure 2: Import delays in Sub-Saharan Africa

Notes.– Figure shows country-specific distributions of border delays in days. The box plots cover the 25th to 75th percentiles of delays. Medians are indicated by the horizontal bar. The lines extending from the boxes show the 10th and 90th percentiles. Averages are shown as red diamonds. The black triangles show the maximum delay. Source: World Bank Enterprise Survey and author' calculations.

So, why are border delays so long in SSA compared to the rest of the World ? Montagnat-Rentier and Parent (2012) identified many factors including poor infrastructures, but according to Djankov, Freund, and Pham (2010), about 75% of the delays are due to administrative hurdles, including red tape and redundant inspections.

Indeed, border administrations performance is still very limited in SSA [7]. The World Economic Forum (WEF) assesses and ranks the easiness of international trade in a large sample of countries around the world. My calculations based on the indicators of the WEF's 2012 report show that the 28 SSAC included in the sample of 132 countries ranked on average 100 with an average score of 3.2 on a 1-to-7 scale of border administration efficiency score, where 1 stands for "extremely inefficient" and 7 for "extremely efficient". This reflects burdensome customs procedures and regulations in these countries, constituting a hurdle for firms that would import capital and intermediate goods. For example, importing goods into South Africa – the most economically developed country in the region – takes 32 days, requires 8 documents in 2012, while the customs administration of Nigeria – the second most economically developed country in the region – is among the least transparent (116th) and least efficient (115th) in the world (The World Economic Forum, 2012). In the same logic, Barka (2012) conducted a research and discovered that the average customs transaction in Africa involves 20–30 different parties, 40 documents, 200 data elements (30 of which repeated at least 30 times), and the rekeying of $60-70\%$ of all data at least once. These facts are corroborated by Djankov et al. (2010).

These confirm the consensus in the litterature that border administrations in SSAC are burdensome [8]. Also, some testimonies of business owners from SSAC corroborate these facts [9]. For example, the head of logistics for a kenyan garment exporter said: "There are so many processes, so much documentation. A centralized place of clearance could solve anything" [10].

Thus, the border delays constitute an impediment to the supply forces of the economies. In the following sections, I propose a simple framework, including analytical results and numerical experimentations to shed light on the mechanisms through which the border delays hamper a country's economic development. Specifically, I show that delays at the border raise the cost of investment and disincentivise saving and inputs (capital and material) accumulation.

[7] See The World Economic Forum and The Global Alliance for Trade Facilitation (2016); Hoffman et al. (2016); Barka (2012); Ocean Shipping Consultants, Ltd. (2008)

[8] See Hoffman et al. (2016); The World Economic Forum and The Global Alliance for Trade Facilitation (2016); The World Economic Forum (2014); Valensisi and Lisinge (2013); Barka (2012); The World Economic Forum (2012); Djankov et al. (2010); Ocean Shipping Consultants, Ltd. (2008)

[9] See The Prepared, The World Economic Forum, and The Business Year

[10] See The World Economic Forum and The Global Alliance for Trade Facilitation (2016)

2 .2 A significant proportion of inputs is imported in SSA

The WBES data also report the proportion of inputs (capital and materials) sourced from local and foreign origins. This information is important for the goal of this paper. In fact, the border delay is likely to matter less if only few quantity of inputs is imported. But figure 3 shows that the proportion of foreign inputs is substantive in most SSAC. In more than half of the countries, this proportion exceeds 40%, and in some cases it reaches more than 60%. Only 5 countries have a proportion of imported inputs of less than 20%, the lowest (3.5%) being in South Africa.

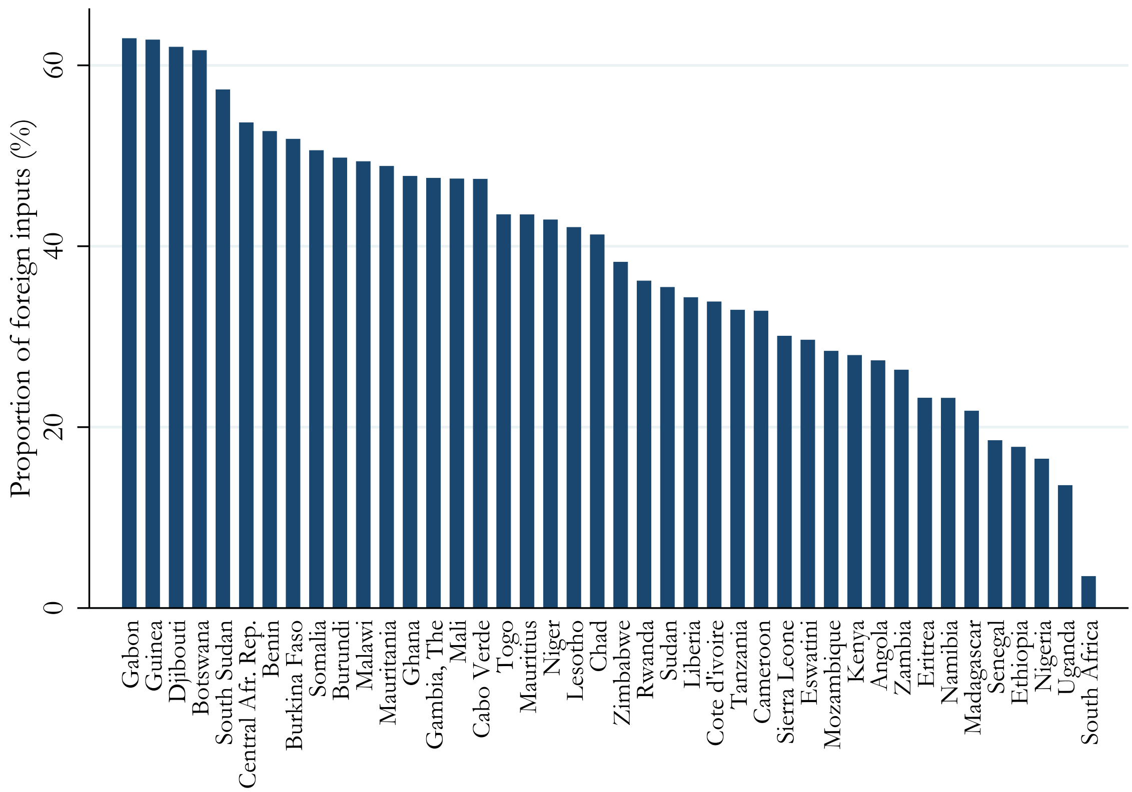

Figure 3: Proportion of foreign inputs by country. Source: WBES data and the author's calculations.

2 .3 Materials and intermediate goods prevail in the imported inputs in SSA

The nature of the delayed inputs is also critical for the goal of this paper. Broadly, I distinguish between two types: capital goods and materials goods. In essence, materials are capital goods with full depreciation. If hypothetically the inputs do not depreciate at all, then the delays will have very limited impact if any [11]. On the other hand, if imported inputs are materials that fully depreciate after a period, the effect of the delays will be the worst. Thus, the structure of the imported inputs is sensitive in the analysis.

Figure 4 shows the proportion of materials in imported inputs in some SSAC, using data from the UNCOMTRADE. In most countries, the proportion of materials is comprised between 50% and 80%, outweighing largely that of capital.

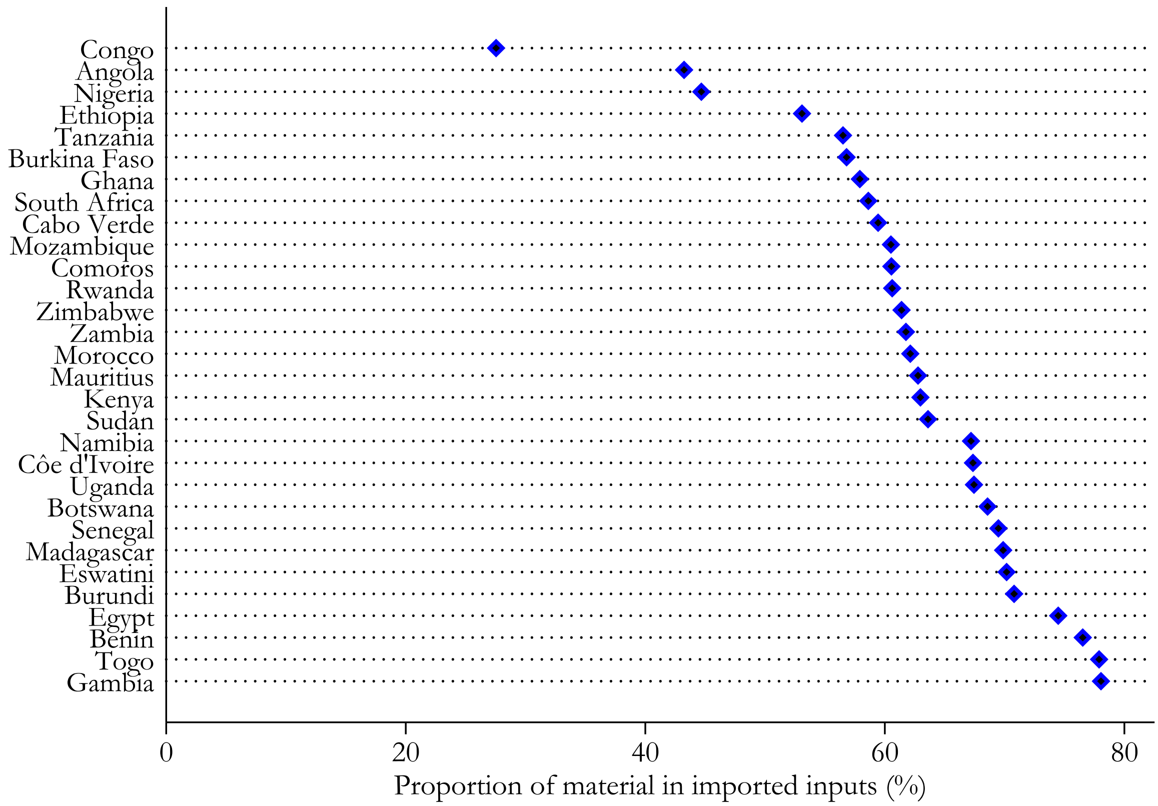

Figure 4: Proportion of materials and intermediate goods in imported inputs.
Note: I aggregate the data using the classification of Broad Economic Categories (BEC) that classifies imported inputs into capital equipments or materials. Source: UNCOMTRADE data and the author's calculations.

[11]With no financial constraints the firm would order once for all the optimal amount of foreign inputs it needs. When it will finally be delivered, the firm will no longer need to import inputs, neither will it be subject to delays even if the border administrations continue to perform poorly.

2.4 Negative correlation between border delays and GDP per capita in SSA

Figure 5 shows that the average border delay is negatively correlated with the real GDP per capita across SSAC. Countries that have lower average border delay tend to have higher real GDP per capita, and vice-versa. For instance, Botswana, Namibia and South Africa are among the few SSA countries that are upper-middle-income economies in the World Bank's 2021 classification. They also have lower average border delays. On the other hand, Burundi, Mali and Togo that have higher average border delays are also among the low-income economies, the poorer group. This fact is in line with The World Economic Forum and The Global Alliance for Trade Facilitation (2016) that found a strong positive correlation between the border administration efficiency index and the real GDP per capita in a large sample of countries around the world.

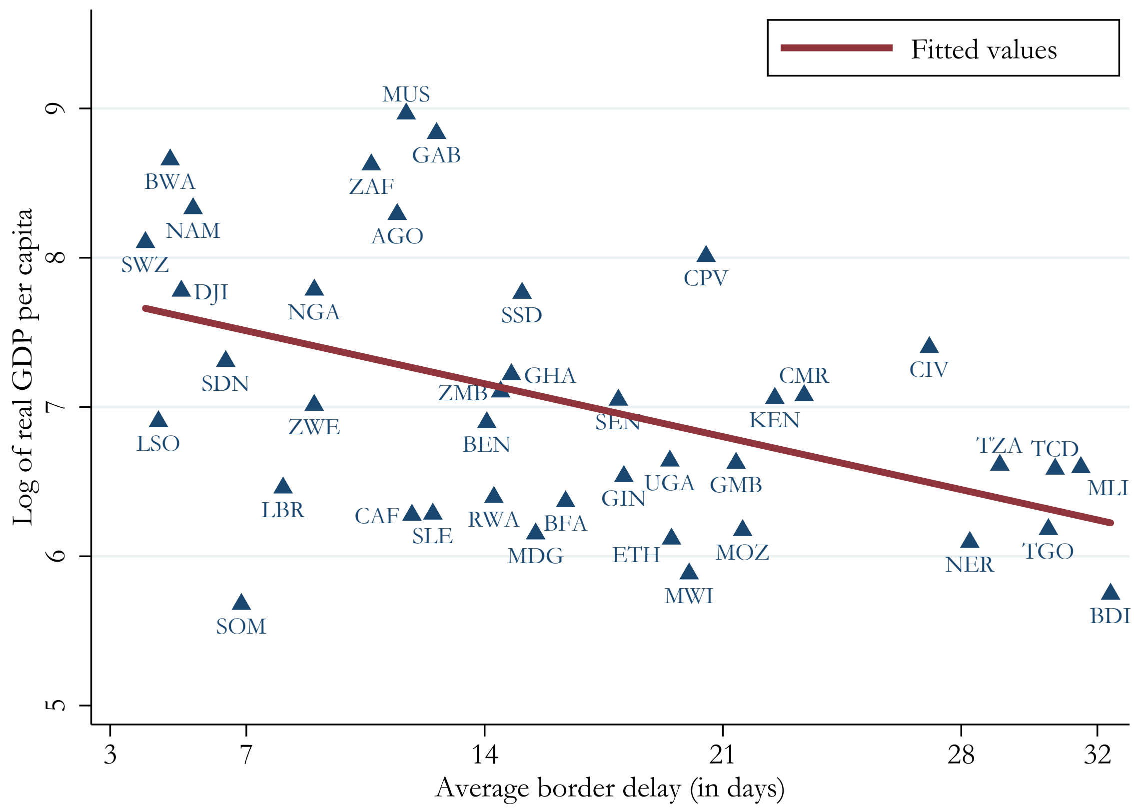

Figure 5: Correlation between border delay and real GDP per capita across Sub-saharan Africa. The figure uses 2010 GDP per capita, in constant 2015 US $. Source: WBES, WDI and the author's calculations.

3 The model economy

The model economy is populated by a constant mass of an infinite number of firms, identical *a priori*. They produce a homogeneous good, using production factors including foreign capital [12], with a decreasing return to scale (DRS) technology. For convenience, I will refer to the inputs as capital. Firms live infinitely and accumulate the foreign capital, which they import. I assume that any investment order is immediately supplied and available at border. Thus, I abstract from sourcing and transportation time and costs. However, imported inputs have to clear at border before the firms can pick them. During the clearance process, input may be delayed, due to administrative burderns, red tape and corruption as described in section 2 .1. So, when the firm places an investment order, it does not know when it would be delivered for sure, but has imperfect knowledge of the delivery time – based on experience – represented by a probability distribution G of the time delay τ (see figure 6). Conceptually the *delivery process* G can be thought of as a stochastic *Poisson arrival process*, and τ as a *waiting time process* [13]. The rationale of this representation is that the investment order stays in a queue at border, where a realization of a Poisson event is a clearance of one importer by the border administration.

The timing is represented in figure 7. Because of the delays, at any time a firm may have a positive amount of investment order pending at the border, waiting in the queue. After production at a period, the firm would decide whether to place a new investment order, $i_{f,t}$, and the amount of such an investment order. Let's define:

$$d_{t,t+j} = \begin{cases} 1 \text{ if } i_{f,t} \text{ arrives after } t+j-1 \text{ production round, but before that of } t+j \\ 0 \text{ otherwise} \end{cases}$$

with $\sum\limits_{j=1}^{\infty} d_{t,t+j} = 1$. That means that $i_{f,t}$ arrival occurs only once at a time, and it surely occurs, but not at a given date known in advance. Then the motion of foreign capital can be writen as follow:

$$k_{f,t+1} - (1-\delta_f)k_{f,t} = \sum_{j=0}^{t} d_{t-j,t+1} i_{f,t-j} \tag{1}$$

[12] *capital* stands for *inputs* other than labor. They include durable equipement on the one hand, and materials that are fully depreciable on the other hand. In the data, both durable equipment and materials are present within the importation of inputs, materials representing the larger proportion except in Congo, Nigeria and Angola. I abstract from disentangling them in my model for the sake of simplicity: distinguishing both inputs highlights the same mechanisms that I discuss later, but makes the maths and the computations harder. On the other hand, lots of paper make the same assumption, not disentangling between capital equipment and intermediate inputs (e.g. Chan (2017); Dissou and Ghazal (2010)). I will discuss in the calibration part how I take into account both input types in my quantitative experiments.

[13] See Lessard (2014), p. 99-104

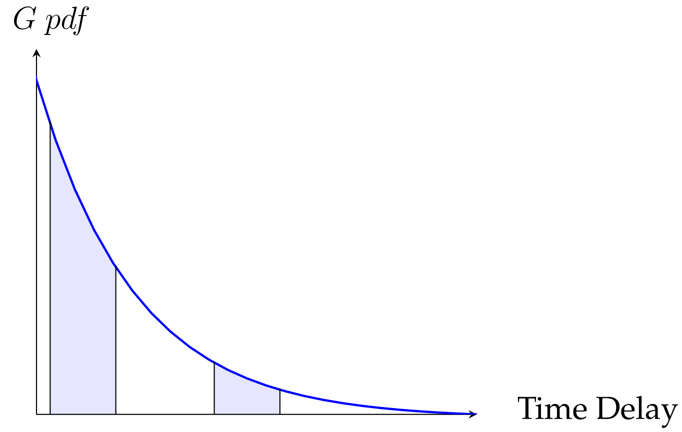

Figure 6: Prior knowledge on delivery process

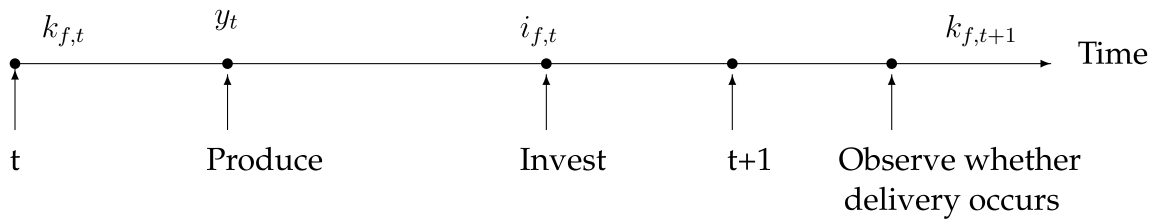

Figure 7: Timing

where δ_f is the depreciation rate of the foreign capital. According to equation (1), the increase of the stock of capital at the firm level net of depreciation between two subsequent periods is the sum of investment orders placed in the past that are just delivered. Because an order may not be delivered at a period due to delays at border, the net increase in the productive capital may be null even if the firm placed positive investment order. This is not the case in standard macroeconomic models where an investment enters production by the subsequent period. It is not either the case in *time to build* models. In these models, although an investment requires a maturity period to become productive, it is usually assumed that a constant proportion is achieved each period. So, at any period the net variation of the capital is non-null as long as the agent plans for a non-null investment.

Note that the framework is not that of a single representative firm. Although firms may be identical at the beginning, they become heterogeneous in the foreign capital at any period because they may and will have different realizations of delivery hazard [14]. But I abstain from entry and exit so that the mass of the firms is irrelevent for the analysis.

[14] This gives motivation for the DRS technology representation. CRS technology is commonly used for a representative firm because ressources can be reallocated from many identical firms to one firm with no effect on aggregate production. In the case of this paper, firms are heterogeneously subject to delivery hazard and this hypothetical reallocation can not be.

3 .1 Border delays and investment's net present value

In this subsection, I highlight the effect that delays at border may have on an investment's net present value in a very simple setup. Let's consider a firm that invests $i_{f,t}$ in foreign capital goods at time t in the environment that is just described. Without lost of generality, let's assume that foreign capital is the only production factor, and technology is $y_t = k_{f,t}^{\alpha}$, $0 < \alpha < 1$. To avoid additional unnecessary complications, let's further suppose that the firm has no stock of capital, and places no other investment from period $t+1$ and afterward. Thus, we keep track on the one stream of investment $i_{f,t}$, and compare its net present value under and without border delays. Capital depreciates at the rate δ_f, and future values are discounted at the factor β.

In the standard case where there is no delay, $i_{f,t}$ would be used in production process from period $t+1$. Then, the net present value of that investment is:

$$NPV_0(i_{f,t}) = -i_{f,t} + \sum_{j=1}^{\infty} \beta^j \left[(1-\delta_f)^{j-1} i_{f,t}\right]^{\alpha} \tag{2}$$

The first term in equation (2) is the cost of the investment in the current period, while the second term is the discounted return on that investment in future periods through production flows.

In the case inputs can wait many periods at the border in the clearance process, and delivery may occur later, the agent knows only the distribution of probability of delivery over time (see figure 6). Let $m = (p_1, p_2, ...,)$, with $p_k \geq 0, \forall\ k = 1, 2, ...$, and $\sum_{k=1}^{\infty} p_k = 1$, be such a probability distribution. Then the expected net present value of the investment $i_{f,t}$ under this friction is:

$$NPV_m(i_{f,t}) = -i_{f,t} + \sum_{k=1}^{\infty} p_k \beta^{k-1} \sum_{j=1}^{\infty} \beta^j \left[(1-\delta_f)^{j-1} i_{f,t}\right]^{\alpha} = -i_{f,t} + \sum_{k=1}^{\infty} p_k V^{(k)}(i_{f,t}) \tag{3}$$

where $V^{(j)}(i_{f,t}) = \beta^j i_{f,t}^{\alpha} + \beta^{j+1}\left[(1-\delta_f) i_{f,t}\right]^{\alpha} + \beta^{j+2}\left[(1-\delta_f)^2 i_{f,t}\right]^{\alpha} + ... + \beta^{j+k}\left[(1-\delta_f)^k i_{f,t}\right]^{\alpha} +$ ... is the discounted value of future revenues from $i_{f,t}$, if $i_{f,t}$ is delivered at time $t+j$. The *time to build* of j maturity period (Kydland and Prescott, 1982; Chang, 1995) is nested by the discrete probability distribution that places the weight 1 at the j^{th} period, $m_j = (0, 0, ..., 1, 0, 0, ...)$. In particular the standard representation - no delays and no time to build - corresponds to the m_1 probability distribution, while the m_{∞} probability distribution corresponds to lost of orders. It is straightforward that $NPV_0 = NPV_{m_1}$. Then, the following propositions, whose proofs can be found in annexes A.1.1 and A.1.2, hold.

Proposition 1 *If* $\beta < 1$, *then:*

(i) the net present value of an investment is lower when it is subject to delays than when it is not subject to delays: $NPV_m \leq NPV_0$, $\forall\, m$ *and* $NPV_m < NPV_0$, *if* $m \neq m_1$.

(ii) the farther a probability distribution m *places higher weights (i.e the more* G *is left-skewed), the lower the net present value of an investment* $i_{f,t}$ *under this distribution,* $NPV_m(i_{f,t})$.

(iii) $NPV_m(i_{f,t})$ *is increasing in the discounting factor* β *for all probability distribution* $m \neq m_1$.

Proposition 2 *If the discounting factor is* $\beta = 1$, *then delays do not matter whatever the probability distribution:* $NPV_0 = NPV_m,\ \forall m$.

Proposition 1 says that, if the future is discounted at strictly positive rate, then the delays depress the return to investment and lower its net present value. In other words, all things else equal, the delays increase the opportunity cost of saving, and would thereby discourage investment. The higher the interest rate, the worse the effects of the delays. This is particularly important because in SSAC, the interest rate is much higher than in developped countries, even the risk-free interest rate of governments' bounds. This could be partly due to the fact that saving is lower in these low-income countries where populations are rather hand-to-mouth, making credit relatively scarce. On the other hand, less efficient border administrations would operate propability distributions that are more skewed to the left and thereby causing severer negative impacts. Proposition 2 however estabilishes that delivery delays don't matter if the future is not discounted. This result is predictable though. In reality, impatience, interest rate, financial constraints and uncertainty are all factors that justify the discounting of the future.

In summary, delivery delays and uncertainty lower the net present value of investments, depress the return on investment and discourage capital accumulation. However, this is in the case of a single investment order. I next consider investment in a dynamic setting and show that the results still hold.

3 .2 Border delays and capital accumulation in a dynamic setting

In this subsection the analysis allows for non-zero stock of capital and investments in past and future periods. The environment is the same. The objective is to determine the steady state stock of capital. I state the firm problem using dynamic programming.

$$
\begin{aligned}
V(k_{f,t},\mathcal{H}_t) = \underset{i_{f,t}}{max}\left\{\pi(k_{f,t}) - i_{f,t} + \beta\mathbb{E}_G\left[V((k_{f,t+1},\mathcal{H}_{t+1})\right]\right\} \\
\text{s.t. } k_{f,t+1} - (1-\delta_f)k_{f,t} = \sum_{j=0}^{t} d_{t-j,t+1} i_{f,t-j} \\
i_{f,t} \geq 0
\end{aligned}
\tag{4}
$$

The state $\mathcal{H}_t$ is the history of amount and delivery of all past investments that the firm had made, $\mathcal{H}_t = ((d_{t-j,t-k})_{k<j}, i_{f,t-j})_{1\leq j\leq t-1}^{\infty}$. It is a high dimensional object that is difficult, if not impossible, to numerically solve. To bypass this, I make the simplification assumption, as in Meier (2018), that at a given period a firm receives all its outstanding orders or receives none of them. Thus, $\mathcal{H}_t$ is reduced to the triplet $(O_{f,t}, z_t, \theta_t)$ where z_t is a binary variable whose value is 1, with probability θ_t, if the sum of outstanding orders $O_{f,t}$ is delivered (or cleared) and 0 otherwise. For simplicity I assume $\theta_t = \theta$ is constant over time and for all firms. This assumption can easily be released by letting z_t be a first order Markov chain binary process. This would better represent a *first-in-first-out* organization at the customs; but it is not necessary for the mechanism of inputs chain disruption in the model [15]. With theses simplification assumptions, equation 1 and $\mathcal{H}_t$ simplify to $k_{f,t+1} = (1-\delta_f)k_{f,t} + z_{t+1}(O_{f,t} + i_{f,t})$ and $O_{f,t+1} = (1-z_{t+1})(O_{f,t} + i_{f,t})$. By posing $\tilde{O}_{f,t} = O_{f,t} + i_{f,t}$, one can rewrite the problem (4) simply as:

$$
\begin{aligned}
V(k_{f,t}) = &\underset{\tilde{O}_{f,t}}{max}\Bigg\{\pi(k_{f,t}) - (\tilde{O}_{f,t} - O_{f,t}) + \\
&\beta\Bigg(\theta V\left[(1-\delta_f)k_{f,t} + \tilde{O}_{f,t}, 0\right] + (1-\theta)V\left[(1-\delta_f)k_{f,t}, \tilde{O}_{f,t}\right]\Bigg)\Bigg\} \\
&\text{s.t. } \tilde{O}_{f,t} \geq O_{f,t}
\end{aligned}
\tag{5}
$$

It is worth clarifying two points here. First, since there is no price of the foreign capital, I am implicitly assuming that its price is the same as that of the final good. In other words, it is assumed that the final good produced by the local firms could be transformed into foreign capital at the ratio one to one, but that does not take place within the local economy. This assumption is clearly unrealistic, but it is conservative because in reality the price of foreign capital is likely to be higher, or equivalently the transformation ratio would be less than one. Second disinvestment is not allowed. So the only way to "consume" foreign capital in the setup is by using it for production. This assumption technically implies that problem (5) does not write consistently in finite horizon simply

[15] Most important, representing z_t as an $i.i.d$ process is technically more convenient because then it is not a state variable.

mutatis mutandis as it is the case in most macroeconomic dynamic programming problems. This point notwithstanding, the assumption imposes the valuable restriction that an investment order pending at border cannot be resold before it is cleared. It is possible to allow for disinvestment after clearing, at the firm level. But this may require additional equations and technical complications that I abstain from.

First order condition and envelop conditions applied to problem (5) allow to derive the policy function and the optimal level of capital in steady state:

$$\tilde{O}^*_{f,t}(k_{f,t}) = \left[\frac{1-\beta(1-\theta)}{\beta\theta\alpha}\right]^{\frac{1}{\alpha-1}} - (1-\delta_f)k_{f,t} \tag{6}$$

$$k^*_f = \left[\frac{1-\beta(1-\theta)}{\beta\theta\alpha}\right]^{\frac{1}{\alpha-1}} \tag{7}$$

I would make two points here. First, one would notice that equations (6) and (7) do not depend on θ when $\beta = 1$. That is in line with proposition 2 and generalizes to this case the result that delays do not matter when the future is not discounted. In line with proposition 1, the second point is stated in propositions 3 below and demonstrated in annexes A.1.3.

Proposition 3 *If the discounting factor $\beta < 1$, then the optimal level of capital in steady state, k^*_f, is:*

i) increasing in the delivery parameter θ.

ii) increasing in the discounting factor β.

3 .3 Generalization to include labor and local capital

This section presents the main framework that is used in the quantitative part. I generalize the analysis to allow firms to use labor and local capital in addition to the foreign capital. The technology is a DRS cobb-Douglass of labor and composite capital, of the form $y = k^\alpha n^\nu$, where the composit capital is a CES aggregation of the local capital (k_l) and the foreign capital (k_f), of the form $k = [\psi(k_l)^\rho + (1-\psi)(k_f)^\rho]^{\frac{1}{\rho}}$. $\sigma = \frac{1}{1-\rho}$ measures the elasticity of substitution between the local and the foreign capital, while the parameter ψ measures the relative share of both types of capital.

So, the firms also accumulate local capital in addition to foreign capital. Unlike foreign capital, local capital is not subject to any delivery delay, because it does not cross border, neither does it clear at customs. Therefore, the dynamics of local capital is of the standard motion in most macro models: $k_{l,t+1} = (1-\delta_l)k_{l,t} + i_{l,t}$. Local capital is tradable on a local market, so that a firm may disinvest in the local capital ($i_{l,t} < 0$). On the other hand, the firms rent the labor on a competitive spot market for a wage w. Hence the profit of a firm that operates with $k_{l,t}$ unit of local capital, $k_{f,t}$ unit of foreign capital and n_t unit of labor is $y_t(k_{l,t}, k_{f,t}, n_t) - wn_t$. By maximizing this expression with respect to n_t we find $\pi_t(k_{l,t}, k_{f,t}) = \Gamma k_t(k_{l,t}, k_{f,t})^{\tilde{\alpha}}$, where $\Gamma = w\left(\frac{\nu}{w}\right)^{\frac{1}{1-\nu}}\left(\frac{1}{\nu} - 1\right)$ and $\tilde{\alpha} = \frac{\alpha}{1-\nu}$.

Given the simplification assumptions stated in section 3 .2 about $\mathcal{H}_t$, the number of state variables in the model at this stage is three: $k_{f,t}$, $O_{f,t}$ and $k_{l,t}$. It is possible to reduce that dimensionality by altering the timing suggested in figure 7 in the following way. The states of the firm, $k_{f,t}$ and O_t are taken after the production round, at the moment when the investment decision is made. Then the motion of the foreign capital is $k_{f,t+1} = (1-\delta_f)\left[k_{f,t} + z(O_{f,t} + i_{f,t})\right]$ and that of the outstanding (undelivered) order is $O_{f,t+1} = (1-z)(O_{f,t} + i_{f,t})$. That way, $k_{l,t}$ is not a state variable and one can write consistently the investment choice problem of the firm in the form of a Bellman equation as follows.

$$
\begin{aligned}
V(k_f, O_f) = \underset{k_l, i_f}{max}\ & \left\{\left[-1 + \beta(1-\delta_l)\right]k_l - i_f + \beta\mathbb{E}_z\left[\pi(k_l, k_f + z(O_f + i_f)) + V(k'_f, O'_f)\right]\right\} \\
\text{s.t. } k'_f &= (1-\delta_f)\left[k_f + z(O_f + i_f)\right] \qquad (8) \\
O'_f &= (1-z)(O_f + i_f) \\
k_l,\ i_f &\geq 0
\end{aligned}
$$

It has not been possible to solve this problem analytically as in the previous subsections. But we can still derive some lessons from the first order conditions. Let's pose $r = 1/\beta - 1$ the risk-free interest rate where β is the household discounting factor. This condition can be interpreted as a general equilibrium property of the economy, as in Cooley and Quadrini (2001). In particular, since the model does not account for any financial friction, the means of financing the investment is irrelevant in the model. Only the optimum scale of operation (k_l^* and k_f^*) matters, and nothing would prevent the firm from seting up this scale, except the delivery delays. However, this is a conservative simplification because any financial constraint in the economic environment will tend to exacerbate the effect of the delivery delays.

Taking the first order condition of (8) with respect to k_l, we get:

$$
r + \delta_l = \mathbb{E}_z\left[\frac{\partial\pi}{\partial k_l}(k_l, k_f + z(O_f + i_f))\right] \qquad (9)
$$

The left hand side of equation (9) is the actual usage cost of the local capital. Recall that z is a dummy variable that is equal to 1 with the probability θ and 0 with the probability $(1-\theta)$. If local and foreign capital are perfect complements, then the marginal profit of the local capital is increasing in the amount of operating foreign capital: $\frac{\partial \pi}{\partial k_l}(k_l, k_f+O_f+i_f) \geq \frac{\partial \pi}{\partial k_l}(k_l, k_f)$. This implies that the right hand side of equation (9), the expected marginal return to the local capital under delivery delays is lower than $\frac{\partial \pi}{\partial k_l}(k_l, k_f + O_f + i_f)$, the frictionless return to the local capital. Consequently, the optimum scale of operating local capital is lower under the delivery delays. That is what proposition 4 states.

Proposition 4 *If local and foreign capital are perfect complements and if $\beta < 1$, then the optimum scale of operating local capital is lower under the delivery delays.*

However, if local and foreign capital are imperfect substitutes the marginal profit of the local capital may be increasing or decreasing in the amount of foreign capital depending on their degree of substitutability (σ). So the effect of the delays on the local capital may reverse depending on the interaction between the discounting factor (β) and the substutability (σ). Indeed, if local and foreign capital are perfect substitutes and if $\beta < 1$, then the optimum scale of operating local capital is greater under the delivery delays (proposition 5). This result is intuitive and works as follows. The delivery delays depress the value of an investment in foreign capital. But if local capital can perfectly substitute to foreign capital, one can avoid the supplementary delay-related costs by just reallocating investment from the foreign capital to the local capital.

Proposition 5 *If local and foreign capital are perfect substitutes and if $\beta < 1$, then the optimum scale of operating local capital is greater under the delivery delays.*

Likewise we can write the first order condition of the problem (8) with respect to i_f:

$$\begin{aligned} 1 + r =& \theta \left[\frac{\partial \pi}{\partial i_f}(k_l, k_f + O_f + i_f) + \frac{\partial V}{\partial i_f}\left((1-\delta_f)(k_f + O_f + i_f), 0\right) \right] \\ &+ (1-\theta) \frac{\partial V}{\partial i_f}\left[(1-\delta_f)k_f, O_f + i_f\right] \end{aligned} \tag{10}$$

If $\beta < 1$, then $\frac{\partial \pi}{\partial i_f}(k_l, k_f+O_f+i_f)+\frac{\partial V}{\partial i_f}\left((1-\delta_f)(k_f + O_f + i_f), 0\right) \geq \frac{\partial V}{\partial i_f}\left[(1-\delta_f)k_f, O_f + i_f\right]$, so the certain return on the foreign capital investment is higher than the expected return under delivery uncertainty. But the effect on the foreign capital in a dynamic setting depends also on the inputs disruption effect of the border delays. In fact, there is a negative effect due to lower return on investment. Nonetheless, there may also be a positive effect due to anticipation of possible inputs break. Hoarding foreign inputs investment may therefore help build foreign inputs buffer to self-insure against the breaks. The threat of inputs break depends on the length of the delays (or the probability of delivery each period) and on the depreciation rate (or the nature of the inputs). The numerical experiments in section 4 .2 show indeed positive effect of the delays on foreign inputs in the short run, and a negative effect in the long run.

Households

On the other side of the economy, there is a representative household supplying labor service at the wage w on a competitive market, and deriving utility from consumption of the final good and from leisure. Preferences are separable, represented by the utility function $U(C_t, N_t) = Log(C_t) - \chi N_t$, where N_t is the time fraction spent working in production firms, and χ is the parameter of labor disutility. The household ressources consist in labor income $w.N$ and dividend from firms, $D = \int(\pi_i - i_{i,f} - i_{i,l})di$, which is the balance of profits after investments. The household consumes all its income. Some algebra help derive the household labor supply $N^s = \frac{1}{\chi} - \frac{D}{w}$.

Stationary competitive equilibrium

A stationary competitive equilibrium in the model is a vector $(w, \tilde{O}_f, k_l, n, C, N, F(k_f, O_f, z))$ of wage, policy functions and an invariant ditribution such that:

$i)$ $\tilde{O}_f,\ k_l$ and n optimize the firms' dynamic problem, given w;

$ii)$ C and N optimize the household's problem, given w;

$iii)$ the labor market clears:

$$N = N^s = N^d = \sum_{z\,=\,0}^{1} \int n\,(k_f, O_f, z)\,dF(k_f, O_f, z);$$

$iv)$ the aggregate resource constraint holds:

$$Y = \int y(k_f, O_f, z)dF(k_f, O_f, z) = C + \int \left[i_f(k_f, O_f, z) + i_l(k_f, O_f, z)\right] dF(k_f, O_f, z);\ \text{and}$$

$v)$ The distribution $F(k_f, O_f)$ is consistent and stationary:

$$\begin{aligned} F(k'_f, O'_f) =& \mathbb{P}(z=1) F(k_f'^{-1}(k_f, O_f), O_f'^{-1}(k_f, O_f))|_{z=1} + \\ & \mathbb{P}(z=0) F(k_f'^{-1}(k_f, O_f), O_f'^{-1}(k_f, O_f))|_{z=0} \end{aligned}$$

In the following, I calibrate the parameters of the model, solve it numerically and perform conterfactual simulations to numerically measure the extent of the effects of the delivery delays established in propositions 1 through 5.

4 Quantitative analysis

4 .1 Calibration

Because countries that perform best clear imported inputs within a week, the model period is set to a week in order to better benchmark the delivery parameter. I calibrate most of the paramaters outside the model, based on the literature and the data. The global return to scale ($\alpha + \nu$) is set to 0.85 [16], two thirds of which is directed to labor. So, the labor share ν is set to 0.5667 and the capital share α to 0.2833, which are in the range of the values commonly used in the literature.

The capital depreciation rates calibration proceeds as follows. First, I assume that local and foreign inputs depreciate at the same rate ($\delta_l = \delta_f = \delta$) for the sake of technical and computational easiness [17]. Second, recall that *capital* in the model stands for a *mixture of capital equipments and materials*. As discussed previously in section 2 .3 , the structure of imported inputs is sensitive for the analysis. However, no distinction between capital equipment and material inputs is made in the model because the mecanism is the same for both and disentangling them would only add to the state variables, making the computation harder since there is no closed form solution for the problem with the CES specification. Indeed, material inputs are virtually capital inputs with unity depreciation rate. Therefore, I compute the average depreciation rate between capital equipment and materials, weighted by the relative proportion of each in total imported inputs. Namely, $\delta = \omega_k \delta_k + \omega_m \delta_m$, where δ_k and δ_m are the depreciation rates of capital and materials respectively, and ω_k and ω_m are the proportions of capital and materials within total imported inputs respectively [18]. Finally, δ_k and δ_m are set to 10% and 100% per year, respectively.

The future discounting factor, β is set to 0.9985, corresponding to the median yearly-average risk-free interest rate of 7.8% [19] , and the disutility of labor χ is calibrated endogenously to match the labor supply to $1/3$. The parameters σ and ψ are yet to be calibrated.

I calibrate ψ internally to match the intensity of foreign inputs - $k_f/(k_l + k_f)$ - in the frictional model with that in the data. I encountered not many studies in the literature that deal with the elasticity of substitution between local and foreign inputs, σ. Boehm,

[16] See Restuccia and Rogerson (2008) and references therein.

[17] Setting the same depreciation rate for both local and foreign capital simplifies the derivation of the steady state of the frictionless model, and the computation strategy.

[18] Chang (1995) proceeds likewise to compute the depreciation of the mixture of capital equipment and capital structure. Besides,The relative share of materials and capital is not available in the data for some countries. For those countries, I use the sample average.

[19] For comparison, the average risk-free interest of the US during the same period is 1.64%, and that of the Japan is 0.1%; meanwhile the average lending rate in China is 5.47%.

Table 1: External calibration

Parameter	Symbol	Value
Capital inputs share	α	0.2833
Labor share	ν	0.5667
Depreciation rate	$\delta = \omega_k \delta_k + \omega_m \delta_m$	0.1454
Discounting factor	β	0.9985
Elasticity of substitution between local and foreign capital	$1/(1-\rho)$	0.8

Table 2: Internal calibration (Cameroon)

Parameter	Value	Moment	Target	Model
ψ	0.6250	Foreign inputs intensity	32.8%	32.9853%
χ	2.3817	Working time fraction	1/3	0.3258

Flaaen, and Pandalai-Nayar (2019) is the exception, dealing with such an estimate. They dealt with the substitutability between Japan originated material inputs and non-Japan originated material inputs in the U.S. and found an elasticity of 0.2. They concluded that the substitutability of Japanese-produced intermediates with other inputs is very low. Other papers dealt with elasticity of substitution between inputs more generally and tend to suggest that inputs are not much substitutable (Chan, 2017; Barrot and Sauvagnat, 2016; Krusell, Ohanian, Ríos-Rull, and Violante, 2000; Chang, 1995; Recka, 2013). In the numerical experiments, I set σ equal 0.8, which is a middle value within the range of the estimates in the literature as I show in annexe A.3 . I also perform robustness checks in the same annexe for other values of σ and found that the results do not change significantly for σ equal 0.5, while they are stronger with $\sigma = 1.5$ and much less stronger with $\sigma = 2$.

The delivery probability θ is calibrated as follows. I observe in the data the average number of days inputs are delayed at the borders. Following Heer and Maussner (2010), I compute the probability of delivery within a week in a country with an average delay at border μ days as $\theta(\mu) = min(1; \frac{7}{\mu})$. This is based on a simple rule of three and the principle is intuitive. If in a country inputs are delayed for two weeks (14 days) on average, then delivery occurs on average once in two weeks and the probability of delivery within a week is 1/2 [20] . Thus, $\theta(\mu)$ is unity in any case inputs clear within a week, and less than 1 otherwise. The poorer the efficiency of the border administration the longer the delays at border and the lower the probability θ. In other words, the model considers the clearance efficiency level in countries like Germany, Ireland, etc. as the best-ever that

[20] Heer and Maussner (2010) used this approach to calibrate the probability of getting a job, knowing the average unemployment duration.

can be achieved. In particular, any customs clearance delay of less than one week is not distorting in the analysis. This assumption is limited compared to the reality where even one day delay could be a big deal for a firm. For example, Hummels and Schaur (2013) found that a one-day delay triggers 0.6% to 2.1% ad-valorem lost of consumption good from the consummer perspective while parts and components are 60% more time sensitive. However, I believe that a weekly period in the model is fairly short. Generally, macroeconomic models are assumed to be annual or semi-annual. On the other hand, this way of benchmarking the analysis is more policy-relevant since it would be unrealistic to wish border administrations to eliminate delays at border totally, but one can expect them to catch up with the best pratices in the world (Montagnat-Rentier and Parent (2012); The World Economic Forum (2012); Hoffman et al. (2016)).

Table 1 summarizes the external calibration for all countries, and table 2 shows the parameters internally calibrated for the Cameroon economy [21]. The same procedure is followed for each country of the sample.

4 .2 Results

The model is solved using the value function iteration method (to solve the firm problem) and a Monte-Carlo approach [22] (to compute the stationary distribution of inputs). By construction the frictionless economy corresponds to that with a delivery probability $\theta = 1$. So the baseline is that of the situation where $\theta < 1$ for most countries, and the counterfactual consists in shutting down the delays by setting θ to 1, anything else equal. In the following, I first present the results of the numerical analyses in detail for the Cameroon economy. Then I present some numerical summaries for the sample of 41 SSAC [23], and draw some comparisons. For example Ethiopia and Uganda are both median countries in terms of average border delay, which is 19.4 days. But they differ in their reliance on foreign inputs for production: the average percentage of firms' purchases of material inputs of foreign origin (i.e. $k_f/(k_l + k_f)$) in Uganda in 2014 was only 14.3% whereas that of Ethiopia in 2015 was as much as 49.55%. This leads to different degrees of the impact of the delays in these two countries. There is also such a pattern between Nigeria and

[21]Cameroon is nearly a median country in regards to the dimensions of the economy structure that are relevant for the analysis: average border delay, and proportion of imported inputs. The relative shares of imported capital and materials data are not available for the country. I impute therefore this moment with the sample mean of countries that have the data.

[22]Adapted from the Monte-Carlo simulation developed in Heer and Maussner (2010), p.353-355

[23]I exclude South Africa for this exercise, because the WBES is run there in 2020-2021, during the COVID-19 pandemic. This undermines for sure the comparability of South Africa WBES with the other countries, if not the quality of the survey per see. For example, the average proportion of imported inputs is only 3% for that country. That reflects certainly the effect of international supply chains break implied by the pandemic.

Zimbabwe, and between Senegal and Guinea.

4 .2.1 Inputs hoarding

In Figure 8, I plot the firm's investment in foreign inputs in the baseline and in the frictionless models [24]. First, as expected new order of foreign inputs is decreasing in the firm's foreign input [25], and there is inaction when the firm's foreign inputs exceed a certain threshold. Second, foreign inputs investment is higher in the frictional model compared to that in the frictionless one. This *overinvestment* in the short run is not at odds to the statements fom propositions 1 and 3 that the delivery delays lower the return on investment. Rather, it reflects a strategy to mitigate the inputs disruptions effect of the border delays - that I will discuss soon - and depends on the nature of the inputs being imported, namely either materials or capital [26]. Most importantly, overinvestment in the short run is consistent with inputs hoarding behaviour observed in the countries under review. Business owners in Kenya, South Africa, and Nigeria have been asked how they cope with long delays due to international supply chains. They often reported that they order a large quantity of inputs far in advance[27].

Inputs hoarding is indeed a means of self-insurance against the inputs disruption risk. In figure 9 , I simulate a firm with *systematic ex-post delivery*. This means that *ex-ante* there is a non-null probability that the firm does not receive its order on time, but *ex-post* I mechanically force delivery to happen [28]. So, such a firm does not experience the delay actually, but only faces a *threat* of delay. *Ex-ante*, the firm internalizes the risk of non-delivery and places a higher investment order in foreign inputs. In the figure, the stock of foreign inputs is about 30% higher in the presence of the delivery hazard compared to the frictionless case. I introduce a three-month-delay after one year of regular delivery. Due to depreciation (or intermediates consumption), the foreign inputs stock decreases significantly, dropping 30% lower than the frictionless optimal level. Meanwhile, the pending investment orders accumulate at border.

[24] As discussed before, elimination of delays in the counterfactual is not absolute elimination of the border delays in the real world. It rather corresponds to a reduction of the border delays to a week or less in the real world.

[25] In the baseline model, the new investment is also decreasing in the firm's outstanding order, which I do not show here.

[26] In the analysis reported here, materials dominate imported inputs (62%). When I perform the same analysis assumming that imported inputs is capital goods, I find that the new investment order is lower under the delivery hazard.

[27] See The Business Year, and The Prepared

[28] Technically $\theta < 1$ (induced by average delay in the data) and $z = 1$.

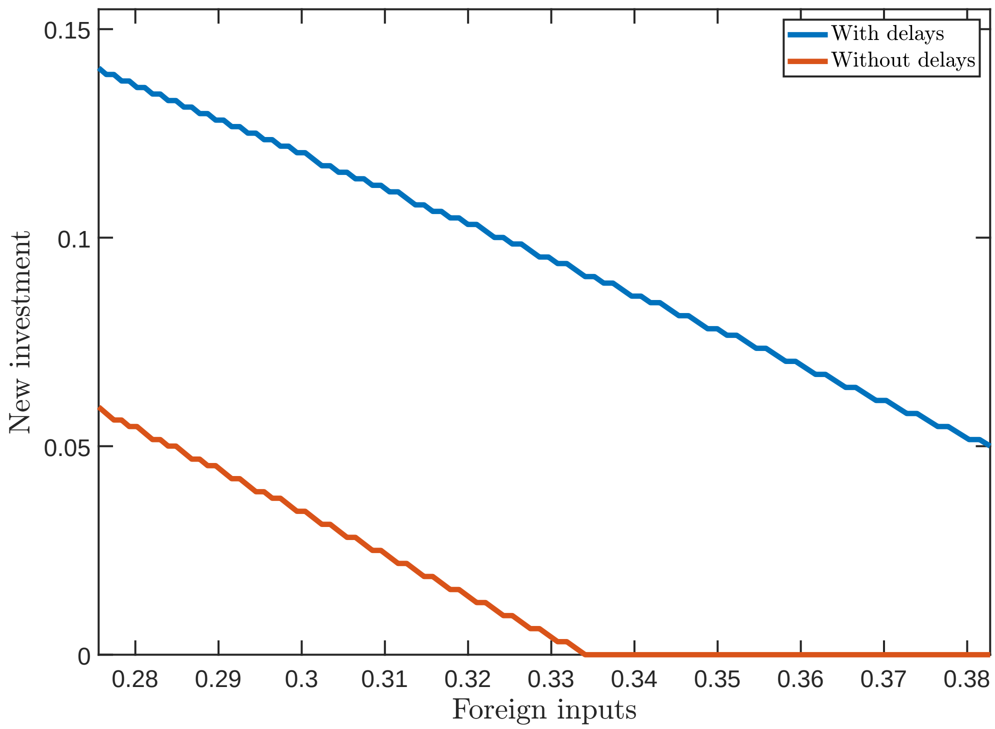

Figure 8: Effects of the border delays on ivestment.

4 .2.2 Inputs disruption by border delays

Border delays trigger uncertainty and inputs disruptions. Figure 10 depicts an example of foreign inputs holding (relative to the frictionless counterfactual) by a firm, through time, in perspective with its delivery realizations (on the right-hand y-axis). When foreign inputs clear customs, they are delivered and the firm's foreign inputs holding increases. On the other hand, when they fail to clear customs there is no delivery and the firm's foreign inputs decrease. Importantly, the fluctuations of the delivery process lag behind that of the foreign inputs, showing that when border delay hits, the firm will still have foreign inputs for some time before running out.

figure 11 shows the steady state distribution of initialy identical (simulated) firms. It shows that the delays affect firms differently. Even though they all face the same ex-ante probability of delay, the actual realization of the delay differs potentially from one firm to another. Therefore, delays also generate heterogeneity in the effective marginal cost of investment among the firms. In another project, we investigate the extent of this *misallocation* effects of border delays on firms in SSA.

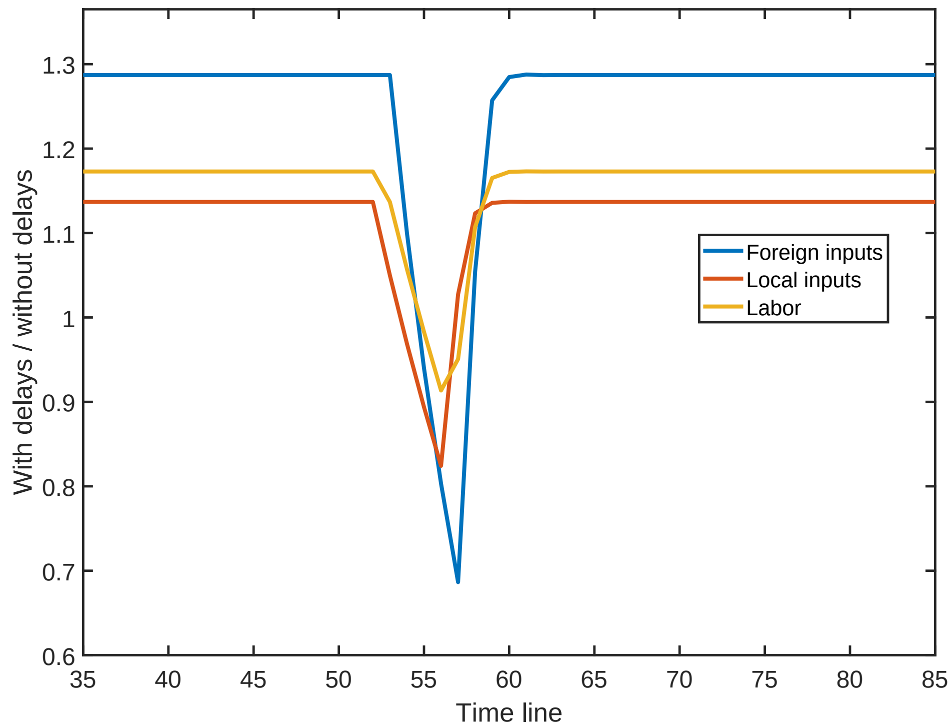

Figure 9: Foreign inputs under delay risk and ex-post systemic delivery

4 .2.3 Macroeconomic effects of the border delays in steady state: Cameroon

Figure 12 shows the effects of eliminating the border delays on some macroeconomic aggregates, in steady state. Reducing the average border delay in Cameroon from 23.4 days to one week or less would increase the foreign inputs by 18.5%, and the local input by 2.7%. As a higher amount of the foreign and local inputs raises the marginal productivity of labor, the labor demand and the equilibrium wage increase as well. The increase of the employment is about 3.2%, while that of the wage is about 1.9%. Eventually, aggregate production would increase by as much as 4.9%, and welfare as measured by consumption by 3.6%. These sizeable quantitative effects of the border delays on the production chain are triggered not only by the relatively long delays at border in the country, but also by the preponderance of materials within the imported inputs (62%).

4 .2.4 Macroeconomic effects of the border delays in steady state: other countries

I follow the same calibration steps described for Cameroun above to calibrate the model for each of the remaining countries. The results are reported in table 3 .

Seven among the considered countries – Botswana, Djibouti, Eswatini, Lesotho, Namibia,

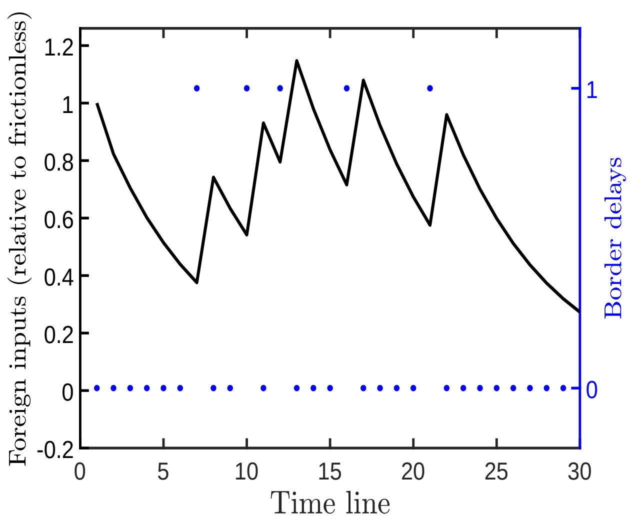

Figure 10: Example of a firm subject to delays

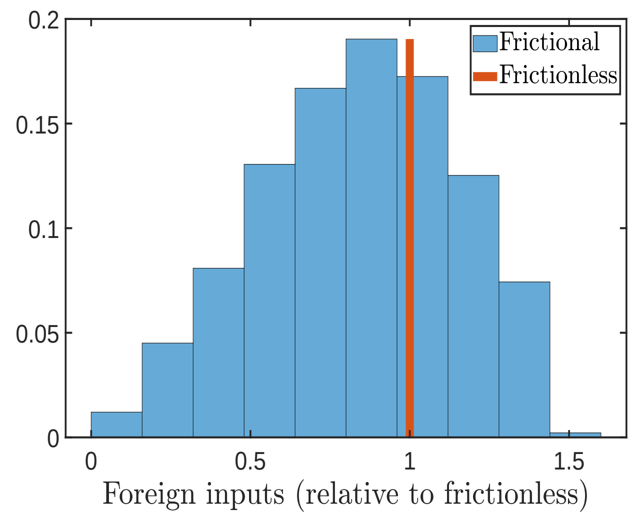

Figure 11: Steady state distribution of foreign inputs

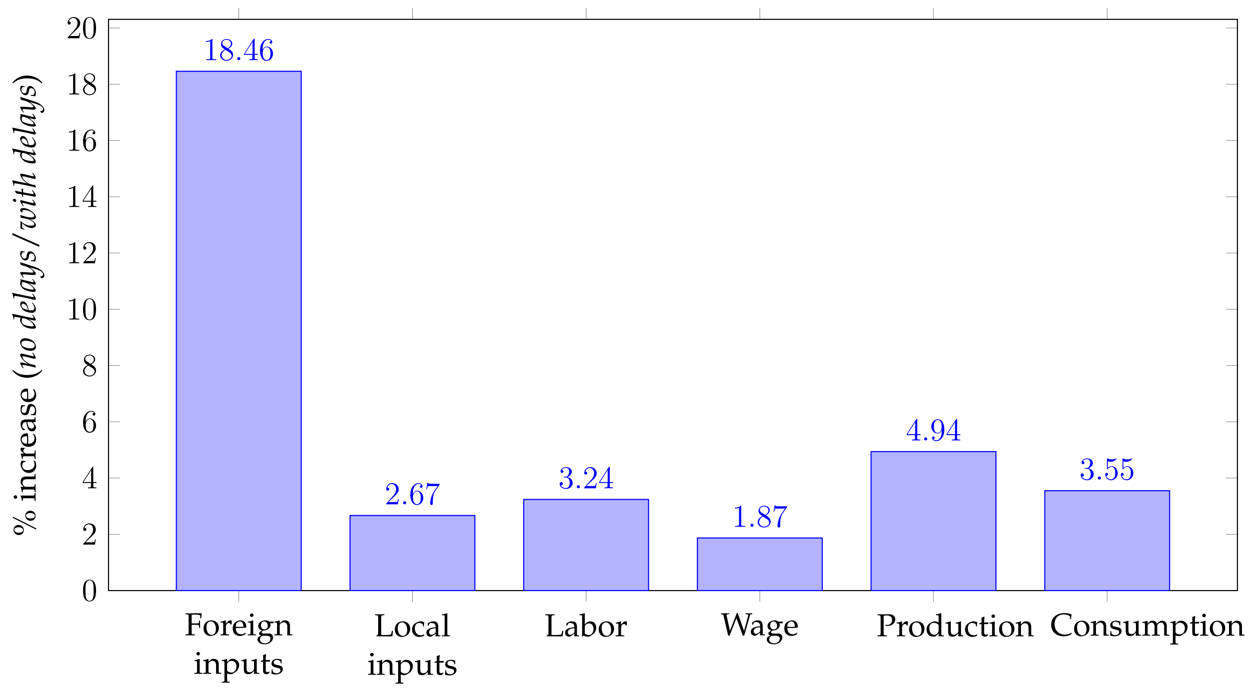

Figure 12: Macoreconomic effects of removing border delays. The figure shows the percentage variation of the aggregates in the frictionless conterfactual relative to their frictional value.

Somalia, and Sudan – have displayed an average delay at border less than a week. The delivery probability parameter for them is calibrated to 1; therefore they do not incur any lost due to border delay in this analysis. For the remaining countries, the potential gain from reducing border delays to one week or less in terms of production (respectively consumption) varies from 0.1% (respectively -0.4%) to 10.2% (respectively 6.4%), with a median of 2.7% (respectively 1.7%). The potential gain in terms of employment is also sizeable, more than 3% in many cases.

Importantly, the effects of the border delays vary with the economies' fundamentals (proportion of imported inputs and proportion of materials in imported inputs) as I discussed previously. For example, Ethiopia and Uganda have approximately the same average border delays of 19.4 days. However, they have different fundamentals. The former has 17.8% imported inputs, 53% of which are material goods, while the later has 13.6% imported inputs, 67% of which are material goods. In the results, the potential gain in terms of production (respectively consumption) from reducing border delays to one week or less is 1.3% (respectively 0.4%) for Ethiopia, and 2.8% (respectively 2.1%) for Uganda. Similar comments can be made between Nigeria and Zimbabwe, or between Senegal and Guinea.

The poorest performance in terms of border delay is found in Burundi-2014, with 32.4 days delay at border on average. That corresponds to 22% probability of delivery within a week. The resulting potential gains from removing the border delays amount to an increase of the foreign inputs by 29.8%, the local inputs by 6.8%, aggregate employment by 2.6%, aggregate production by 8.3%, and consumption by 4.2%. On the other hand, the *best-yet-distorting* performance is met in Liberia-2017, with 8 days delay on average during clearance process, and an implied probability of 88% to clear and deliver within a week. The potential gains from removing the border delays in this case amount to an increase of the foreign inputs, the local inputs, aggregate production and consumption by 0.1%, while aggregate employment decreases by 2.5%. The greatest gain, in terms of production, from eliminating the border delay is achieved in Chad, with more than 10% increase compared to the frictional case.

Table 3: Macroeconomic effects of the border delays in steady state per country

Country	Economy fundamentals				Gain (in%) from ↓ border delays to ≤ 1 week					
	Avg. delay	Foreign inputs (%)	Capital Proportion	Materials Proportion	Foreign inputs	Local inputs	Labor	Wage	Prod.	Cons.
Burundi	32.39	49.77	0.29	0.71	29.84	6.79	2.65	6.25	8.31	4.15
Mali	31.52	47.45	0.38	0.62	31.95	9.00	2.56	5.00	9.98	5.97
Chad	30.76	41.27	0.38	0.62	32.46	10.02	5.77	4.38	10.16	6.43
Togo	30.56	43.50	0.22	0.78	30.28	7.24	3.07	6.25	7.95	4.00
Tanzania	29.13	32.95	0.43	0.57	28.89	8.80	3.62	3.75	7.91	4.78
Niger	28.25	42.92	0.38	0.62	24.21	-2.11	0.01	4.38	4.22	1.98
Côte-d'ivoire	27.06	33.86	0.33	0.67	23.91	7.36	2.60	3.75	6.33	3.47
Mauritania	26.72	48.84	0.38	0.62	18.17	6.99	2.46	2.50	7.20	5.03
Cameroon	23.39	32.84	0.38	0.62	18.46	2.67	3.24	1.87	4.94	3.55
Kenya	22.52	27.94	0.37	0.63	21.43	7.59	1.63	2.50	5.89	3.59
Mozambique	21.58	28.40	0.39	0.61	13.37	3.67	1.99	2.50	2.20	0.44
Gambia	21.39	47.52	0.22	0.78	14.30	4.74	0.52	2.50	4.32	2.20
Capeverde	20.51	47.42	0.41	0.59	10.22	3.69	1.01	1.88	3.33	1.73
Eritrea	20.12	23.22	0.38	0.62	11.66	-0.45	-0.89	1.88	0.44	-0.43
Malawi	20.01	49.37	0.38	0.62	16.92	6.27	1.40	2.50	5.83	3.43
Ethiopia	19.49	17.79	0.47	0.53	10.73	1.94	-1.45	1.25	1.27	0.39
Uganda	19.44	13.56	0.33	0.67	11.81	2.89	1.41	0.63	2.76	2.13
Guinea	18.09	62.81	0.38	0.62	5.58	1.00	-0.62	1.87	1.16	-0.07
Senegal	17.93	18.53	0.31	0.69	16.15	0.72	0.21	1.88	1.38	0.32
Burkina-Faso	16.38	51.84	0.43	0.57	7.47	2.96	1.68	1.25	2.62	1.45
Madagascar	15.50	21.79	0.30	0.7	14.15	3.46	2.84	0.63	3.87	3.03
South Sudan	15.10	57.31	0.36	0.64	6.03	2.32	2.76	1.25	2.03	0.97
Ghana	14.79	47.74	0.42	0.58	6.32	2.23	2.32	1.25	1.75	0.67
Zambia	14.47	26.32	0.38	0.62	8.82	5.48	1.74	0.00	4.59	3.87

Continues on next page . . .

Table 3 – continued from previous page

Country	Economy fundamentals				Gain (in%) from ↓ border delays to ≤ 1 week					
	Avg. delay	Foreign inputs (%)	Capital Proportion	Materials Proportion	Foreign inputs	Local inputs	Labor	Wage	Prod.	Cons.
Rwanda	14.27	36.17	0.39	0.61	2.19	0.73	-1.58	0.63	0.46	0.10
Benin	14.06	52.70	0.23	0.77	6.09	2.64	2.03	1.25	2.21	1.15
Gabon	12.59	62.97	0.38	0.62	3.71	1.68	0.90	0.63	1.54	0.91
Sierra Leone	12.48	30.07	0.38	0.62	3.53	1.45	0.12	0.63	0.87	0.37
CAR	11.86	53.66	0.38	0.62	2.77	1.98	2.69	0.00	1.88	1.64
mauritius	11.70	43.49	0.37	0.6277	5.98	2.56	1.84	0.00	3.08	2.60
Angola	11.43	27.36	0.57	0.43	1.15	-0.82	1.72	0.00	0.06	0.25
Zimbabwe	8.99	38.25	0.39	0.61	0.05	0.29	0.53	0.00	0.22	0.24
Nigeria	9.00	16.48	0.55	0.45	0.12	0.11	-2.75	0.00	0.10	0.10
Liberia	8.08	34.33	0.38	0.62	0.13	0.12	-2.54	0.00	0.12	0.13
somalia	6.85	50.59	0.38	0.62	-	-	-	-	-	-
Sudan	6.40	35.46	0.36	0.64	-	-	-	-	-	-
Namibia	5.44	23.21	0.33	0.67	-	-	-	-	-	-
Djibouti	5.09	62.02	0.38	0.62	-	-	-	-	-	-
Botswana	4.76	61.65	0.31	0.69	-	-	-	-	-	-
Lesotho	4.42	42.09	0.38	0.62	-	-	-	-	-	-
Eswatini	4.04	29.64	0.30	0.7	-	-	-	-	-	-
Min	4.04	13.56	0.22	0.43	0.05	-2.11	-2.75	0.00	0.06	-0.43
Max	32.39	62.97	0.57	0.78	32.46	10.02	5.77	6.25	10.16	6.43
Median	15.50	41.27	0.38	0.62	11.19	2.66	1.70	1.56	2.69	1.69
Mean	16.79	39.39	0.37	0.63	12.91	3.41	1.34	1.91	3.56	2.08

4 .2.5 Discussion

The effects of the border delays estimated by my model in this paper are fairly sizeable. However, it is worth highlighting that they apply only to the formal economy of the related countries. That is because the WBES data are only representative of the formal economy of the countries where the surveys took place. Thus, in the case of Cameroon for example, my model predicts that, *ceteris paribus*, reducing the average border delay from 23.4 days to one week or less (70% reduction) would imply 4.9% increase in the *formal economy*'s production.

Though the type of data needed to empirically test the results of my model [29] are not currently available to my knowledge (which justifies the need for the structural model developed in the paper), the model is able to replicate some empirical facts, especially the negative correlation between the average border delay and the real GDP per capita, and the inputs hoarding. If anything, the estimated effects of the border delays here would rather be conservative than overestimated, because my model builds on many conservative assumptions. For example, the price of foreign inputs is likely higher than that of local inputs in reality. So assuming equal price for both as I do in the model, due to lack of data on price of imported inputs, is likely to bias the effects downwardly. Likewise, the omission of some additional costs directly related to the border delays – including inventory keeping costs, depreciation during the process (my model takes into account only depreciation during production), and the effect of the delays on customers' relationship (Hummels and Schaur, 2013; Djankov et al., 2010) – is also likely to bias the estimated effects downwardly. On the other hand, the predictions of my model lie well in the range one could expect from the literature. Djankov et al. (2010) estimated that a reduction of exports delays by just one day would increase exports by 1%. Considering that export is approximately 25% of GDP in Sub-saharan Africa [30] , this amounts to 4% increase of GDP. Moreover, they found that the effects are stronger in SSA. For example, if Uganda reduced its delay from 58 days to 27, exports would be expected to increase by 31% according to the authors. [31]

[29]To accuratly and empirically estimate the effects of border delays on macroeconomic outcomes like GDP, employment and investment, one would need panel data on the border delays and the portion of the aggregates related only to the formal economy as discussed in the previous paragraph. In addition to the need to control for key factors (the classic determinants of economic growth), one would need to control for time and country specific effects.

[30]See https://wits.worldbank.org/CountryProfile/en/SSF

[31]More directly related, Minor and Tsigas (2008) estimated the effect of imports delays on GDP in many regions of the world using a computational general equilibrium (CGE) model. Their results show that 50% reduction of import delay (from 24.8 days to 12.4) in sub saharan Africa would result in 4.2% increase in real GDP.

5 Conclusion and recommandations

In this paper I show both analytically and quantitatively that foreign inputs delays at borders affect negatively firms and slow down economic growth. To mitigate the effects of the border delays on inputs disruption the firms would place higher investment order at a time.

My analyses and findings suggest that the leaders of the sub-saharan african countries should take the appropriate measures to hasten clearence procedures at borders. Thereby, they would reduce the investment costs of inputs importing firms and unleash economic growth. My recommandations echo the outcomes of many studies from the trade literature [32]. Since "modernizing border administration is, relatively speaking, less costly, less time consuming and politically easier than other interventions [. . .], border administration appears to be an appealing choice for countries wishing to implement speedy reforms; in other words, a *low-hanging fruit* for policymakers" (The World Economic Forum and The Global Alliance for Trade Facilitation, 2016). So, why do the policy makers not just implement that ?

References

ALTUG, S. (1989): "Time-to-Build and Aggregate Fluctuations: Some New Evidence," *International Economic Review*, 30, 889–920, publisher: The Economics Department of the University of Pennsylvania, and the Osaka University Institute of Social and Economic Research Association.

ARAÙJO, E. (2012): "Investment-specific shocks and real business cycles in emerging economies: Evidence from Brazil," *Economic Modelling*, 29, 671–678.

BABIN, F. G., C. E. WILLIS, AND P. G. ALLEN (1982): "Estimation of Substitution Possibilities between Water and Other Production Inputs," *American Journal of Agricultural Economics*, 64, 148–151.

BARKA, H. B. (2012): "Border Posts, Checkpoints, and Intra-African Trade: Challenges and Solutions," Tech. rep., The African Development Bank.

[32] See Moïsé and Sorescu (2013); Montagnat-Rentier and Parent (2012); The World Economic Forum (2014); The World Economic Forum and The Global Alliance for Trade Facilitation (2016); Hoffman et al. (2016).

BARROT, J.-N. AND J. SAUVAGNAT (2016): "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks," *Quarterly Journal of Economics*, 131, 1543–1592.

BEN ZEEV, N. AND H. KHAN (2015): "Investment-Specific News Shocks and U.S. Business Cycles," *Journal of Money, Credit and Banking*, 47, 1443–1464.

BOEHM, C. E., A. FLAAEN, AND N. PANDALAI-NAYAR (2019): "Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Toōhoku Earthquake," *Review of Economics and Statistics*, 101, 60–75.

BONADIO, B., Z. HUO, A. A. LEVCHENKO, AND N. PANDALAI-NAYAR (2021): "Global supply chains in the pandemic," *Journal of International Economics*, 133, 103534.

CASARES, M. (2006): "Time-to-build, monetary shocks, and aggregate fluctuations," *Journal of Monetary Economics*, 53, 1161–1176.

CHAN, M. (2017): "How Substitutable Are Labor and Intermediates?" University of Minnesota.

CHANG, L.-J. (1995): "Business cycles with distorting taxes and disaggregated capital markets," *Journal of Economic Dynamics and Control*, 19, 985–1009, publisher: Elsevier BV.

CHEN, K. AND E. WEMY (2015): "Investment-specific technological changes: The source of long-run TFP fluctuations," *European Economic Review*, 80, 230–252.

CHRISTIANO, L. J. AND R. M. TODD (1996): "Time to Plan and Aggregate Fluctuations," *Federal Reserve Bank of Minneapolis Quarterly Review*, 20, 14–27.

COOLEY, T. F. AND V. QUADRINI (2001): "Financial Markets and Firm Dynamics," *American Economic Review*, 91, 1286–1310, publisher: American Economic Association.

DISSOU, Y. AND R. GHAZAL (2010): "Energy Substitutability in Canadian Manufacturing Econometric Estimation with Bootstrap Confidence Intervals," *The Energy Journal*, 31, 121–148.

DJANKOV, S., C. FREUND, AND C. S. PHAM (2010): "Trading on Time," *The Review of Economics and Statistics*, 92, 166–173.

DOGAN, A. (2019): "Investment specific technology shocks and emerging market business cycle dynamics," *Review of Economic Dynamics*, 34, 202–220.

Greenwood, J., Z. Hercowitz, and P. Krusell (1997): "Long-Run Implications of Investment-Specific Technological Change," *The American Economic Review*, 87, 342–362.

——— (2000): "The role of investment-specific technological change in the business cycle," *The European Economic Review*, 44, 91–115.

Guerrieri, L., D. Henderson, and J. Kim (2010): "Interpreting Investment-Specific Technology Shocks," *International Finance Discussion Papers*, 2010, 1–46.

Heer, B. and A. Maussner (2010): "Dynamic general equilibrium modeling : computational methods and applications," *2nd ed., corr. print. 2010.*, 329–387.

Hoffman, A. J., S. Grater, A. Schaap, J. Maree, and E. Bhero (2016): "A simulation approach to reconciling customs and trade risk associated with cross-border freight movements," *South African Journal of Industrial Engineering*, 27, 251–264.

Hummels, D. L. and G. Schaur (2013): "Time as a Trade Barrier," *American Economic Review*, 103, 2935–2959.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2010): "Investment shocks and business cycles," *Journal of Monetary Economics*, 57, 132–145.

Krusell, P., L. E. Ohanian, J.-V. Ríos-Rull, and G. L. Violante (2000): "Capital-skill Complementarity and Inequality: A Macroeconomic Analysis," *Econometrica*, 68, 1029–1053, place: Oxford, UK and Boston, USA Publisher: Blackwell Publishers Ltd.

Kydland, F. E. and E. C. Prescott (1982): "Time to build and aggregate fluctuations," *Econometrica : journal of the Econometric Society, an internat. society for the advancement of economic theory in its relation to statistics and mathematics*, 50, 1345–1370.

Lessard, S. (2014): "Processus stochastiques," *Editions Ellipses*, 99–104.

Ma, X. (2018): "Investment specific technology, news, sentiment, and fluctuations: Evidence from nowcast data," *Journal of Macroeconomics*, 57, 55–70.

Meier, M. (2018): "Supply Chain Disruption, Time to Build, and the Business Cycle," .

Miller, N. J., J. S. Bergtold, and A. M. Featherstone (2019): "Economic elasticities of input substitution using data envelopment analysis," *PLOS ONE*.

Minor, P. and M. Tsigas (2008): "Impacts of Better Trade Facilitation in Developing Countries: Analysis with a New GTAP Database for the Value of Time in Trade," Research report, Nathan Associates Inc.

MONTAGNAT-RENTIER, G. AND G. PARENT (2012): "Customs administration reform and modernization in Francophone sub-Saharan Africa, 1995-2010," *Revue d'économie du développement*, 20, 105–146.

MOÏSÉ, E. AND S. SORESCU (2013): "Trade Facilitation Indicators: The Potential Impact of Trade Facilitation on Developing Countries' Trade," OECD Trade Policy Papers 144, OECDE.

OCEAN SHIPPING CONSULTANTS, LTD. (2008): "DIAGNOSTICS DES INFRASTRUCTURES NATIONALES EN AFRIQUE," Tech. rep., Ocean Shipping Consultants, Ltd.

OECD (2005): "The Economic Impact of Trade Facilitation," OECD Trade Policy Papers 21, OECD.

PLANE, P. (2021): "What Factors Drive Transport and Logistics Costs in Africa?" *Journal of African Economies*, 30, 370–388.

RECKA, L. (2013): "Estimation of the elasticity of substitution of production factors in Central and Eastern European economies," Charles University Environment Center.

RESTUCCIA, D. AND R. ROGERSON (2008): "Policy distortions and aggregate productivity with heterogeneous establishments," *Review of Economic Dynamics*, 11, 707–720.

ROUWENHORST, K. G. (1991): "Time to build and aggregate fluctuations: A reconsideration," *Journal of Monetary Economics*, 27, 241–254, publisher: Elsevier BV.

THE WORLD ECONOMIC FORUM (2012): "The global enabling trade report 2012: reducing supply chain barriers ; highlights," Tech. rep., The World Economic Forum, OCLC: 931362595.

——— (2014): "The Global Enabling Trade Report 2014," Tech. rep., The World Economic Forum.

THE WORLD ECONOMIC FORUM AND THE GLOBAL ALLIANCE FOR TRADE FACILITATION (2016): *The Global Enabling Trade Report*, World Economic Forum, and Global Alliance for Trade Facilitation.

UNECA (2013): "Building Trade Capacities for Africa's Transformation: A critical review of Aid for Trade," Tech. rep., UNECA.

VALENSISI, G. AND R. T. LISINGE (2013): *Trade facilitation from an African perspective*, United Nations, Economic Commission for Africa.

A Annexes

A.1 Proofs

A.1.1 Proposition 1

Case 1: No delay on investment delivery

$$\begin{aligned} NPV_0(i_{f,t}) &= -i_{f,t} + \beta i_{f,t}^{\alpha} + \beta^2\left[(1-\delta_f)i_{f,t}\right]^{\alpha} + \beta^3\left[(1-\delta_f)^2 i_{f,t}\right]^{\alpha} + \cdots + \beta^j\left[(1-\delta_f)^{j-1} i_{f,t}\right]^{\alpha} + \ldots \\ &= -i_{f,t} + \sum_{j=1}^{\infty}\beta^j\left[(1-\delta_f)^{j-1} i_{f,t}\right]^{\alpha} \\ &= -i_{f,t} + \beta i_{f,t}^{\alpha}\sum_{j=1}^{\infty}\beta^{j-1}(1-\delta_f)^{\alpha(j-1)} \\ &= -i_{f,t} + \beta i_{f,t}^{\alpha}\sum_{j=0}^{\infty}\left[\beta(1-\delta_f)^{\alpha}\right]^{(j)} \\ NPV_0(i_{f,t}) &= -i_{f,t} + \frac{\beta}{1-\beta(1-\delta_f)^{\alpha}} i_{f,t}^{\alpha} \end{aligned}$$

Case 2: investment is subject to delivery delay

Pose: $V^{(j)}(i_{f,t}) = \beta^j i_{f,t}^{\alpha} + \beta^{j+1}\left[(1-\delta_f)i_{f,t}\right]^{\alpha} + \beta^{j+2}\left[(1-\delta_f)^2 i_{f,t}\right]^{\alpha} + \cdots + \beta^{j+k}\left[(1-\delta_f)^k i_{f,t}\right]^{\alpha} + \ldots$ the discounted value of future revenues from $i_{f,t}$, if $i_{f,t}$ is delivered at time $t+j$; and $m_j = (0, 0, ..., 1, 0, 0, ...)$ the discrete probability distribution that places weight 1 in the j^{th} period. m_j corresponds to a delay of j periods with certainty. This is the case of the most common *time to build* (Kydland and Prescott (1982), Altug (1989), Rouwenhorst (1991), Chang (1994), Casares (2006), Chang (1995), etc.). Moreover, any delay system caracterized by a discrete probability distribution $m = (p_1, p_2, ..., p_k, ...)$ is a convexe combination of the elements of the canonical base $\{m_j\}_{j=1}^{\infty}$. Thus:

$$\begin{aligned} NPV_0(i_{f,t}) &= -i_{f,t} + V^{(1)}(i_{f,t}) = NPV_{m_1}(i_{f,t}), \quad and \\ NPV_m(i_{f,t}) &= -i_{f,t} + \sum_{k=1}^{\infty} p_k V^{(k)}(i_{f,t}) \end{aligned}$$

Finally, notice that by construction $V^{(j+k)}(i_{f,t}) = \beta^k V^{(j)}(i_{f,t}) \leq V^{(j)}(i_{f,t}), \forall k \geq 0$. Therefore $V^{(1)}(i_{f,t}) = \max_{j\geq 1} V^{(j)}(i_{f,t})$, and $NPV_0(i_{f,t}) = NPV_{m_1}(i_{f,t}) = \max_{m} NPV_m(i_{f,t})$. *QED*.

A.1.2 Proposition 2

From proof A.1.1 it is clear that $NPV_m(i_{f,t})$ is invariant with respect to m if $\beta = 1$, because then $V^{(j+k)}(i_{f,t}) = \beta^k V^{(j)}(i_{f,t}) = V^{(j)}(i_{f,t})$, $\forall k \geq 0$. That is delivery delay doesn't matter if the future is not discounted. This result is intuitive however.

A.1.3 Proposition 3

Recall the firm problem stated in equation (5):

$$\begin{aligned} V(k_{f,t}) = \max_{\tilde{O}_t} \Big\{ & \pi(k_{f,t}) - \tilde{O}_t + O_t + \beta \Big(\theta V \Big[(1-\delta_f) k_{f,t} + \tilde{O}_t, 0 \Big] + \\ & (1-\theta) V \Big[(1-\delta_f) k_{f,t}, \tilde{O}_t \Big] \Big) \Big\} \\ & \text{s.t. } \tilde{O}_t \geq O_t \end{aligned}$$

If we assume an interior solution we can apply lagrangian approach to derive the optimal $\tilde{O}_f^*$. Taking the FOC and by applying the envelop condition, we get

$$\tilde{O}_f^* = \left[\frac{1-\beta(1-\theta)}{\alpha\beta\theta} \right]^{\frac{1}{\alpha-1}} - (1-\delta_f) k_f.$$

We further impose that $\tilde{O}_f^* = i_f^* = \delta_f k_f^*$ in steady state, and get $k_f^* = \left[\frac{1-\beta(1-\theta)}{\alpha\beta\theta} \right]^{\frac{1}{\alpha-1}}$.

i) Then take the derivative of k_f^* with respect to θ and get the result:

$$\frac{\partial k_f^*}{\partial \theta} = \frac{1+\beta\theta}{\alpha\beta\theta(1-\alpha)} \left[\frac{1-\beta(1-\theta)}{\alpha\beta\theta} \right]^{\frac{2-\alpha}{\alpha-1}} \geq \mathbf{0}. \ QED.$$

ii)

$$\frac{\partial k_f^*}{\partial \beta} = \frac{1}{\alpha\theta\beta^2(1-\alpha)} \left[\frac{1-\beta(1-\theta)}{\alpha\beta\theta} \right]^{\frac{2-\alpha}{\alpha-1}} \geq \mathbf{0}. \ QED.$$

A.2 Frictionless economy steady state derivation

In the frictionless economy, we have[33] $z = 1$, $O_f = 0$, $k_f' = (1-\delta_f)(k_f + i_f)$, $\forall$ t. So, $i_f = \Delta k_f' - k_f$ and $k_f + i_f = \Delta k_f$, where $\Delta = \frac{1}{1-\delta_f}$. Then the problem of the firm is:

$$V(k_f) = \max_{k_l, k_f'} \ \left\{ \left[-1 + \beta(1-\delta_l) \right] k_l - (\Delta k_f' - k_f) + \beta \left[\pi(k_l, \Delta k_f') + V(k_f') \right] \right\} \tag{11}$$

[33]We recall that a period begins after the production round in our model.

We pose $f(k_l, k_f) = [\psi(Ak_f)^\rho + (1-\psi)(Bk_f)^\rho]^{\frac{1}{\rho}}$, derive the first order conditions of (11) and apply the envelop condition to get:

$$\begin{cases} \beta\tilde{\Gamma}k_l^{\rho-1}\left[f(k_l, \Delta k_f')\right]^{\tilde{\alpha}-\rho} = 1-\beta(1-\delta_l) \\ \beta\hat{\Gamma}(\Delta k_f')^{\rho-1}\left[f(k_l, \Delta k_f')\right]^{\tilde{\alpha}-\rho} = \Delta-\beta \end{cases}$$

where $\tilde{\Gamma} = \tilde{\alpha}\Gamma\psi A^\rho$, $\hat{\Gamma} = \tilde{\alpha}\Gamma(1-\psi)B^\rho$. Finally, solving this system yields $k_f' = \left(\dfrac{\Delta-\beta}{\hat{\hat{\Gamma}}}\right)^{\frac{1}{\tilde{\alpha}-1}}$, $k_l = \tilde{\tilde{\Gamma}}\Delta k_f'$, and $i_f = (\Delta-1)k_f'$, with $\tilde{\tilde{\Gamma}} = \left[\dfrac{(1-\beta(1-\delta_l))\,\Delta\hat{\Gamma}}{(\Delta-\beta)\tilde{\Gamma}}\right]^{\frac{1}{\rho-1}}$ and $\hat{\hat{\Gamma}} = \beta\hat{\Gamma}\left[f(\tilde{\tilde{\Gamma}}, 1)\right]^{\tilde{\alpha}-1}\Delta^{\tilde{\alpha}}$.

A.3 Elasticity of substitution between inputs and Robustness checks for σ

The elasticity of substitution σ between local and foreign inputs is a potentially sensitive parameter for the quantitative analyses as shown in propositions 4 and 5. But we barely have estimate for the substitutability of inputs along this particular taxonomy in the literature, let alone for the specific countries this paper is interested in. Because of data constraints, I can not either estimate the elasticity of substitution in this paper. However, there are estimates of the substitutability between various taxonomies of inputs in the literature that converge to show that inputs are mostly complement than substitute. Considering the information in table 4 , the value of 0.8 I pick for the analyses lies well withing the range of the estimates made in the literature. In addition, I complement the analysis with robustness checks with different values of the elasticity of substitution, σ. The results are reported in table 5 . The estimates with $\sigma = 0.8$ are fair. Note that in the experiments shown in table 5, the relative shares of local and foreign inputs are not held constant, because I calibrate them each time to match the shares in the data. Even so, the effects of the border delays are much less stronger with $\sigma = 2$.

Table 5: Robustness checks with respect to σ (Cameroon)

σ	Foreign inputs	Local inputs	Labor	Wage	Production	Consumption
0.5	17.93	5.83	1.09	3.75	4.09	1.74
0.8	18.46	2.67	3.24	1.87	4.94	3.55
1.5	22.91	2.87	3.79	1.25	6.19	4.53
2	15.77	-3.60	-1.49	1.22	1.25	0.38

Table 4: Estimates of the elasticity of substitution between inputs in the literature

Inputs	Elasticity of substitution	Paper
Japan-originated and non-Japan-originated inputs	0.2	Boehm et al. (2019)
Material inputs	0.3, 0.5 or 1.5	Barrot and Sauvagnat (2016)
Capital equipment and unskilled labor	1.67	Krusell et al. (2000)
Capital equipment and skilled labor	0.67	
Capital equipment and capital structure	1.1	Chang (1995)
Water and other factors (capital, production workers and non-production workers)	Complements or very low substitutes	Babin, Willis, and Allen (1982)
Seed and fertilizer	0.28	Miller, Bergtold, and Featherstone (2019)
Energy and non-energy inputs	≤ 0.54	Dissou and Ghazal (2010)
Labor and materials	1.5 to 4	Chan (2017)
Labor and energy	Perfect	Recka (2013)
The composit of labor and energy, and capital	0.13	