Trade and Shocks Transmission in a Regional Trade Agreement

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Abstract

Using an IV strategy, we show that productivity shocks in an origin country, namely climatic and political shocks, affect inflation in the destination country through trade in Africa. Second, we extend an international trade model à la Eaton and Kortum (2002) to include money to discuss how Regional Trade Agreements (RTA) amplify shock transmission across countries. We use the model to explore how the African Continental Free Trade Agreement (AfCFTA), adopted in 2021, could affect countries' inflation and its implications for their monetary policy.

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1 Introduction

Despite an increasing number of Regional Trade Agreements (RTA), Africa's intra-regional trade was 18% in 2020, compared to 68% in Europe and 58% in Asia (United-Nations, 2022)[1]. To increase Regional trade, African countries adopted the African Continental Free Trade Area (AfCFTA) in 2021, the largest African RTA covering 54 out of 55 countries [2]. With the implementation of AfCFTA, regional trade is projected to increase significantly (Maliszewska et al., 2020; ElGanainy et al., 2023; World Trade Organization, 2023). Most studies project a 15 to 25% increase in trade over a decade following its full implementation (AfBD, 2019; IMF, 2019; UN, 2022) [3]. The recent trade war, which is disrupting traditional global supply chains and increasing protectionism in developed markets, presents a potential opportunity for African countries to strengthen intra-African trade and reposition themselves as alternative trade partners.

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[1]See the cumulative number of RTAs among African countries in figure 4.

[2]Only Eritrea has not signed yet the AfCFTA to date (ElGanainy et al., 2023)

[3](Maliszewska et al., 2020) states that trade could increase by 52% in 2035 and more than double

However African countries are more exposed to many productivity shocks, namely political and climatic shocks compared to other regions in the world (Hassler and Krusell, 2012; IPCC, 2022, 2023). In addition, Herrendorf et al. (2022) documents that low-income countries have a huge agricultural sector with low productivity. Therefore, understanding the effect of trade in productivity shocks transmission across African countries is crucial for policymakers, especially for Central Banks monetary policy since the role of monetary policy, in general, is about achieving price stability and managing economic fluctuations. Indeed, one characteristic of African countries is that they are less industrialized and produce mainly raw materials. Consequently, by affecting their production, climate change could affect their exports and therefore prices with their African trading partners. Given the anticipated surge in trade and the region's exposure to the shocks mentioned above, our research focuses on two main questions: how does trade contribute to the transmission of productivity shocks across African countries? And how does a Regional Trade Agreement, in our case AfCFTA, amplify the transmission of these shocks?

To address these questions, we employ an instrumental variable (IV) strategy to show how trade transmits climatic and political shocks from exporting countries to domestic prices within African countries. We rely on two primary data sources for this analysis. To capture climatic shocks, we use the PRIO-GRID framework, which provides global temperature data (Tollefsen et al., 2012), focusing on agricultural land in African countries. For socio-political shocks, we use the Social Conflict Analysis Database (SCAD) from Idean et al. (2012), using the number of fatalities from protests, riots, strikes, political and military conflicts, and other social disturbances. Following Jones and Olken (2010), we justify the exclusion restriction of these instruments by arguing that the temperature in the origin country does not directly affect inflation in the destination country, except in cases where the two countries are contiguous. However, we propose that trade acts as an indirect channel of transmission, which is the focal point of our analysis. Similarly, we argue that there is no direct link between the number of deaths due to sociopolitical conflicts in the origin country and inflation in the destination country. Nevertheless, violent conflicts may reduce exports, representing a productivity (or supply) shock likely to affect prices in the destination country. The validity of these instruments is discussed in Section 2.3.

We begin by assessing the relevance of our instruments, examining whether they induce variation in trade flows across African countries. We find a significant negative association between higher temperatures on agricultural land in the origin country and its export flows. We observe similar results for the number of deaths resulting from social conflicts. We then investigate the inflationary effects of trade variations driven by these negative productivity shocks in the origin country on imports to the destination country. The results indicate that a 1% decrease in imports, caused by either higher temperatures or violent social conflicts in the origin country, leads to a 0.26 to 0.58 percentage point increase in inflation in the destination country, depending on the specification and sample used.

In the second part of the paper, we develop a dynamic stochastic model of international trade à la Eaton and Kortum (2002) that incorporates money to study how Regional Trade Agreements (RTAs) amplify the transmission of productivity shocks to

after full implementation of AfCFTA.

inflation. We have two main findings from the model. First, a trading partner's productivity shocks significantly affect the domestic country's capital and prices. Second, the spillover effects of these shocks are more pronounced among countries engaged in a Regional Trade Agreement.

Related Literature

This paper is related to two strands of literature. First, it is related to the literature on the transmission of shocks through trade across countries (Corsetti et al., 2008; di Giovanni and Levchenko, 2009; Enders and Müller, 2009; Caselli et al., 2020; Kejžar et al., 2022; Baqaee and Farhi, 2024; Benguria et al., 2024; Camara et al., 2024). Enders and Müller (2009) and Corsetti et al. (2008) provide empirical evidence on how international trade can act as a conduit for transmitting economic disturbances across borders. More recently, Baqaee and Farhi (2024), Benguria et al. (2024), and Camara et al. (2024) have explored the network effects and sectoral spillovers that amplify shock transmissions in global trade networks. Further, Kpodar and Imam (2016) investigates the effects of Regional Trade Agreements (RTAs) on growth volatility. Analyzing data from 172 countries over the period 1978-2012, they find that RTAs significantly reduce growth volatility. Their study suggests that countries are more likely to join RTAs when they are exposed to higher growth shocks and have potential partners with stable economic growth. We focus in this study on prices stability.

Somanathan et al. (2021) and Burke et al. (2015) explore the impact of temperature variations on productivity and labor supply, demonstrating a non-linear relationship between temperatures and macroeconomic productivity. These studies suggest that climate shocks in one country can significantly affect its trade partners through changes in productivity and export capacities. We explore empirically that question among African countries. In addition to climate shocks, we study the effect of political shocks in an origin country on inflation in the destination country through trade. Despite this rich literature, studies on shock transmission through intra-trade in Africa are scarce, with some exceptions including Ncube et al. (2014), which focuses on output co-movement in Africa. This scarcity might be due to two reasons. First, the low level of intra-trade in Africa, around 18% in 2020, may have a negligible effect on shock transmission. However, with the recent African Continental Free Trade Area (AfCFTA), intra-trade in Africa is likely to increase, making the question of how trade transmits shocks in Africa a timely topic. Second, there is a lack of data to identify shocks that could be transmitted through trade. In this paper we use PRIO-GRID data on temperature and the Social Conflict Analysis Database (SCAD) from Idean et al. (2012) to provide evidence of shock transmission through trade among African countries.

The paper is also related to how RTAs transmit shocks across countries and their implications for monetary policy (Silveira, 2015; Corsetti et al., 2007, 2005). Eaton and Kortum (2012) discusses how the popular Ricardian model can be used to address many economic issues, including the welfare effects of trade deficits, wage responses to decreases in trade barriers, and responses to technological changes. Eaton and Kortum (2002) develops a Ricardian model that incorporates technology and geography in trade among countries. This model is used to quantify gains from trade and from tariff reductions. They find that all countries gain from free trade, with smaller countries gaining more than larger ones. They also calculate the role of trade in spreading technology across countries. Caliendo and Parro (2015) estimate the trade and welfare effects of NAFTA from tariff changes using a Ricardian model similar to Eaton and Kortum (2002). Importantly, they study how gains from tariff reduction spread across sectors and find that tariff reduction leads to more specialization, especially for Mexico. They also find that, unlike Mexico and the US, Canada suffers a welfare loss. Shikher (2012) Build an Eaton and Kortum Model to study the effect of US-EU trade wars and the effect of trade barriers reduction between high-income and middle-income countries. Lind and Ramondo (2024) Study how international trade can transmit ideas across countries and influence countries' growth. Our model is closer to Naito (2017), which combines an Eaton and Kortum (2002) model of trade with an Acemoglu and Ventura (2002) AK model to explain the implications of trade on economic growth. Since we are primarily interested in the effects of productivity shocks from an exporting partner on inflation in the destination country, we augment the model with a Central Bank.

The remainder of this paper is structured as follows. In Section 2, we provide empirical evidence of the transmission of climatic and political shocks across African countries through trade. Section 3 presents the theoretical model. Section 4 discusses the results of the theoretical model. Finally, Section 5 concludes the paper.

2 Empirical investigation

This section aims to provide empirical evidence of shock transmission through trade. We begin by presenting the data and analyzing how climatic and political shocks in an origin country affect inflation in its trading partner, the destination country.

2.1 Data presentation

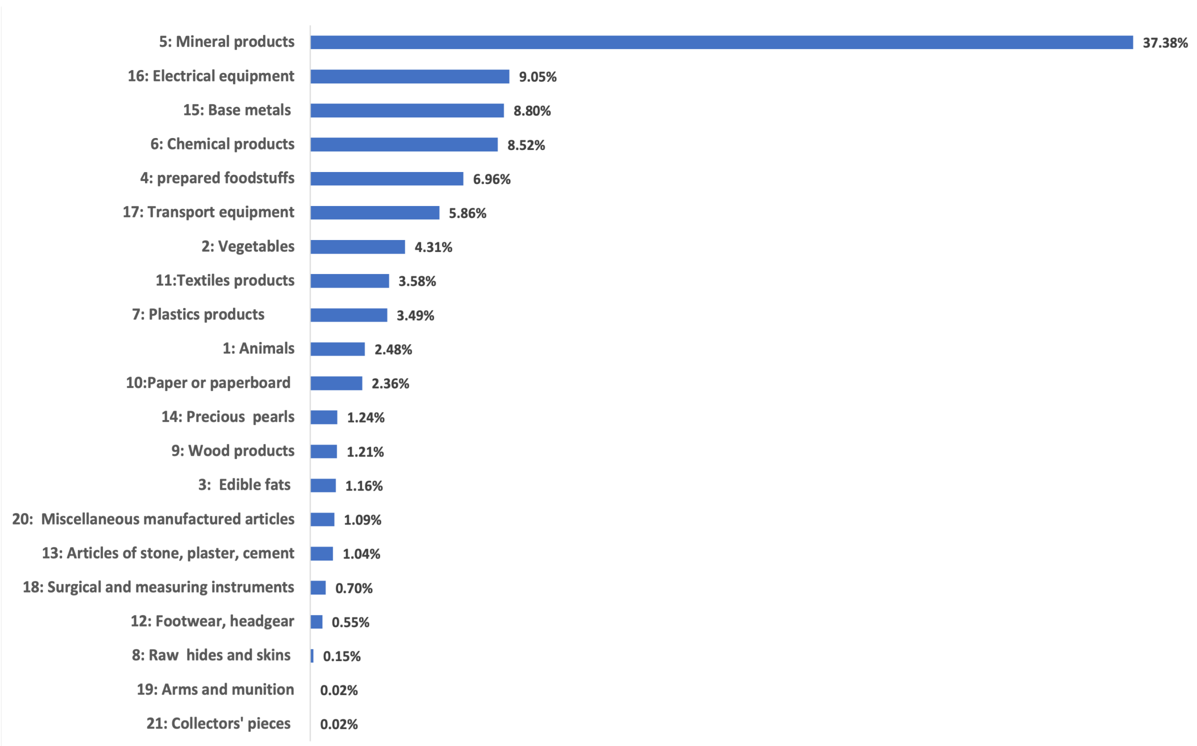
The data for the analysis of shocks transmission through trade comes from two principal sources. On the one hand, to capture climatic shocks we rely on the *PRIO-GRID* framework, a standardized grid of 0.5 x 0.5 decimal degrees covering the globe Tollefsen et al. (2012). We consider the grid-level average annual temperature, precipitation level and grid-level population (cite individual sources). Temperature and precipitation are aggregated at the country level by considering the weighted mean across all grid cells falling inside its boundaries. Each grid is weighted by the share of national population falling inside its area. On the other hand, to capture socio-political shocks, we rely on the Social Conflict Analysis Database (SCAD) from Idean et al. (2012). We use the number of fatalities from protests, riots, strikes, political and military conflicts, and other social disturbances. We aggregate this event-level information by computing the total number of fatalities at the country-year level. We exclude events that span multiple years as their occurrence in one year might be endogenized by agents in the following years.

2.2 Descriptive statistics

Our study, illustrated in Figure 1, examines the average trade share of product categories among African countries between 1996 and 2016. We employed a detailed product classification at the two-digit level Word Custom Organization's website. To compute the share, we aggregated the total trade volume for each year across all products and calculated the proportion of each product's trade volume to the total. Our findings show that *mineral products*, comprising oil, gas, cement, cobalt, aluminum, uranium, and other materials, were the most commonly exchanged products among African countries, followed by *electrical equipment, base metals, and chemical products*, each accounting for approximately 9% of total trade. In contrast, the least traded products were collector's pieces, arms and munitions, and raw hides and skins, which accounted for less than 0.5% of total trade.

However, it is essential to note that there was a substantial variance in trade volume across different products. For example, animals had the least variation with a standard deviation of 279,816, while the standard deviation of transport equipment was 554 times higher. The most commonly traded products, *mineral products*, had a standard deviation approximately 94 times higher than animals. This heteroskedasticity in the data implies that some products are significantly more volatile in terms of trade volume than others. Moreover, this heteroskedasticity is still apparent at the country pairs level, as illustrated in Figure 6.

Figure 1: Intra African trade share by product category



Notes: Average trade among African countries by product over the period 1996-2016

Table 1 presents descriptive statistics of variables used in the estimations. Sample 1 and 2 contain respectively 1712 and 1160 pairs of countries. Sample have 51 origin countries and 38 destination countries while in sample 2 have the same set of origin countries but with 3 less destination countries (Gambia, Guinea-Bissau and Sierra

Leone).[4]

Table 1: Descriptive Statistics

Sample 1

	count	min	p25	p50	mean	p75	max
bilateral imports (million USD)	15941	1.9e-09	0.024	0.34	35.8	5.06	5132.5
temperature deviation in origin	14971	-2.00	-0.12	0.084	0.089	0.31	3.47
#deaths in social conflict in origin	15941	0	0	2	152.6	26	8791
#deaths in social conflict in origin if $\#deaths > 0$	9180	1	4	18	265.1	152	8791
#deaths Above Q3	15249	0	0	0	0.15	0	1
pairwise SD of log(Imports)	15941	0.0011	0.92	1.58	1.68	2.27	6.65
pairwise SD of temperatures in origin	15941	0.0076	0.26	0.33	0.39	0.46	2.68
inflation in destination	15673	-2.20	2.27	4.91	5.92	8.50	32.9
RTA	15941	0	0	0	0.23	0	1
Observations	15941						

Sample 2

	count	min	p25	p50	mean	p75	max
bilateral imports (million USD)	13716	1.9e-09	0.044	0.60	41.0	6.97	5132.5
temperature deviation in origin	12916	-2.00	-0.12	0.084	0.088	0.31	3.47
#deaths in social conflict in origin	13716	0	0	2	156.0	30	8791
#deaths in social conflict in origin if $\#deaths > 0$	8030	1	4	18	266.5	152	8791
#deaths Above Q3	13181	0	0	0	0.15	0	1
pairwise SD of log(Imports)	13716	0.13	0.90	1.51	1.62	2.21	6.18
pairwise SD of temperatures in origin	13716	0.083	0.26	0.33	0.39	0.45	2.06
Inflation in destination	13491	-2.20	2.18	4.77	5.89	8.68	32.9
RTA	13716	0	0	0	0.25	0	1
Observations	13716						

Notes: To Regis: Above Q3, did we used numb deaths in social conflict in origin if numb deaths positive?

2.3 Trade and shock transmission across African countries

2.3.1 Empirical specification

To what extent do trade flows transmit shocks across African countries? To answer this question, we focus on one type of climatic shock, namely temperature shocks in the origin country, and ask whether inflation in the destination country is affected. We rely on the local average treatment effect (LATE) interpretation of the instrumental

[4] Sample 1
Origins: AGO BDI BEN BFA BWA CAF CIV CMR COD COG COM CPV DJI DZA EGY ETH GAB GHA GIN GMB GNB GNQ KEN LBR LBY LSO MAR MDG MLI MOZ MRT MUS MWI NAM NER NGA RWA SDN SEN SLE STP SWZ SYC TCD TGO TUN TZA UGA ZAF ZMB ZWE
Destinations: BDI BEN BFA BWA CAF CIV CMR CPV EGY GAB GHA GIN GMB GNB KEN LSO MAR MDG MLI MOZ MRT MUS MWI NAM NER NGA RWA SEN SLE SWZ TCD TGO TUN TZA UGA ZAF ZMB ZWE
Sample 2
Origins: AGO BDI BEN BFA BWA CAF CIV CMR COD COG COM CPV DJI DZA EGY ETH GAB GHA GIN GMB GNB GNQ KEN LBR LBY LSO MAR MDG MLI MOZ MRT MUS MWI NAM NER NGA RWA SDN SEN SLE STP SWZ SYC TCD TGO TUN TZA UGA ZAF ZMB ZWE
Destinations: BDI BEN BFA BWA CAF CIV CMR CPV EGY GAB GHA GIN KEN LSO MAR MDG MLI MOZ MRT MUS MWI NAM NER NGA RWA SEN SWZ TCD TGO TUN TZA UGA ZAF ZMB ZWE

variable estimand put forward in Angrist and Imbens (1994); Angrist et al. (1996). Indeed, for a given instrument Z, a treatment X, and an outcome variable Y, the IV-estimator identifies under suitable conditions the change in the outcome variable due to changes in the treatment X for those units who respond to the instrument Z. In our setup, a unit of observation is a pair of origin-destination countries (o, d), the instrument is the temperature in the origin country (z_{ot}) and the treatment variable is the trade flow from country o to country d (x_{dot}). One of the conditions underlying the IV-regression LATE interpretation is for the instrument to actually induce changes in the treatment variable. [5] Jones and Olken (2010) show that higher temperatures in poor countries have a negative effect on the growth of their exports to the US and to the world. Moreover, the decrease is experienced not only in agricultural goods but also in light manufacturing. For temperature shocks to be a valid instrument in our setup, they might first induce changes in trade flows across African countries.

We show below, by estimating equation 2, that for a given pair of trading countries (o, d), an increase in temperature in the origin country o reduces trade flow from o to d. The second condition, which is referred to as the exclusion restriction, states that the instrument should only influence the outcome variable through the treatment variable. Thus in our case, a temperature shock in the origin country should only affect inflation in the destination country through its effect on the supply of goods to the destination country. This would be violated for example, if temperature increases systematically simultaneously in the origin and destination country. In this case, both partners would experience a negative supply shock and the estimated IV-effect would conflate inflationary pressures originating both inside and outside the destination country. We control for this possibility by also adding the temperature in the destination country in equation 1 which links inflation in the destination country to the trade flow between origin and destination countries. We implement the IV procedure described above by estimating the following equations:

$$y_{dt}^{d} = a_{do} + \lambda_t + \alpha x_{dot} + \varepsilon_{dot} \tag{1}$$

$$x_{dot} = b_{do} + \gamma_t + \beta z_{ot} + u_{dot} \tag{2}$$

Where for each period t, y_{dt}^{d} denotes inflation in the destination country d, x_{dot} imports of country d from country o , a_{do} a pair destination $\times$ origin fixed effect , λ_t a time fixed effect, and ε_{dot} an error term capturing other factors influencing inflation aside from international trade. We assume that trade flows are potentially correlated with these latter factors: $cov(x_{dot}, \varepsilon_{dot}) \neq 0$. For example, an increase in public spending in country d might simultaneously increase inflation and imports in machinery. To deal with this endogeneity issue, we use alternatively climatic and socio-political shocks in exporter country o (denoted by z_{ot}) as an instrument to import of d from o.

On the one hand to control for the unbalanced panel nature of the available data on trade, we estimate the above regressions using two samples as described in table 1. In sample 1, we consider all the pairs of origin-destinations for which some data on trade is available between 2001 and 2015, while in Sample 2, we consider only pairs

[5] also called endogenous variable

that have trade observations for more than half the period 2001-2015. Although trade flows data are available up to 2019, information on temperature from the PRIO-GRID is only available up to 2014. On the other hand to control for the heteroskedasticity of trade flows across different pairs of countries (see Figure 6), we estimate the regressions using both OLS and Feasible Generalized Least Squares as in Jones and Olken (2010) [6].

In a given year, for each pair, we use as a measure of climatic shocks for trade flows the temperature in the previous year in the origin country. Socio-political shocks in the origin country are captured by a dummy variable equal to 1 if the number of deaths in socio-political conflicts is in the last quartile of the sample (precise the threshold absolute value of deaths: see table 1).

2.3.2 Results

We begin by answering the question of whether the instrumental variables we consider do induce variations in trade flows across African countries. Results for the first-step regression are given in table 2. Overall, we find a significant negative impact of higher temperatures and deaths in social conflicts in the origin country on import flows to the destination country. The effect of temperature appears to be more robust both across specifications and to sample selection than the effect of deaths in social conflict. Columns 1 to 4 presents estimation realized on sample 1 while columns 5 to 8 presents the same estimation run on sample 2.

Focusing on OLS regressions, one degree increase on the temperature of the origin country induce a 12% to 18% reduction of imports to destination countries depending on whether one uses sample 1 or sample 2. A correction for heteroskedasticity using FGLS brings the estimates across both sample more in line, with one degree increase in origin country temperature leading to a 9 to 11% decrease in trade flows. These estimated effects are robust to the inclusion of temperatures in the destination country, supporting the fact that they are not driven by a spatial correlation in temperatures. Regarding the effect of deaths in social conflicts in the origin country, the results point to a decrease in imports as social conflicts grow more violent. At the bottom of Table 2, F-statistics across all regressions range from 7 to 14. This may suggest that our instruments are weakly correlated with trade flows as they are not likely to be the main determinants of trade flow variations across African countries.

However, given the evidence of heteroscedasticity in the trade data, the Kleibergen-Paap (KP) test is the more reliable indicator of instrument strength than the Cragg-Donald (CD) test. For a 10% maximal bias, the critical value of 8.96 is a commonly accepted threshold. Since the KP F-statistics exceed this critical value, it indicates that our instruments are strong enough to limit bias in the IV estimates to within a tolerable 10% relative to OLS (Baum et al., 2007) (provide additional sources).

[6] Residuals from the OLS regressions are used to estimate pair-specific variances which are used as weights in a second OLS regression

Table 2: First-step regression: shock-induced variations in trade flows (Two-digits data)

	$log(Import_{dot})$							
	Sample 1				Sample 2			
	OLS		FGLS		OLS		FGLS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Temperature_{ot-1}$	-0.125***	-0.124***	-0.0842***	-0.0861***	-0.185***	-0.184***	-0.107***	-0.109***
	(0.0435)	(0.0435)	(0.0212)	(0.0215)	(0.0475)	(0.0475)	(0.0238)	(0.0240)
$NDeaths - AboveQ3_{ot}$	-0.181***	-0.180***	-0.0909***	-0.0924***	-0.125*	-0.124*	-0.0663**	-0.0694**
	(0.0636)	(0.0636)	(0.0256)	(0.0257)	(0.0667)	(0.0669)	(0.0277)	(0.0280)
$Temperature_{dt-1}$		0.0273		0.0111		0.0399		0.0216
		(0.0492)		(0.0187)		(0.0534)		(0.0203)
$NDeaths - AboveQ3_{dt}$		0.0364		-0.0202		0.0659		-0.0156
		(0.0582)		(0.0224)		(0.0608)		(0.0238)
Constant	12.69***	12.69***	11.78***	12.58***	13.17***	13.16***	16.55***	16.57***
	(0.0104)	(0.0139)	(0.00976)	(0.00780)	(0.0110)	(0.0146)	(0.00504)	(0.00585)
Origin * destination FE	T	T	T	T	T	T	T	T
Year FE	T	T	T	T	T	T	T	T
R2	0.783	0.783	0.988	0.987	0.776	0.776	0.947	0.948
F-stat	8.318	4.406	13.87	7.398	9.507	5.407	12.62	6.748
Observations	15941	15941	15941	15941	13716	13716	13716	13716

Notes: Results based on data from 2001 to 2015. Bilateral import flows are aggregated from the product-level bilateral import data set of the WTO Standards errors are clustered at the Origin * destination level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Standards errors are clustered at the Origin * destination level.
Instruments: L_temp_agr_c_o Id0_ndeath_c_o
Dummies Cuttoffs: 75: What does this mean?

We next turn to the analysis of possible inflationary effects of trade variations due to negative supply shocks in origin countries. Table 3 gives the results of the OLS and IV estimations of the effects of trade variations on domestic inflation. OLS estimates (column 1 and 7) are small in magnitude, non significant, and with opposite signs from sample 1 to sample 2. A correction for heteroskedasticity using FGLS lead to comparable small coefficients with the same sign across samples. This suggests that OLS estimates might be biased.

Indeed, the relationship between inflation and importation is not unambiguous as both variables are simultaneously determined. A strong domestic demand could lead to inflationary pressures and also increase import levels. In this case both variables will be positively correlated. Conversely, a negative foreign supply shock could reduce imports and create inflationary pressure in the domestic country if demand stays at its prior level. This latter channel is the one we are interested in estimating in this work.

Simple IV estimates (see columns 2, 3, 8, and 9), with temperature and violent social conflict as instruments, yield larger and negative coefficients but not statistically significant. A correction for heteroskedasticity using FGLS (see columns 5, 6, 11, and 12), gives coefficients similar in magnitude and statistically significant at least at 10% level. We regard this similarity in terms of magnitude between the unweighted and weighted IV regressions as suggestive of possible bias being of small magnitude. These latter results imply that a 1% decrease in imports due to increased temperatures or violent social conflicts in the origin country leads to an increase in inflation of 0.26 to 0.58 percentage points in the destination country, depending on the specification and the sample used. The preferred regression is the one controlling for the temperature and number of Deaths above the third quarter in the destination country (columns 6 and 12). When using the whole sample (sample 1) between 2001 and 2015, the effect is 0.4 percent, while it increases up to 0.58 percent when considering a more balanced sample (sample 2), which keeps only countries for which the data are available for at least half of the period 2001-2015.

Table 3: Inflationary effect of shock-induced trade variations

	$Inflation_{dt}$											
	Sample 1						Sample 2					
	OLS	IV-OLS		FGLS	IV-FGLS		OLS	IV-OLS		FGLS	IV-FGLS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$log(import_{dot})$	0.000326	-0.275	-0.416	0.00521	-0.259***	-0.397*	-0.0144	-0.428	-0.524	0.00751	-0.448*	-0.587*
	(0.0170)	(0.434)	(0.430)	(0.00460)	(0.0720)	(0.225)	(0.0191)	(0.429)	(0.422)	(0.00903)	(0.245)	(0.314)
$Temperature_{dt-1}$			0.802***			0.463***			0.853***			0.348***
			(0.0767)			(0.163)			(0.0846)			(0.0585)
$NDeaths - AboveQ3_{dt}$			1.016***			0.843***			1.158***			0.827***
			(0.123)			(0.0859)			(0.133)			(0.0710)
Constant	5.917***			7.086***			6.080***			3.504***		
	(0.214)			(0.0482)			(0.251)			(0.117)		
Origin * destination FE	T	T	T	T	T	T	T	T	T	T	T	T
Year FE	T	T	T	T	T	T	T	T	T	T	T	T
Observations	16072	15666	15666	16072	15666	15666	13746	13491	13491	13746	13491	13491
CD Fstat		8.361	8.256		6.407	4.040		8.961	8.854		6.238	4.403
KP Fstat		16.31	16.11		7.110	7.881		17.10	16.91		11.73	8.346
KP pval		0.000287	0.000317		0.0286	0.0194		0.000193	0.000212		0.00283	0.0154

*Notes: Results based on data from 2001 to 2015. Inflation is annually winsorized at 5%. Bilateral import flows are aggregated from the 2-digit product-level bilateral import data set of the WTO. In all IV estimations, both lagged temperature and a dummy indicating large casualties in social conflicts in the origin country are used as instruments. Standards errors are clustered at the Origin * destination level.*

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In this section we have shown that trade transmits political and climatic shocks to inflation across African countries. Now how do RTAs amplify the transmission of productivity shocks? In the next section, we build a model to provide an answer to that question.

3 The model

In the model, we consider three countries, each with different levels of risk (productivity shocks). Agents in the model include representative consumers, firms (both final and intermediate), and a Central Bank. Countries import and export intermediate goods to produce their non-tradable final good. Each firm produces a unique variety (*intermediate good*) with its own price, which varies between countries. *Final goods* are aggregated from intermediate goods. These goods can be used to consume and invest in the production of intermediate good.

Every period, each country experiences a shock drawn from an independent and identically distributed (iid) Fréchet distribution in the intermediate tradable good sector. Following Eaton and Kortum (2002), we assume that the shape parameter of the Fréchet distribution, which governs the relative comparative advantage (θ), is constant but can vary between countries. Home bias is implicitly considered through bilateral trade costs, such as distance and tariffs.

3.1 Households

We introduce money into the utility function (MIU) to generate a demand for money. Utility is derived from real money balances, represented as $m_{jt} = \frac{M_{jt}}{P^Y_{jt}}$, where M_{jt} denotes nominal money holdings and P^Y_{jt} is the price level in country j at time t. Additionally, we incorporate public bonds D_t as an asset in the model, with their interest rate i_{jt} determined by the central bank's monetary policy in country j. The interest rate on public bonds influences household decisions through its effect on wealth and consumption over time.

The household's optimization problem is defined as:

$$\max_{K_{jt+1}, m_{jt}, D_{jt}, C_{jt}} \sum_{t=0}^{\infty} \beta^t U(C_{jt}, m_{jt})$$

$$\text{s.t: } C_{jt} + K_{jt+1} - (1-\delta_j)K_{jt} + \frac{D_{jt}}{P^Y_{jt}} + \frac{M_{jt}}{P^Y_{jt}} = \frac{r_{jt}}{P^Y_{jt}} K_{jt} + \frac{(1+i_{jt-1})D_{jt-1}}{P^Y_{jt}} + \frac{M_{jt-1}}{P^Y_{jt}} \quad (3)$$

By substituting the real money balance expression, the budget constraint can be rewritten as:

$$C_{jt} + K_{jt+1} - (1-\delta_j)K_{jt} + \frac{D_{jt}}{P^Y_{jt}} + m_{jt} = \frac{r_{jt}}{P^Y_{jt}} K_{jt} + \frac{(1+i_{jt-1})D_{jt-1}}{P^Y_{jt}} + m_{jt-1} \cdot \frac{1}{1+\pi_{jt}},$$

where π_{jt} is the inflation rate in country j at time t.

3.2 Central Bank

To employ the previous MIU framework to analyze monetary issues, one should specify how the Central Bank conducts its monetary policy. The Central Bank supply money following this equation:

$$M_{jt} = (1+\mu_{jt})M_{jt-1}$$

$$m_{jt} = (1+\mu_{jt})\frac{m_{jt-1}}{(1+\pi_{jt})}. \quad (4)$$

where μ_{jt} is an exogenous (stochastic) growth rate of the nominal stock of money set by the Central Bank and π_{jt} domestic inflation.

Denote $\bar{\mu}_j$ the average growth rate of money supply. Let define $u_t = \mu_{jt} - \bar{\mu}_j$ be the deviation in period t of the growth rate from its unconditional average value. Following Walsh (2003), this deviation is assumed to follow the stochastic process given by:

$$u_{jt} = \rho^u_j u_{jt-1} + \phi z_{jt-1} + \varphi_{jt} \quad (5)$$

with φ_{jt} is a white noise process and $|\rho^u_j| < 1$. One could note that the growth rate of the money stock displays persistence (if $\rho^u_j > 0$), responds to the real productivity shock z in the final good sector, and is subject to random disturbances through the realizations of φ_{jt}.

z_j is the productivity and follows:

$$log(z_{jt}) = \rho_j^z log(z_{jt-1}) + e_{jt} \tag{6}$$

e_{jt} is an iid process following a normal distribution according to: $e_{jt} \sim \mathcal{N}(0, \sigma_j^z)$.

3.3 Intermediate goods-producing firms

Each country j produces a variety $s_j \in S_j \subseteq [0, 1]$. The profit maximization problem for an intermediate goods-producing firm is:

$$\max_{K^x(s_j)} \Pi^x(s_j) = p(s_j)x(s_j) - r_j K^x(s_j)$$

subject to:

$$s.t : x(s_j) = \frac{K^x(s_j)}{a_j(s_j)} \tag{7}$$

where $a_j(s_j)$ and $p(s_j)$ represent the unit capital requirements and the supply price, respectively. The zero-profit condition implies:

$$p(s_j) = a_j(s_j) r_j$$

Let A_j be an iid random variable for $a_j(s_j)$. As in Eaton and Kortum (2002), A_j^{-1} follows a Fréchet distribution:

$$F_j(h) = Pr(1/A_j \leq h) = \exp(-b_j h^{-\theta})$$

where $b_j > 0$ and $\theta > 1$.

We consider iceberg trade costs: shipping τ_{nj} units from country j delivers one unit to country n ($\tau_{nj} \geq 1$). Producing variety s_j in country j and delivering it to country n costs:

$$p_{nj}(s_j) = \tau_{nj} p(s_j) = \tau_{nj} a_j(s_j) r_j \tag{8}$$

The demand price of variety s in country n is:

$$P_n(s) = \min(\{p_{nj}(s)\}_{j=1}^N)$$

3.4 Final Goods-Producing Firms

Shocks z_n in the final good sector in country n, represented as labor productivity shock, are drawn from an iid AR(1) distribution for each country as shown in equation 6. The profit maximization problem for final goods-producing firms is:

$$\max_{x_n(s)} \Pi_n^Y = P_n^Y Y_n - \int_0^1 P_n(s) x_n(s)\, ds \tag{9}$$

subject to:

$$Y_n = z_n \left(\int_0^1 x_n(s)^{\frac{\sigma_n - 1}{\sigma_n}} \, ds \right)^{\frac{\sigma_n}{\sigma_n - 1}}$$

where z_n is the productivity and P_n^Y is the price of the final good in country n. Following Lemma 1 in Naito (2017), we have:

$$P_n^Y(\{\tau_{nj} r_j\}_{j=1}^N) = c_n \left[\sum_{j=1}^N b_j (\tau_{nj} r_j)^{-\theta} \right]^{-1/\theta} \tag{10}$$

where $c_n = z_n^{-1} \Gamma \left(1 + \frac{1-\sigma_n}{\theta}\right)^{\frac{1}{1-\sigma_n}}$ and Γ is the gamma function.

As shown in Appendix B.1, the price of the final good is an index of intermediate goods prices denoted by Q_n. The probability that country n imports goods from country j is the share of import from j in country n's total imports and is given by:

$$\Pi_{nj} = \int_{s_j \in S_{nj}} p_{nj}(s_j) x_n(s_j) \, ds_j / Q_n Y_n \tag{11}$$

3.5 Equilibrium

3.5.1 Definition of the Equilibrium

An equilibrium in a given country j is a set of quantities and prices such that:

- $C_{j,t}, K_{j,t+1}, m_{j,t}, D_{j,t}$ solve consumer's problem defined in (3) given prices $r_{j,t}, i_{j,t-1}, P_{j,t}^Y, \pi_{j,t}$
- $K^x(s_j)$ solve intermediate firms problem in (7) given $r_j, p(s_j)$
- The intermediate good $x_j(s)$ solve final good firm problem in (9) given $P_{jt}^Y, P_{j,t}(s)$
- Central Bank supplies the quantity of money following (4).
- Market clearing conditions:
  - Bonds market (closed financial market): $D_{jt} = 0$
  - Intermediate goods market:

$$x(s_j) = \sum_{n=1}^N \tau_{nj} x_n(s_j), \; s_j \in S_j \tag{12}$$

  - Capital market:

$$K_j = \int_{s_j \in S_j} K^x(s_j) \, ds_j \tag{13}$$

  - The final goods market clearing:

$$Y_{j,t} = C_{j,t} + K_{j,t+1} + (1 - \delta_j) K_{j,t} \tag{14}$$

  - Money market clears, supply by the CB is equal to the demand by consumers

3.5.2 Charactization of the equilibrium

The equilibrium is characterized by a system of equations that solve for the **endogenous variables:** $C_{j,t}, K_{j,t}, m_{j,t}, D_{j,t}, P^Y_{jt}, \pi_{jt}, r_{jt}, i_{jt}$. For that, let first derive the Euler equations.

Euler Equations

The first-order conditions give the Euler Equations.
Euler Equation for Capital:

$$U_C(C_{jt}, m_{jt}) = \beta E_t \left[U_C(C_{j,t+1}, m_{j,t+1}) \left(\frac{r_{jt+1}}{P^Y_{jt+1}} + 1 - \delta_j \right) \right] \tag{15}$$

Euler Equation for Debt:

$$U_C(C_{jt}, m_{jt}) = \beta E_t \left[U_C(C_{j,t+1}, m_{j,t+1}) \left(\frac{1 + i_{jt}}{1 + \pi_{jt+1}} \right) \right] \tag{16}$$

Euler Equation for Money:

$$U_m(C_{jt}, m_{jt}) = U_C(C_{jt}, m_{jt}) - \beta E_t \left[U_C(C_{j,t+1}, m_{j,t+1}) \left(\frac{1}{1 + \pi_{jt+1}} \right) \right] \tag{17}$$

These Euler equations describe the intertemporal optimization conditions for consumption, capital, money, and debt. Combined with the budget constraint, they describe citizens' optimization solutions.

$$C_{jt} + K_{jt+1} + \frac{D_{jt}}{P^Y_{jt}} + m_{jt} = \left(\frac{r_{jt}}{P^Y_{jt}} + 1 - \delta_j \right) K_{jt} + \frac{(1 + i_{jt-1}) D_{jt-1}}{P^Y_{jt}} + \frac{m_{jt-1}}{1 + \pi_{jt}} \tag{18}$$

Next, let's derive the equations that serve to solve nominal return on capital r_{jt}.

Lemma:
The return on Capital solves the following equation (abstracting time script):

$$r_j K_j = \sum_{n=1}^{N} \Pi_{nj} (r_n K_n - M_{n,t-1} \mu_n), j = 1, ..., N - 1 \tag{19}$$

A detailed proof of this lemma can be seen in appendix B.3.
This equation can be broken down and interpreted as follows [7] :

- Π_{nj}: represents the probability or fraction of the total value from country n that influences country j. It acts as a weighting factor that indicates the interaction between country n and country j.

- $(r_n K_n - M_{n,t-1} \mu_n)$: This term inside the summation can be broken down further:

[7] Note that it's redundant to add the N-th equation, for more details see appendix B.5. In other

- $r_n K_n$: The total returns to capital in country n.
- $M_{n,t-1}\mu_n$: represents the additional money supply in country n at time t relative to time $t-1$. This term is subtracted from the total returns to capital, indicating the impact of monetary policy or money supply on the returns.

Interpretation: The equation states that the total returns to capital in country j ($r_j K_j$) are determined by summing up the weighted and adjusted returns to capital from all other countries. Each term in the summation adjusts the returns to capital from country n by subtracting the impact of the money supply.

This equation is crucial in understanding the dynamics of capital allocation and the influence of monetary policy across different countries in the model. It illustrates the interdependencies and the role of trade in determining the distribution of capital returns among countries. It highlights how monetary policies in one country propagate through the system and affect the overall equilibrium of returns to capital in other countries.

Finally, $C_{j,t}, K_{j,t}, m_{j,t}, D_{j,t}, P^Y_{jt}, \pi_{jt}, r_{jt}, i_{jt}$ solve the system of equations summarized in 15, 16, 17, 18, 4, 10, 24, and bonds market clearing, to these equations, one should add the stochastic exogenous variables in 5 and 6. The complete stationary version of the system can be found in appendix B.4.

4 Results

Here we present the main proposition and some results of a simple simulation of the model.

Proposition

Regional Trade Agreements (RTAs) amplify the transmission of external shocks to domestic capital and domestic prices among member countries.

A proof of this proposition will be added soon. But let simulate the model to illustrate it.

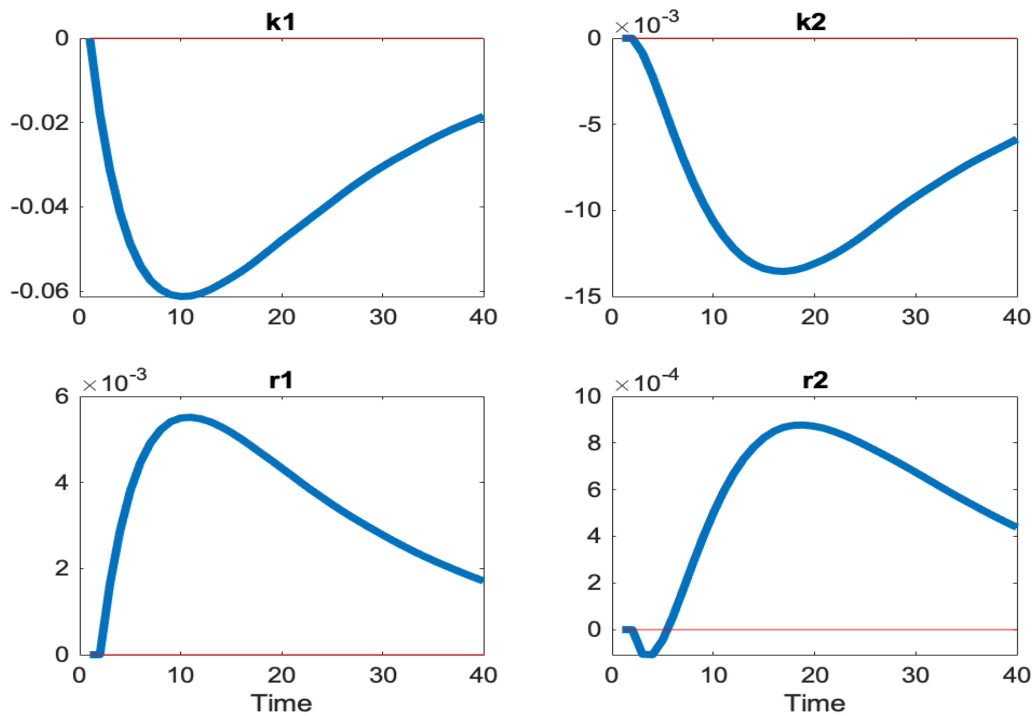
Simulation: We make a simple three-country calibration to investigate how the model works. The key element of this calibration is that there is a bilateral Regional Trade Agreement between Country 1 and Country 2 and no Regional Trade Agreement with Country 3. Typically, the trade cost between countries 1 and 2 is half of the trade cost with country 3. The simulation consist in making a one standard deviation shock on productivity and see it spillover effect on countries 2 and 3.

Figures 2 and 3 present the simulation of the model variables after a one standard deviation shock in country 1's final good sector productivity. In figure 2, $k1$ (respectively $k2$) represents the ratio of country 1's (respectively country 2's) capital to that of country 3, which has been normalized to one. Similarly, $r1$ (respectively $r2$) is the

words, this means that r_N can't be identified, we therefore normalized it to 1.

relative capital of country 1 (respectively country 2) to country 3, also normalized to one.

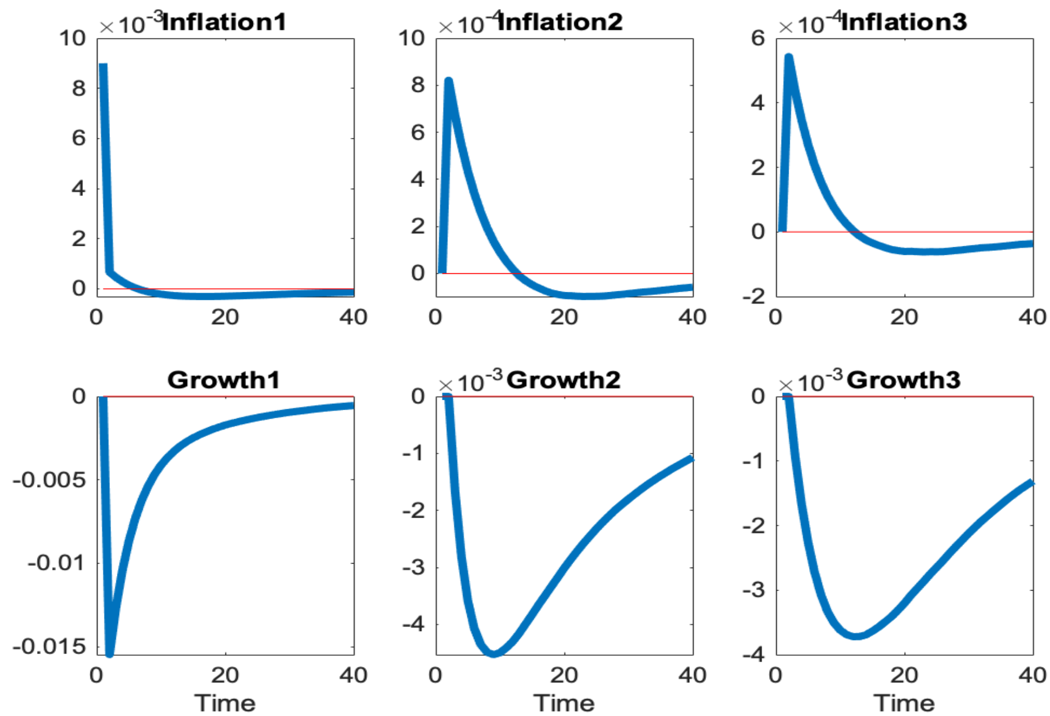
Figure 2: Relative capital and interest rate dynamics



Notes: *This figure displays the comparative capital and interest rates of country 1 and country 2 relative to those of country 3 following a one standard deviation in country 1's final good productivity.* $k1$ *(respectively* $k2$*) represents the ratio of country 1's (respectively country 2's) capital to that of country 3, which has been normalized to one. Similarly,* $r1$ *(respectively* $r2$*) is the relative capital of country 1 (respectively country 2) to country 3, also normalized to one. All the variables are expressed as a percentage deviation from the steady states.*

After the shock in country 1, the capital decreases to reach its minimum of -6% after 10 periods. The recovery is relatively slow toward the balanced growth path. Because capital becomes scarce, the interest rate increases. We see similar results in country 2 but with a lower magnitude. Indeed, capital in country 2 reaches its minimum after nearly 20 periods (compared to 10 in country 1) but with a minimum of approximately -0.13% (compared to -6% in country 1). We observe similar results for the interest rate. Thus, besides the fact that the effect is lower in magnitude in country 2, it lasts longer than in country 1. This is because of the importance of trade between country 1 and country 2. Indeed, as shown in Figure 10 in the appendix, when country 1 and country 2 enter the regional trade agreement, the trade share of country 2 from country 1 increases. Consequently, when there is a negative productivity shock in country 1, country 2's trade share in intermediate goods from country 1 decreases, which reduces its final goods production and thus the capital (as capital investment in the model comes from the final good). Overall, this means that country 2 cannot fully recover until country 1 has recovered, explaining the delayed effects in country 2.

Figure 3: Inflation and Growth dynamics



Notes: *This figure presents inflation and growth dynamics following a one standard deviation productivity shock in country 1's final good sector.*

In Figure 3, we can see similar results as in Figure 2 for inflation and growth in all the countries. The most interesting part here is that we can compare the effect of a shock in country 1 on country 2's inflation and growth to similar effects in country 3. Remember that country 2 has an RTA with country 1 while country 3 has no RTA signed.

As can be seen, the shock in Country 1 affects Country 2's inflation and growth more compared to Country 3. Indeed, a negative productivity shock in country 1 increases inflation up to 0.8% in country 2 compared to nearly 0.6% in country 3. We observe similar results for growth. These results highlight the role of RTAs in transmitting shocks across countries [8].

5 Conclusion

In this paper, we document the transmission of climatic and political shocks through trade. Using an instrumental variable strategy, we show that a 1% decrease in imports due to these shocks raises inflation in the importing country by 0.4 to 0.58%. This highlights trade's critical role as a conduit for external shocks, with significant implications for inflation dynamics in Africa.

We developed a theoretical model to rationalize the aforementioned empirical evidence. Our simulations suggest that RTAs could significantly impact participating

[8]We are working to include a Central Bank in the model to study the ability of Monetary Policy to manage the effect of these shocks.

countries' inflation and necessitate adjustments in monetary policy to maintain economic stability. Our findings underscore the complex role of regional trade agreements (RTAs) in promoting economic stability, especially when trading with partners more exposed to economic shocks.

Policymakers should consider these issues when implementing trade policies to fully harness the benefits of economic integration.

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Appendix

Figure 4: cumulative numbers of RTA among African countries

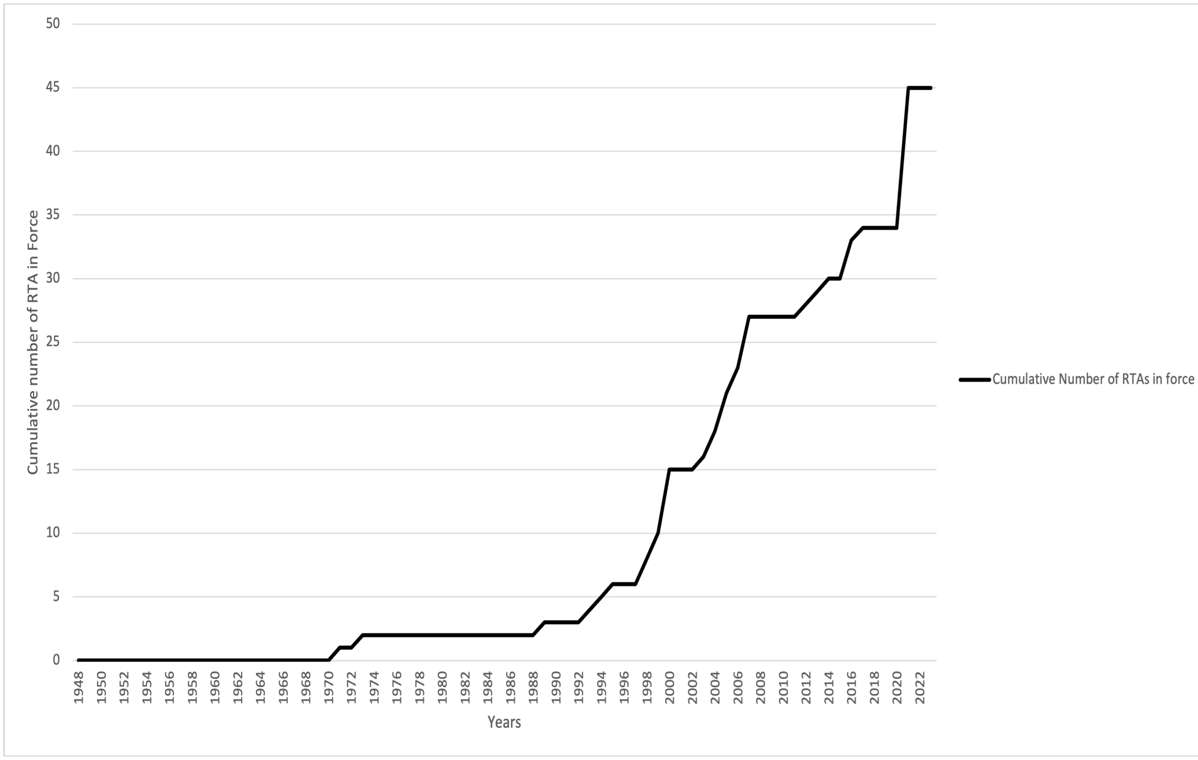

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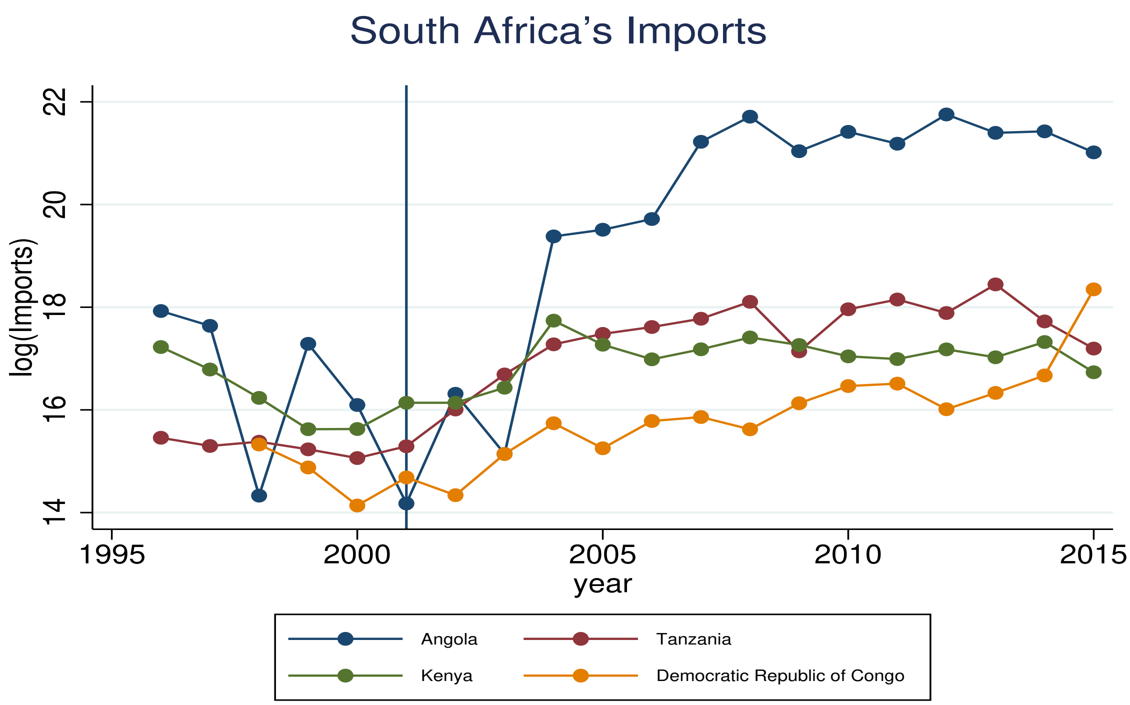
Figure 5



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A Trade and shock transmission

Construction of shock data Gridded Population of the World (GPWv4) 30 arc-seconds (approximately 1 km at the equator) population count for the years 2000, 2005, 2010, 2015, and 2020, consistent with national censuses and population registers

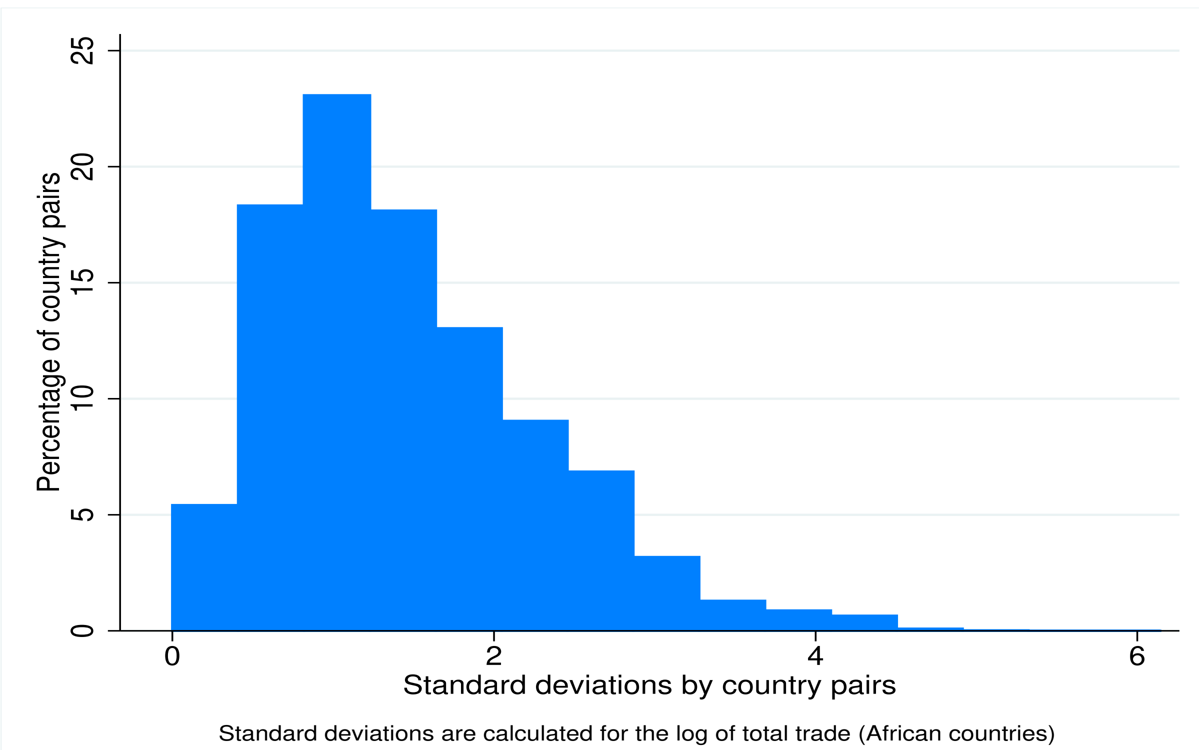
Table 4: IV-regression: inflationary effect of shock-induced trade variations

	(1) infl_cpi_d	(2) infl_cpi_d	(3) infl_cpi_d	(4) infl_cpi_d	(5) infl_cpi_d	(6) infl_cpi_d	(7) infl_cpi_d	(8) infl_cpi_d
log_import_ij	-0.0218	-0.370	3.718	-0.416	-0.00248	-0.393***	-1.298	-0.425***
	(0.0197)	(0.723)	(12.47)	(0.713)	(0.00767)	(0.122)	(16.55)	(0.109)
above_med_supplier_import			-6.648				-0.201	
			(18.37)				(22.85)	
above_Q3_supplier_import				-0.279				-0.108
				(1.189)				(0.460)
Constant	6.238***	8.567*	-27.86	8.705*	1.776***			
	(0.254)	(5.069)	(108.8)	(5.043)	(0.0634)			
Origin * destination FE	T	T	T	T	T	T	T	T
Year FE	T	T	T	T	T	T	T	T
R2	0.646	0.632	-0.539	0.624	0.900	-0.0232	-0.213	-0.0139
Observations	13266	11816	11816	11816	12532	11815	11815	11815
CD Fstat		5.025	0.0493	2.894		4.287	0.0395	1.006
KP Fstat		5.589	0.113	6.342		3.223	0.0840	2.253
KP pval		0.0181	0.736	0.0118		0.0726	0.772	0.133

Notes: Results based on data from 2001 to 2015. Inflation is annually winsorized at 5%. Bilateral import flows are aggregated from the product-level bilateral import data set of the WTO Standards errors are clustered at the Origin * destination level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

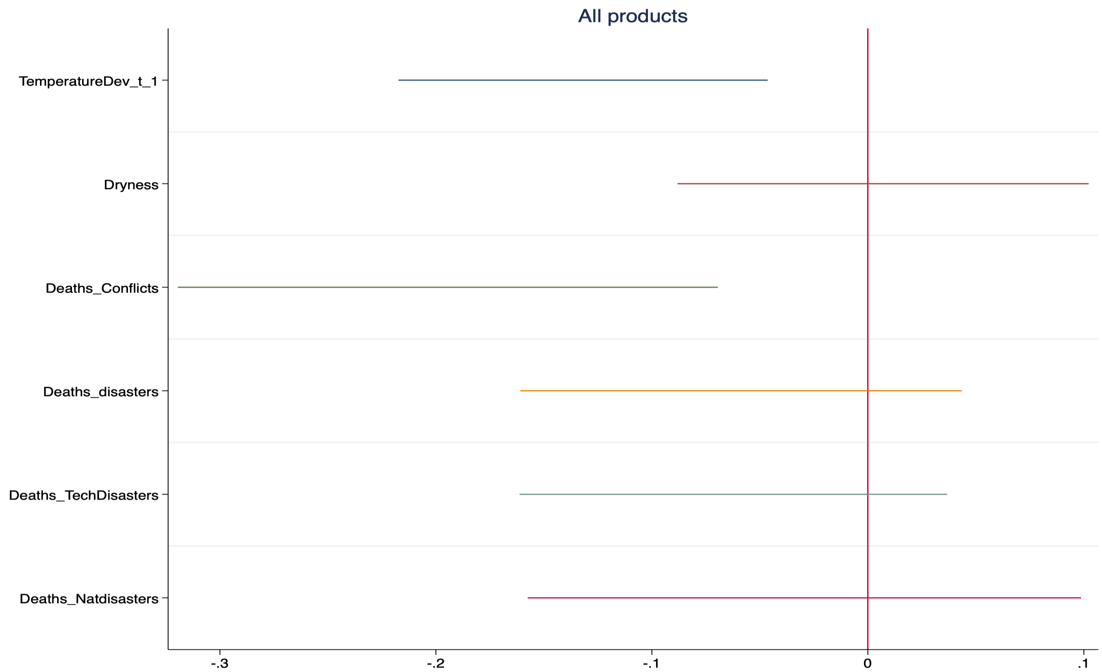
Figure 6: standard deviations of bilateral imports across pair of countries



Notes: This graph presents standard deviations of bilateral imports by pairs of countries. When we also do the same exercise for the most exchanged products "mineral products", we get similar results.

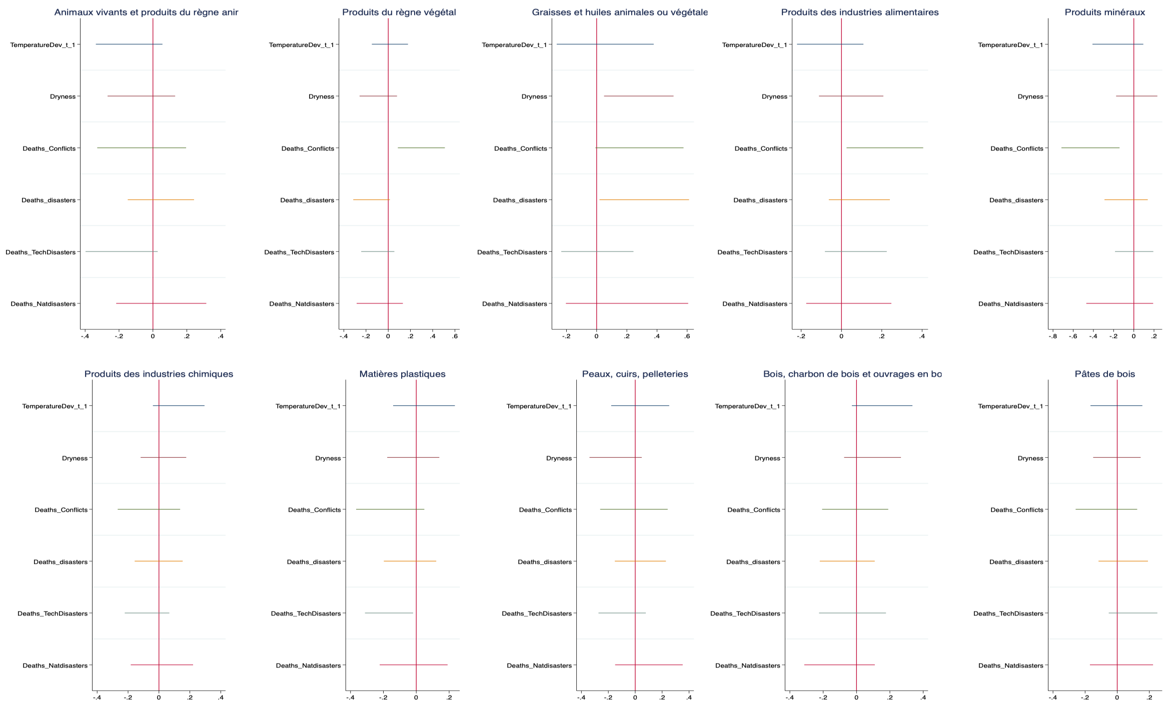
cross African countries.

Figure 7



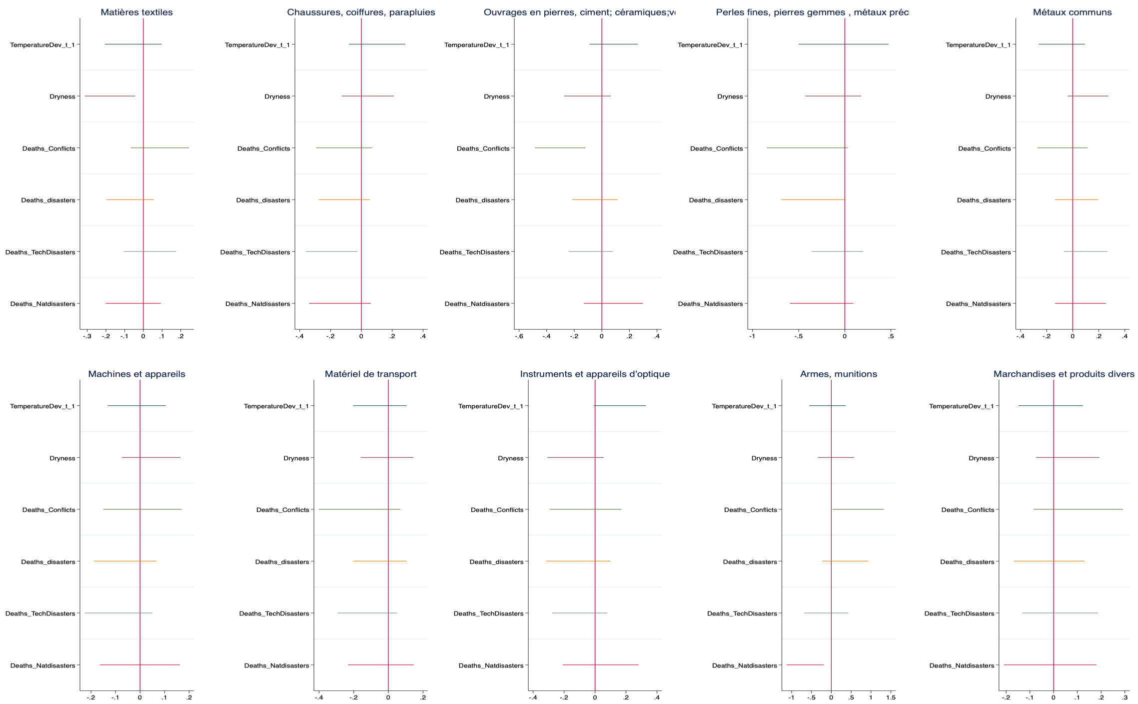
Notes:

Figure 8



Notes:

Figure 9



Notes:

Table 5: First-step regression: shock-induced variations in trade growth

	(1) D_log_import_ij05	(2) D_log_import_ij05	(3) D_log_import_ij05	(4) D_log_import_ij05	(5) D_log_import_ij05	(6) D_log_import_ij05	(7) D_log_import_ij05	(8) D_log_import_ij05
L.temp_pop_c_o	-0.125***	-0.126***	-0.0376**	-0.0408**	-0.115***	-0.116***	-0.0306*	-0.0315*
	(0.0439)	(0.0440)	(0.0167)	(0.0170)	(0.0434)	(0.0435)	(0.0167)	(0.0168)
Id0_ndeath_c_o	-0.109	-0.109	-0.0279	-0.0210	-0.103	-0.102	-0.0343*	-0.0340*
	(0.0680)	(0.0680)	(0.0203)	(0.0219)	(0.0682)	(0.0682)	(0.0198)	(0.0201)
L.temp_pop_c_d		-0.100**		-0.0375***		-0.0853*		-0.0344***
		(0.0441)		(0.0139)		(0.0447)		(0.0130)
Id0_ndeath_c_d		0.0195		-0.0257		0.0394		-0.0251
		(0.0596)		(0.0206)		(0.0585)		(0.0204)
Constant	0.133***	0.139***	0.0437***	-0.0434***	0.139***	0.141***	0.108***	0.112***
	(0.0113)	(0.0150)	(0.00379)	(0.00490)	(0.0113)	(0.0148)	(0.00367)	(0.00471)
Destination FE	F	F	F	F	F	F	F	F
Origin FE	F	F	F	F	F	F	F	F
Origin * destination FE	T	T	T	T	T	T	T	T
Year FE	T	T	T	T	T	T	T	T
R2	0.0609	0.0612	0.291	0.444	0.0436	0.0439	0.0769	0.0772
F-stat	5.849	4.286	3.698	3.807	5.051	3.572	3.332	3.678
Observations	12731	12731	12731	12731	11887	11887	11887	11887

Notes: Results based on data from 2001 to 2015. Bilateral import flows are aggregated from the product-level bilateral import data set of the WTO Standards errors are clustered at the Origin * destination level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Standards errors are clustered at the Origin * destination level.

B Theorethical appendix

B.1 Index of intermediate goods prices

The price of the final good is an index of intermediate goods prices

Let consider the minimisation problem:

$$\min_{\{x_n(i)\}} C_n = \int_0^1 P_n(i) x_n(i)\, di$$

Subject to:

$$Y_n = z_n(\int_0^1 x_n(i)^{\frac{\sigma_n - 1}{\sigma_n}}\, di)^{\frac{\sigma_n}{\sigma_n - 1}} \tag{20}$$

Where:

- $x_n(i)$ is the decision variable representing the quantity of the i-th input used (intermediate good).
- $P_n(i)$ is the price of the i-th input.
- Y_n is the output level that needs to be produced.
- z_n is a productivity parameter.
- σ_n is the elasticity of substitution between the inputs.

Lagrangian Function

To solve this optimization problem, we introduce a Lagrange multiplier λ for the constraint and set up the Lagrangian function $\mathcal{L}$:

$$\mathcal{L} = \int_0^1 P_n(i) x_n(i)\, di + \lambda \left[Y_n - z_n \left(\int_0^1 x_n(i)^{\frac{\sigma_n - 1}{\sigma_n}}\, di \right)^{\frac{\sigma_n}{\sigma_n - 1}} \right]$$

First-Order Conditions

To find the optimal $x_n(i)$, we take the derivative of $\mathcal{L}$ with respect to $x_n(i)$ and set it to zero:

$$\frac{\partial \mathcal{L}}{\partial x_n(i)} = P_n(i) - \lambda z_n \frac{\sigma_n}{\sigma_n - 1} \left(\int_0^1 x_n(j)^{\frac{\sigma_n - 1}{\sigma_n}}\, dj \right)^{\frac{1}{\sigma_n - 1}} x_n(i)^{-\frac{1}{\sigma_n}} = 0$$

Simplifying, we get:

$$P_n(i) = \lambda z_n \frac{\sigma_n}{\sigma_n - 1} \left(\int_0^1 x_n(j)^{\frac{\sigma_n - 1}{\sigma_n}}\, dj \right)^{\frac{1}{\sigma_n - 1}} x_n(i)^{-\frac{1}{\sigma_n}}$$

To find the relation between $x_n(i)$ and $x_n(i')$, we start from the first-order conditions derived:

$$P_n(i) = \lambda z_n \frac{\sigma_n}{\sigma_n - 1} \left(\int_0^1 x_n(j)^{\frac{\sigma_n - 1}{\sigma_n}} \, dj \right)^{\frac{1}{\sigma_n - 1}} x_n(i)^{-\frac{1}{\sigma_n}}$$

Similarly, for another input i':

$$P_n(i') = \lambda z_n \frac{\sigma_n}{\sigma_n - 1} \left(\int_0^1 x_n(j)^{\frac{\sigma_n - 1}{\sigma_n}} \, dj \right)^{\frac{1}{\sigma_n - 1}} x_n(i')^{-\frac{1}{\sigma_n}}$$

Now, we compute the ratio $\frac{P_n(i)}{P_n(i')}$:

$$\frac{P_n(i)}{P_n(i')} = \frac{\lambda z_n \frac{\sigma_n}{\sigma_n - 1} \left(\int_0^1 x_n(j)^{\frac{\sigma_n - 1}{\sigma_n}} \, dj \right)^{\frac{1}{\sigma_n - 1}} x_n(i)^{-\frac{1}{\sigma_n}}}{\lambda z_n \frac{\sigma_n}{\sigma_n - 1} \left(\int_0^1 x_n(j)^{\frac{\sigma_n - 1}{\sigma_n}} \, dj \right)^{\frac{1}{\sigma_n - 1}} x_n(i')^{-\frac{1}{\sigma_n}}}$$

Notice that many terms cancel out:

$$\begin{aligned}
\frac{P_n(i)}{P_n(i')} &= \frac{x_n(i)^{-\frac{1}{\sigma_n}}}{x_n(i')^{-\frac{1}{\sigma_n}}} \\
\frac{P_n(i)}{P_n(i')} &= \left(\frac{x_n(i')}{x_n(i)} \right)^{\frac{1}{\sigma_n}} \\
\left(\frac{P_n(i)}{P_n(i')} \right)^{\sigma_n} &= \frac{x_n(i')}{x_n(i)} \\
\frac{x_n(i)}{x_n(i')} &= \left(\frac{P_n(i')}{P_n(i)} \right)^{\sigma_n}
\end{aligned}$$

Thus, the optimal allocation of $x_n(i)$ in terms of $P_n(i)$ and $P_n(i')$ is:

$$x_n(i) = x_n(i') \left(\frac{P_n(i')}{P_n(i)} \right)^{\sigma_n} \tag{21}$$

Now integrate this expression in

$$\begin{aligned}
Y_n &= z_n \left(\int_0^1 x_n(i)^{\frac{\sigma_n - 1}{\sigma_n}} \, di \right)^{\frac{\sigma_n}{\sigma_n - 1}} \\
&= z_n \left(\int_0^1 (x_n(i') \left(\frac{P_n(i')}{P_n(i)} \right)^{\sigma_n})^{\frac{\sigma_n - 1}{\sigma_n}} \, di \right)^{\frac{\sigma_n}{\sigma_n - 1}} \\
&= z_n P_n(i')^{\sigma_n} x_n(i') \left(\int_0^1 P_n(i)^{1 - \sigma_n} \, di \right)^{\frac{\sigma_n}{\sigma_n - 1}}
\end{aligned}$$

$$
\begin{aligned}
x_n(i') =& Y_n/(z_n P_n(i')^{\sigma_n} \left(\int_0^1 P_n(i)^{1-\sigma_n} \, di \right)^{\frac{\sigma_n}{\sigma_n - 1}}) \\
x_n(i') =& P_n(i')^{-\sigma_n} \left(\int_0^1 P_n(i)^{1-\sigma_n} \, di \right)^{\frac{\sigma_n}{1-\sigma_n}} Y_n/z_n \\
\int_0^1 P_n(i') x_n(i') \, di =& \int_0^1 P_n(i')^{1-\sigma_n} \, di \left(\int_0^1 P_n(i)^{1-\sigma_n} \, di \right)^{\frac{\sigma_n}{1-\sigma_n}} Y_n/z_n \\
=& z_n^{-1} \left(\int_0^1 P_n(i)^{1-\sigma_n} \, di \right)^{\frac{1}{1-\sigma_n}} Y_n \\
=& Q_n Y_n
\end{aligned}
$$

Q_n is a price index.

Coming back to the profit maximization problem:

$$
\begin{aligned}
\max_{x_n} \Pi_n^Y =& P_n^Y Y_n - \int_0^1 P_n(i) x_n(i) \, di \\
=& P_n^Y Y_n - Q_n Y_n
\end{aligned}
$$

subject to:

$$
Y_n = z_n (\int_0^1 x_n(i)^{\frac{\sigma_n - 1}{\sigma_n}} \, di)^{\frac{\sigma_n}{\sigma_n - 1}}
$$

Zero profit maximization yields

$$
Q_n = P_n^Y \tag{22}
$$

The probability that country n imports goods from country j is given by:

$$
\Pi_{nj} = \int_{s_j \in S_{nj}} p_{nj}(s_j) x_n(s_j) \; ds_j / Q_n Y_n \tag{23}
$$

B.2 Establishing: $Y_{jt} Q_{jt} = r_{jt} K_{jt} - M_{jt-1} \mu_{jt}$

Equating final goods market clearing to consumers' budget constraints taking into account bonds market clearing gives:

$$
\begin{aligned}
Y_{jt} &= C_{jt} + K_{jt+1} - (1-\delta) K_{jt} \text{ (Goods market clearing)} \\
&= \frac{r_{jt}}{P_{jt}^Y} K_{jt} + \frac{M_{jt-1} - M_{jt}}{P_{jt}^Y} \text{ (Consumer Budget constraint, with } D_{jt} = 0) \\
&= \frac{r_{jt}}{P_{jt}^Y} K_{jt} - \frac{M_{jt-1} \mu_{jt}}{P_{jt}^Y} \quad \text{(Using money supply in 4)} \\
Y_{jt} Q_{jt} &= r_{jt} K_{jt} - M_{jt-1} \mu_{jt} \quad \text{(Using 22)}
\end{aligned}
$$

B.3 Proof of lemma

Lemma: From Capital market clearing in (13), we have (abstracting time script):

$$
\begin{aligned}
K_j &= \int_{s_j \in S_j} K^x(s_j)\ ds_j \\
&= \int_{s_j \in S_j} x(s_j)a_j(s_j)\ ds_j \text{ (By using intermediate production technology)} \\
&= \int_{s_j \in S_j} \sum_{n=1}^{N} \tau_{nj} x_n(s_j)a_j(s_j)\ ds_j \text{ (By using intermediate goods market clearing)} \\
&= \int_{s_j \in S_j} \sum_{n=1}^{N} \frac{p_{nj}(s_j)}{r_j} x_n(s_j)\ ds_j \text{ (By using (8))} \\
&= \sum_{n=1}^{N} (\int_{s_j \in S_j} p_{nj}(s_j)x_n(s_j)\ ds_j)/r_j \text{ (Interverting sum and integral)} \\
&= \sum_{n=1}^{N} \Pi_{nj} Q_n Y_n / r_j \text{ (Using (11))} \\
K_j &= \sum_{n=1}^{N} \Pi_{nj}(r_n K_n - M_{n,t-1}\mu_n)/r_j \text{ (using B.2)}
\end{aligned}
$$

$$
r_j K_j = \sum_{n=1}^{N} \Pi_{nj}(r_n K_n - M_{n,t-1}\mu_n), j = 1, ..., N-1 \tag{24}
$$

$$
\Pi_{nj}(\{\tau_{nk} r_k\}_{k=1}^{N}) = \frac{(b_j \tau_{nj} r_j)^{-\theta}}{\sum_{k=1}^{N} (b_k \tau_{nk} r_k)^{-\theta}}
$$

B.4 The stationary (scaled) model

The main change in consumers problem will be in their Budget constraint, let look at it in detail. We start by the initial Budget Constraint:

$$
C_{jt} + K_{jt} - (1-\delta_j)K_{jt-1} + \frac{D_{jt}}{P^Y_{jt}} + \frac{M_t}{P^Y_{jt}} = \frac{R_{jt-1}}{P^Y_{jt}} K_{jt-1} + \frac{(1+i_{jt-1})D_{jt-1}}{P^Y_{jt}} \frac{P^Y_{jt-1}}{P^Y_{jt-1}} + \frac{M_{t-1}}{P^Y_{jt}} \frac{P^Y_{jt-1}}{P^Y_{jt-1}}
$$

$$
C_{jt} + K_{jt} - (1-\delta_j)K_{jt-1} + \frac{D_{jt}}{P^Y_{jt}} + m_{jt} = \frac{R_{jt-1}}{P^Y_{jt}} K_{jt-1} + \frac{(1+i_{jt-1})D_{jt-1}}{P^Y_{jt-1}} \frac{P^Y_{jt-1}}{P^Y_{jt}} + m_{jt-1} \frac{P^Y_{jt-1}}{P^Y_{jt}}
$$

$$
C_{jt} + K_{jt} - (1-\delta_j)K_{jt-1} + d_{jt} + m_{jt} = \frac{r_{jt-1}}{1+\pi_{jt}} K_{jt-1} + ((1+i_{jt-1})d_{jt-1} + m_{jt-1}) \frac{1}{1+\pi_{jt}}
$$

(with $r_{jt-1} = \dfrac{R_{jt-1}}{P_{jt-1}}$, next we divide by K_{Nt})

$$
\frac{C_{jt}}{K_{Nt}} + \frac{K_{jt}}{K_{Nt}} + \frac{d_{jt}}{K_{Nt}} + \frac{m_{jt}}{K_{Nt}} = (\frac{r_{jt-1}}{1+\pi_{jt}} + 1 - \delta_j) \frac{K_{jt-1}}{K_{Nt-1}} \cdot \frac{K_{Nt-1}}{K_{Nt}} + (\frac{(1+i_{jt-1})d_{jt-1} + m_{jt-1}}{(1+\pi_{jt})K_{Nt-1}} \cdot \frac{K_{Nt-1}}{K_{Nt}}
$$

$$
\tilde{c}_{jt} + \tilde{k}_{jt} + \tilde{d}_{jt} + \tilde{m}_{jt} = (\frac{r_{jt-1}}{1+\pi_{jt}} + 1 - \delta_j) \frac{\tilde{k}_{jt-1}}{\gamma_{Nt}+1} + (\frac{(1+i_{jt-1})\tilde{d}_{jt-1} + \tilde{m}_{jt-1}}{(1+\pi_{jt})(\gamma_{Nt}+1)} \quad \text{(For stationarity)}
$$

The modified problem to solve is therefore:

$$\max_{\{\tilde{c}_{jt},\tilde{k_j}_t,\tilde{d}_{jt},\tilde{m}_{jt}\}} E_0 \sum_{t=0}^{\infty} \beta_j^t u\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right)$$

$$\text{st:} \quad \tilde{c}_{jt} + \tilde{k}_{jt} + \tilde{d}_{jt} + \tilde{m}_{jt} = (\frac{r_{jt-1}}{1+\pi_{jt}} + 1 - \delta_j)\frac{\tilde{k}_{jt-1}}{\gamma_{Nt}+1} + (\frac{(1+i_{jt-1})\tilde{d}_{jt-1} + \tilde{m}_{jt-1}}{(1+\pi_{jt})(\gamma_{Nt}+1)}$$

To derive the Euler equations, let write the Lagrangian $\mathcal{L}$, where the Lagrange multiplier for the constraint is λ_t :

$$\mathcal{L} = E_0 \sum_t \left[\beta_j^t u\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right)\right.$$
$$\left. + \lambda_t \left(\left(\frac{r_{jt-1}}{1+\pi_{jt}} + 1 - \delta_j\right)\frac{\tilde{k}_{jt-1}}{\gamma_{Nt}+1} + \frac{(1+i_{jt-1})\tilde{d}_{jt-1} + \tilde{m}_{jt-1}}{(1+\pi_{jt})(\gamma_{Nt}+1)} \qquad - \left(\tilde{c}_{jt} + \tilde{k}_{jt} + \tilde{d}_{jt} + \tilde{m}_{jt}\right)\right)\right]$$

First-Order Conditions

With respect to $\tilde{c}_{jt}$:

$$\frac{\partial \mathcal{L}}{\partial \tilde{c}_{jt}} = \beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) - \lambda_t = 0$$
$$\Rightarrow \quad \lambda_t = \beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right)$$

With respect to $\tilde{k}_{jt}$:

$$\frac{\partial \mathcal{L}}{\partial \tilde{k}_{jt}} = -\lambda_t + E_t\left[\lambda_{t+1}\left(\frac{r_{jt}}{1+\pi_{jt+1}} + 1 - \delta_j\right)\frac{1}{\gamma_{N,t+1}+1}\right] = 0$$
$$\Rightarrow \quad \lambda_t = E_t\left[\lambda_{t+1}\left(\frac{r_{jt}}{1+\pi_{jt+1}} + 1 - \delta_j\right)\frac{1}{\gamma_{N,t+1}+1}\right]$$

With respect to $\tilde{d}_{jt}$:

$$\frac{\partial \mathcal{L}}{\partial \tilde{d}_{jt}} = -\lambda_t + E_t\left[\lambda_{t+1}\left(\frac{1+i_{jt}}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right] = 0$$
$$\Rightarrow \quad \lambda_t = E_t\left[\lambda_{t+1}\left(\frac{1+i_{jt}}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right]$$

With respect to $\tilde{m}_{jt}$:

$$\frac{\partial \mathcal{L}}{\partial \tilde{m}_{jt}} = \beta_j^t u_m\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) - \lambda_t + E_t\left[\lambda_{t+1}\left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right] = 0$$
$$\Rightarrow \quad \beta_j^t u_m\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \lambda_t - E_t\left[\lambda_{t+1}\left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right]$$

Derivation of Euler Equations

Starting with the first-order condition with respect to $\tilde{k}_{jt}$:

$$\lambda_t = E_t \left[\lambda_{t+1} \left(\frac{r_{jt}}{1+\pi_{jt+1}} + 1 - \delta_j \right) \frac{1}{\gamma_{N,t+1}+1} \right]$$

Substitute $\lambda_t = \beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right)$ and $\lambda_{t+1} = \beta_j^{t+1} u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right)$:

$$\beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \beta_j^{t+1} E_t \left[u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right) \left(\frac{r_{jt}}{1+\pi_{jt+1}} + 1 - \delta_j \right) \frac{1}{\gamma_{N,t+1}+1} \right]$$

Dividing both sides by β_j^t gives the Euler equation for capital:

$$u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \beta_j E_t \left[u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right) \left(\frac{r_{jt}}{1+\pi_{jt+1}} + 1 - \delta_j \right) \frac{1}{\gamma_{N,t+1}+1} \right]$$

Starting with the first-order condition with respect to $\tilde{d}_{jt}$:

$$\lambda_t = E_t \left[\lambda_{t+1} \left(\frac{1+i_{jt}}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)} \right) \right]$$

Substitute $\lambda_t = \beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right)$ and $\lambda_{t+1} = \beta_j^{t+1} u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right)$:

$$\beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \beta_j^{t+1} E_t \left[u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right) \left(\frac{1+i_{jt}}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)} \right) \right]$$

Dividing both sides by β_j^t gives the Euler equation for debt:

$$u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \beta_j E_t \left[u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right) \left(\frac{1+i_{jt}}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)} \right) \right]$$

Starting with the first-order condition with respect to $\tilde{m}_{jt}$:

$$\beta_j^t u_m\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \lambda_t - E_t \left[\lambda_{t+1} \left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)} \right) \right]$$

Substitute $\lambda_t = \beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right)$ and $\lambda_{t+1} = \beta_j^{t+1} u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right)$:

$$\beta_j^t u_m\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = \beta_j^t u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) - \beta_j^{t+1} E_t \left[u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right) \left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)} \right) \right]$$

Divide both sides by β_j^t gives the Euler equation for money:

$$u_m\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) = u_c\left(\tilde{c}_{jt}, \tilde{m}_{jt}\right) - \beta_j E_t \left[u_c\left(\tilde{c}_{j,t+1}, \tilde{m}_{j,t+1}\right) \left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)} \right) \right]$$

Summary of Euler Equations

Euler Equation for Capital:

$$u_c\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)=\beta_j E_t\left[u_c\left(\tilde{c}_{j,t+1},\tilde{m}_{j,t+1}\right)\left(\frac{r_{jt}}{1+\pi_{jt+1}}+1-\delta_j\right)\frac{1}{\gamma_{N,t+1}+1}\right] \tag{25}$$

Euler Equation for Debt:

$$u_c\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)=\beta_j E_t\left[u_c\left(\tilde{c}_{j,t+1},\tilde{m}_{j,t+1}\right)\left(\frac{1+i_{jt}}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right] \tag{26}$$

Euler Equation for Money:

$$u_m\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)=u_c\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)-\beta_j E_t\left[u_c\left(\tilde{c}_{j,t+1},\tilde{m}_{j,t+1}\right)\left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right] \tag{27}$$

These Euler equations describe the intertemporal optimization conditions for consumption, capital, money, and debt. These equations, combined with the Budget Constraint below in equation 28, they describe citizens' optimization solutions.

$$\tilde{c}_{jt}+\tilde{k}_{j_t}+\tilde{d}_{jt}+\tilde{m}_{jt}=(\frac{r_{jt-1}}{1+\pi_{jt}}+1-\delta_j)\frac{\tilde{k}_{jt-1}}{\gamma_{Nt}+1}+(\frac{(1+i_{jt-1})\tilde{d}_{jt-1}+\tilde{m}_{jt-1}}{(1+\pi_{jt})(\gamma_{Nt}+1)} \tag{28}$$

(The following system of equations summarizes the stationary solution to sole for (Eliminating debt for now: $\tilde{c}_{j,t},\tilde{k}_{j,t},\tilde{m}_{j,t},,P^Y_{jt},\pi_{jt},r_{jt},z_{jt},u_{jt},\gamma_{j,t}$:

$$\begin{aligned}
u_c\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)&=\beta_j E_t\left[u_c\left(\tilde{c}_{j,t+1},\tilde{m}_{j,t+1}\right)\left(\frac{r_{jt}}{1+\pi_{jt+1}}+1-\delta_j\right)\frac{1}{\gamma_{N,t+1}+1}\right]\\
u_m\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)&=u_c\left(\tilde{c}_{jt},\tilde{m}_{jt}\right)-\beta_j E_t\left[u_c\left(\tilde{c}_{j,t+1},\tilde{m}_{j,t+1}\right)\left(\frac{1}{(1+\pi_{jt+1})(\gamma_{N,t+1}+1)}\right)\right]\\
\tilde{c}_{jt}+\tilde{k}_{j_t}+\tilde{m}_{jt}&=(\frac{r_{jt-1}}{1+\pi_{jt}}+1-\delta_j)\frac{\tilde{k}_{jt-1}}{\gamma_{Nt}+1}+\frac{\tilde{m}_{jt-1}}{(1+\pi_{jt})(\gamma_{Nt}+1)}\\
\tilde{k}_{jt}&=\sum_{n=1}^{N}\Pi_{nj}(\tilde{k}_{nt}r_n/r_j-P_{n,t-1}\frac{\tilde{m}_{n,t-1}}{1+\gamma_N}\mu_n/r_j)\ ;\ j<N;\ k_{3t}=1\text{ set as a parameter}\\
P^Y_{jt}(\{\tau_{jn}r_{nt}\}_{n=1}^N)&=c_j[\sum_{n=1}^{N}b_n(\tau_{jn}r_{nt})^{-\theta}]^{-1/\theta}\\
\pi_{jt}&=log(P^Y_{jt}/P^Y_{jt-1})\\
\gamma_{j,t}&=\frac{k_{jt}}{k_{jt-1}}-1=\frac{k_{Nt}\tilde{k}_{jt}}{k_{Nt-1}\tilde{k}_{jt-1}}-1\\
log(z_{jt})&=\rho^z_j log(z_{jt-1})+e_{jt}\\
\mu_{jt}-\bar{\mu}_j=u_t&=\rho^u_j u_{jt-1}+\phi_j z_{jt-1}+\varphi_{jt}
\end{aligned}$$

Note that the Money supply $\tilde{m}_{jt}=(1+\mu_{jt})*\frac{\tilde{m}_{jt-1}}{(1+\pi_{jt})(1+\gamma_{Nt})}$ has been used to get the capital equation, but it can be used to calibrate the SS, it exhibits $\mu=1$ in the ss. Note also that so far the equation on capital has been simplified by setting $d_{jt}=0$, I will therefore delate it for now.

B.5 Redundancy Explanation

Consider the system of equations for $j = 1, \ldots, N-1$:

$$r_j K_j = \sum_{n=1}^{N} \Pi_{nj}(r_n K_n - M_{n,t-1}\mu_n)$$

The equation states that the total returns to capital in country j, $r_j K_j$ are determined by summing up the weighted and adjusted returns to capital from all other countries. Each term in the summation adjusts the returns to capital from country n by subtracting the impact of the money supply.

Now, consider the system of N equations. If we know the equations for $N-1$ countries, the equation for the N-th country is automatically satisfied because the total system must balance.

1. **Equations for $j = 1$ to $j = N-1$:**

$$r_1 K_1 = \sum_{n=1}^{N} \Pi_{n1}(r_n K_n - M_{n,t-1}\mu_n)$$

$$r_2 K_2 = \sum_{n=1}^{N} \Pi_{n2}(r_n K_n - M_{n,t-1}\mu_n)$$

$$\vdots$$

$$r_{N-1} K_{N-1} = \sum_{n=1}^{N} \Pi_{n,N-1}(r_n K_n - M_{n,t-1}\mu_n)$$

2. **Summing these $N-1$ equations**:

$$\sum_{j=1}^{N-1} r_j K_j = \sum_{j=1}^{N-1}\sum_{n=1}^{N} \Pi_{nj}(r_n K_n - M_{n,t-1}\mu_n)$$

3. **Right-Hand Side Simplification**: Using $\sum_{j=1}^{N} \Pi_{nj} = 1$,

$$\begin{aligned}\sum_{j=1}^{N-1}\sum_{n=1}^{N} \Pi_{nj}(r_n K_n - M_{n,t-1}\mu_n) &= \sum_{n=1}^{N}(r_n K_n - M_{n,t-1}\mu_n)\sum_{j=1}^{N-1}\Pi_{nj} \\ &= \sum_{n=1}^{N}(r_n K_n - M_{n,t-1}\mu_n)(1 - \Pi_{nN})\end{aligned}$$

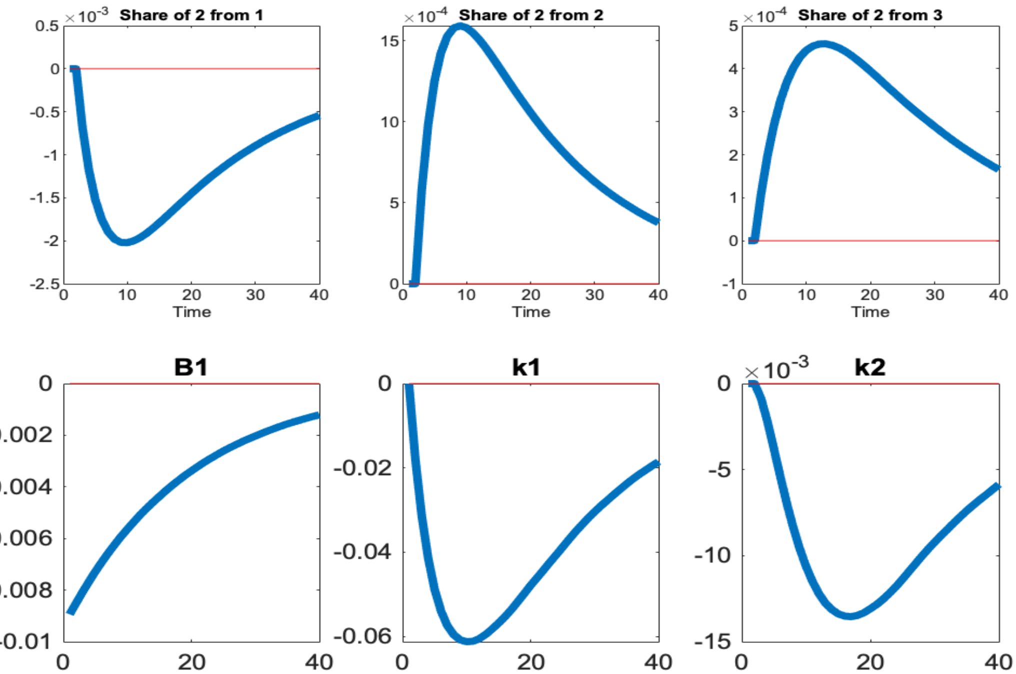
Therefore,

$$
\begin{aligned}
\sum_{j=1}^{N-1} r_j K_j &= \sum_{n=1}^{N} (r_n K_n - M_{n,t-1}\mu_n)(1 - \Pi_{nN}) \\
&= \sum_{n=1}^{N} (r_n K_n - M_{n,t-1}\mu_n) - \sum_{n=1}^{N} (r_n K_n - M_{n,t-1}\mu_n)\Pi_{nN} \\
0 &= r_N K_N - \sum_{n=1}^{N} M_{n,t-1}\mu_n - \sum_{n=1}^{N} (r_n K_n - M_{n,t-1}\mu_n)\Pi_{nN} \\
r_N K_N &= \sum_{n=1}^{N} (r_n K_n - M_{n,t-1}\mu_n)\Pi_{nN} + \sum_{n=1}^{N} M_{n,t-1}\mu_n
\end{aligned}
$$

This latest equation clearly derives the expression for $r_N K_N$. One important feature of this equation is that its structure differs from the remaining $N-1$ equations. An additional term, $\sum_{n=1}^{N} M_{n,t-1}\mu_n$, is added to the sum. This term represents the total monetary adjustments across all countries. It accounts for the overall effect of the growth in the money supply from each country on the returns to capital in country N.

C Model's results appendix

Figure 10: Country 2 trade share dynamics



Notes: This figure presents the The first row shows the trade share of country 2 from the three different countries.