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Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
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JEL Classification: O15, F22, I11, C23, J61

Keywords: Informality, Inequality, Labor market frictions, O-ring theory of development

Douglas Amuli Ibale - douglasamuli@gmail.com
IRES, Uclouvain and Catholic University of Bukavu (UCB)/DRC

Frédéric Docquier - frederic.docquier@liser.lu
Luxembourg Institute of Socio-Economic Research (LISER)

Zainab Iftikhar - iftikhar@econ.uni-frankfurt.de
Goethe University Frankfurt and CEPR

Spatial Inequality, Poverty and Informality in the Democratic Republic of the Congo*

Douglas Amuli Ibale[a], Frédéric Docquier[b] and Zainab Iftikhar[c]

[a] Faculty of Economics and Management, Université Catholique De Bukavu (DRC)

[b] LISER, Luxembourg Institute of Socio-Economic Research (Luxembourg)

[c] Goethe University Frankfurt (Germany), CEPR (UK)

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1 Introduction

Despite some timid progress toward Sustainable Development Goals (SDGs), Africa continues to lag behind with regards to per capita income growth and economic convergence. More than half of the global poor (i.e., people earning less than 1.90 USD per day, in purchasing power parity) live in Africa. Income inequality also remains persistently high, and according to the World Inequality Database (WB, 2020), there are large variations within and between African countries. In Central Africa in particular, there was an increase in income inequality between 1990 and 2015, while other parts of Africa have shown a marginal decline. African nations have experimented with diverse approaches to economic development – for example, prioritizing infrastructure and capital accumulation, fighting against corruption and poor governance, pursuing trade and economic integration, prioritizing human development, etc. However, in most cases these actions have failed, possibly because achieving sustainable development is a multifaceted challenge requiring a combination of favorable conditions that are difficult to reconcile.

We develop an approach that formalizes the interaction between several ingredients of economic development, we then calibrate it using data for the Democratic Republic of Congo (DRC, henceforth), and we investigate whether an "O-ring" model of development can explain economic disparities between provinces and socio-demographic groups. Although the original O-ring theory focuses on micro aspects (Kremer, 1993),[1] our macroeconomic generalization of it implies that policies targeting a specific part of the economy only have a small effect if other complementary components of the development machinery are not working properly. We illustrate the difficulty of reducing inequalities in the DRC using a two-sector model with two skill groups and imperfectly competitive labor markets. We focus on the interactions among four driving forces of development: (i) public infrastructure, (ii) human capital, (iii) production technology (capturing the quality of national and local institutions), and (iv) labor market frictions. In existing literature, these factors are commonly perceived as proximate causes of economic development, and are unequally distributed across DRC provinces. They are potential drivers of inequality between provinces and between different groups of people. We aim to evaluate their relative importance in reducing inequality and increasing per capita income, as well as the strength of interactions between them. Furthermore, we extend the development accounting approach by analyzing the relevance of informal activities when explaining inequalities in poor countries. Due to a lack of data, quantitative assessment of the role played by the informal sector is largely ignored in relevant literature. Our findings are in line with theories showing that the extreme poor need a "big multidimensional push" to escape from the poverty trap (Banerjee et al., 2015).

Our focus on the DRC is justified for two reasons. First, it is among the world's poorest

[1] E.g. the importance of complementarities between tasks at the firm level

countries, and suffers from low levels of public infrastructure and human capital, poor governance, and an overwhelmingly large informal sector. The informal sector is defined as the part of an economy that is not taxed or monitored by any form of government. It drains large numbers of both skilled and unskilled workers in developing countries (Docquier and Iftikhar, 2019; Jütting and De Laiglesia, 2009; Schneider, 2012). DRC is abundant in natural resources, holds a young population with a median age of 17, and has the potential to show great improvement in economic growth and development (WB, 2014) but has failed to realize this potential. Second, microdata are available to characterize the levels of both spatial and within-region inequalities, and the source of income earned by each individual. It is difficult to find such data for other African economies. The "*1.2.3* household survey" is unique, in that it documents the level of income of Congolese working-age people by education level, sector of activity (formal vs. informal), type of activity (entrepreneurship vs. employment), and province. The database provides a unique opportunity to analyze interactions between sectors and the functioning of the labor market. It reveals that spatial inequalities are large, and account for approximately 50 percent of the Theil index between broad groups of income earners. In all provinces, the labor market exhibits a similar structure in general. The informal sector employs a large proportion of both the skilled and the unskilled workers. On average, workers in the informal sector have low earnings compared with similarly skilled workers in the formal sector, and the skill ratio remains the highest in the formal sector. Nonetheless, the data also reveal large differences across provinces in observed characteristics, such as the education structure of the population, the size of the informal sector, and the level of public infrastructure per worker.

We build a one good, two-sector (formal and informal), two-class (low and high-skilled workers) model that can replicate the demographic and economic structure of each province. We then use this to quantify the effect of different types of "policies" on per capita income and on income inequality between and within provinces.[2] We define high-skilled individuals as workers with at least a "state diploma qualification" (12 or more years of education), while the unskilled are those who have not completed secondary education. In each province, the same final product is made by firms in the formal and informal sectors, using different technologies. The economy of each province is characterized by five sets of parameters: (i) socio-demographic indicators (the proportion of secondary-educated workers), (ii) the level of public infrastructure, (iii) technological parameters in the formal sector, (iv) technological parameters in the informal sector, and (v) labor market frictions in the formal economy (partly reflecting poor labor market institutions and arbitrary regulations). The informal sector is characterized by small businesses run by entrepreneurs who hire workers in a competitive labor market. We ignore inter-provincial trade and migration flows, which are commonly perceived to be low in DRC.[3]

[2]We refer to the shocks to structural parameters as "policies". See Section 4 for more details.

[3]Internal exchanges are hampered by insufficient and poor conditions of the road network. Chronic economic mismanagement and internal conflicts have led to serious under-investment in infrastructure over many years.

We parameterize the model to exactly match employment patterns and income disparities between groups, and conduct a set of numerical experiments. We find significant disparities across provinces in calibrated parameters — i.e., total factor productivity (TFP) scale factors of both sectors, and labor market frictions — and in observed characteristics — i.e., human capital and public infrastructure levels. We use counterfactual simulations to analyze the role of province-specific characteristics in explaining the income gap with the richest province, Kinshasa, and within-province inequality. Somewhat unsurprisingly, we show that income disparities are mostly determined by technological characteristics, reflecting endowments in mineral resources, geographic position, topography, institutional quality, etc. More interestingly, we find that stimulating TFP in the formal sector increases the province-wide average level of income, but has a smaller effect on low-skilled workers' income. Stimulating TFP in the informal sector induces larger aggregate gains by generating greater benefits for the low-skilled. Thus, improving TFP in both sectors is desirable to increase the average income of both types of workers.

We show that a development policy that disregards the situation of the informal sector has low or even detrimental effects on inequality and extreme poverty. In particular, policies targeting education and public infrastructure have smaller effects, as they mostly impact on productivity in the formal sector, and reduce the skill ratio and productivity in the informal sector, where many unskilled workers are trapped. Taken in isolation, these policies induce potential undesirable effects on the distribution of income, inequality, and extreme poverty. More generally, the effectiveness of each policy taken in isolation is limited, due to complementarities between them and due to the low mobility of unskilled workers across sectors. We quantify the high level of complementarity between policies and highlight strong O-ring patterns of spatial inequality. Furthermore, we investigate whether the informal sector hampers income growth, as existing literature suggests different views on this issue (de Soto, 1989; McKinsey, 2004a,b, 2015). Our findings are in line with the dual view on the informal sector, suggesting that it is a subsistence sector, and that development comes from the growth of formal sector (La Porta and Shleifer, 2014; Lewis, 1954; Rauch, 1991). Our counterfactual simulations show that focusing solely on reducing the size of the informal sector without creating ample opportunities in the formal sector has little or no effect on spatial inequalities, and may actually increase inequality within a region by reducing wages for some groups of workers.

Reducing frictions to the levels observed in Kinshasa alone, or combined with a policy targeting productivity in the formal sector, can be worse for within-province inequality than targeting the technology only, as it mainly benefits skilled workers. The main conclusion

To put this in perspective, only 5.4% of the road network in the country is asphalted. This also significantly limits the mobility of labor. Indeed, using the *1.2.3* survey database, the proportion of migrants accounts for only 4.2% of the working-age population. This includes both intra-province and inter-province labor mobility. The inter-province mobility itself is likely to be significantly lower.

of our analysis is that even a dramatic reduction in labor market frictions does not benefit unskilled workers. This is because such a reduction does not induce an increase in job creation of a comparable magnitude. In the absence of complementary actions, it only fosters skilled workers' mobility across sectors, reduces the skill ratio in both formal and informal sectors, and leads to a decline in the wages of low-skilled workers. Reducing labor market frictions reduces poverty along the extensive margin, by increasing the job finding probability for low-skilled workers in the formal sector, but increases it along the intensive margin, by reducing the wages offered in both sectors.

Our paper relates to the literature on the effectiveness of development policies. In the discussion of William Estearly's "Elusive Quest for Growth," Wacziarg wrote:

> *"Over the last decades, the list of proposed panaceas for growth in per-capita income included high-rate of physical capital investments, rapid human capital accumulation, low-income inequality, low fertility, being located far from the equator, a low incidence of tropical diseases, access to the sea, favorable weather patterns, hands-off government, trade-policy openness, capital-markets development, political freedom, economic freedom, ethnic homogeneity, British colonial origins, a common-law legal system, the protection of property rights and the rule of law, good governance, political stability, infrastructure, market-determined prices (including exchange rates), foreign direct investment, and suitably conditioned foreign aid."* Wacziarg (2002)

Most of these miracle growth policies have proven disastrous or ineffective, which may be due to the complex system nature of development policies (Mueller, 2020). Growth miracles require a combination of favorable and mutually reinforcing factors. In particular, creating incentives that are conducive to growth-enhancing behaviors (such as private investment in physical and human capital) requires a supportive environment, with political stability and sound governance, a high level of public infrastructure, and functioning markets.

Our approach formalizes the interactions between these ingredients. First, it accounts for large frictions observed in the labor market. In many sub-Saharan African countries, a small number of firms operate in the (productive) formal sector and offer relatively high wages. However, the dysfunctional labor market implies the existence of an overwhelming informal sector, characterized by lower earnings and lower productivity (Dickens, 1985; Jütting and De Laiglesia, 2009; Maloney, 1999, 2004). The likelihood of finding productive employment in the labor market is disappointingly low for the workforce. Reyes et al. (2017) show that in the country, workers find it increasingly difficult to participate in the formal labor market, and education does not shield workers from the informal sector. Job creation was not rapid enough to meet the demand from a growing working-age population between 2005 and 2012.

Second, we account for the role of infrastructure.[4] There is evidence that public infrastruc-

[4]Note that informal employment can generate vicious circles, as the difficulty in raising fiscal revenue is one

ture – transport infrastructure, electricity, sanitation, water and sewage networks, communication systems, etc. – is a key determinant of productivity, growth, and income (Calderon and Serven, 2010, 2014; Dufflo and Pande, 2007; Irmen and Kuehnel, 2009; Wang and Wu, 2015). Nevertheless, a deficit in the public infrastructure is observed in many developing countries (Bhattacharya and Kharas, 2011; Estache, 2010; Fay et al., 2011; Ingram and Kessides, 1994). This is particularly the case in DRC, where equipment is outdated, maintenance levels are inadequate, and new investment is at a low level.[5]

Third, human capital is usually seen as a key determinant of development potential through its effects on health, knowledge, skills, or the resilience of people (Bloom et al., 2004; Hanuschek, 2013). On this basis, the World Bank launched a Human Capital Plan for Africa in 2019, with precise targets for 2023. In DRC, the education system is primarily financed by parents, the school enrolment rate is low, and illiteracy is at a high level among the population (Gyimah-Brempong, 2011). Furthermore, public spending on education is unevenly redirected towards less-developed regions (IMF, 2015).[6]

Lastly, it has long been recognized that strong institutions and stability are needed to enable growth miracles. Good institutions provide secure property rights and more-equal access to resources (Acemoglu et al., 2005). DRC is rich in mineral resources; however, rather than bringing economic prosperity and political stability, natural endowments have led to illegal exploitation (both internal and external), conflicts, and corruption (Asiedu and Lien, 2011; Bhattacharyya and Hodler, 2010; Olson and Congdon Fors, 2004). This translates into lower levels of total factor productivity and reduced incentives to invest for firms in both the formal and informal sectors.

The rest of this paper is organized as follows. Section 2 describes the *1.2.3* survey data and highlights ten stylized facts characterizing the economy of DRC, providing us with the motivation for the specification and parameterization of our model. In Section 3, we develop a labor market model that is consistent with the stylized facts and anecdotal evidence. The results of our numerical experiments are presented in Section 4. Lastly, Section 5 concludes.

of the main reasons for investment in infrastructure being small in developing countries. Besley and Persson (2014) report that low-income countries have similarly low tax rates (varying between 10 and 20% of GDP), while in developed countries, the average level of taxation is close to 40% of GDP. Besley and Persson (2014) argue that this discrepancy is due to the larger size of the informal sector, which makes the sensitivity of taxable income to the tax rate much greater than in developing countries.

[5]As shown by Herderschee et al. (2012), only four out of ten provincial capitals are linked by road to the national capital (Kinshasa), and shipping costs by rail are substantially greater than in other countries. Access to electricity and telecommunications are poor.

[6]In the DRC, the poorest provinces are not the prime recipients of public resources. For instance, in 2013, the government spent 4 USD per capita in education in Kasai Oriental, the poorest province in the DRC, against 57 USD for Kinshasa, the province with the lowest number of poor.

2 Stylized Facts

Our study focuses on the Democratic Republic of Congo (DRC), which is the most populous francophone nation in the world (about 100 million inhabitants), and is among the world's poorest countries. In the next section, we model the labor market of each Province of DRC. Our model endogenizes the size and structure of the formal and informal segments of the labor market, as well as their implications for the distribution of income. We parameterize our model to match ten important stylized facts (SF1–SF10) that are illustrated in Tables 1-3 and Figure 1 below. SF1 describes the overall economic and institutional situation of the country. The microdata used to characterize the economy of each province are mostly extracted from the *1.2.3* database, a broad household and expenditure survey conducted between 2005 and 2012 by the DRC's National Institute of Statistics (INS) in partnership with different actors (including Afristat and the World Bank). A random stratification technique was implemented to guarantee that each of the 11 provinces of DRC has at least 1000 household-level observations.[7]

The *1.2.3* data were collected in three phases, and each of the numbers refers to a collection phase. Phase 1 provides detailed information on employment, unemployment, household, and individual socio-demographic characteristics. Phase 2 focuses on the informal sector and gathers information about the characteristics of firms and firm owners in the sector. Phase 3 is a survey on household expenditures. We exploit Phases 1 and 2 of the 2012 survey, which covers about 88,600 individuals. Given its large scale and recognized quality, this database provides a unique opportunity to study the relationships between informal employment, productivity, and income distribution.

The ten stylized facts (labeled as SF1 to SF10) are as follows:

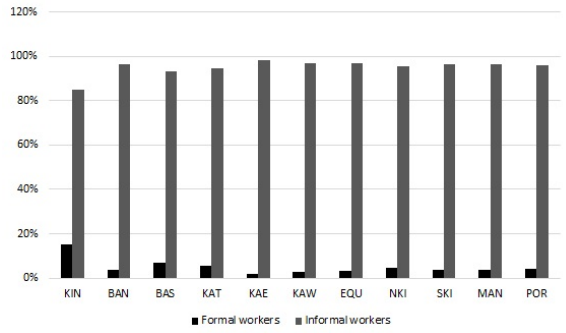
SF1. DRC is one of the least developed countries of the world. Despite an abundance of natural resources, DRC has one of the world's lowest GDP per capita and is characterized by low institutional quality, as illustrated in Table 1. In the 2019 Human Development Report of the United Nations, DRC showed an HDI index of 0.459 and ranked 179 out of 189 countries included in the database. Almost 64 percent of the Congolese population live below the national poverty line, and 76 percent live on less than 1.90 USD per day (in PPP value). Poverty rates range from 36.8 percent of the population in the richest province of Kinshasa, to more than 70 percent in the least developed provinces. Inequality is among the highest in sub-Saharan Africa, with a Gini index of 0.45 in 2012 and a per capita GDP level of 767.4 USD (in PPP value); i.e., 9.4 percent of the Central African average and just 3.6 percent of the worldwide average.

The Corruption Perception Index (CPI) score of DRC was 18 in 2019, placing DRC in position 168 out of the 180 countries included in the database. The DRC constitution protects

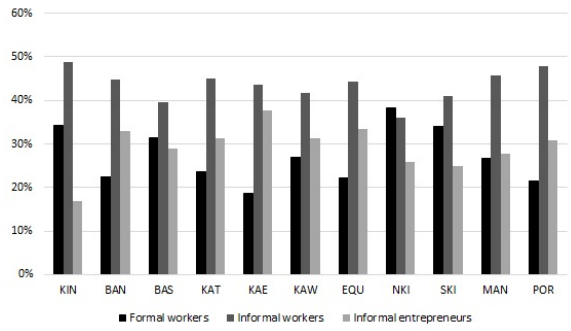
[7]The country was divided into 26 provinces in 2015.

Figure 1: Labor market characteristics by sector and by skill group

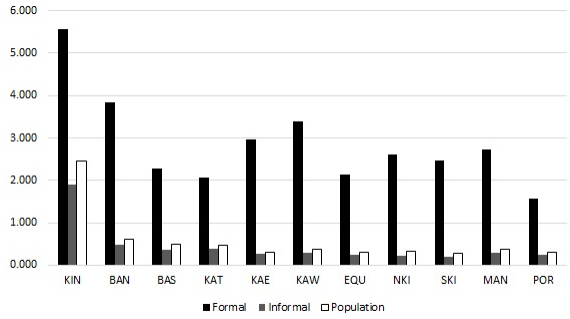
(a) Labor allocation of the unskilled



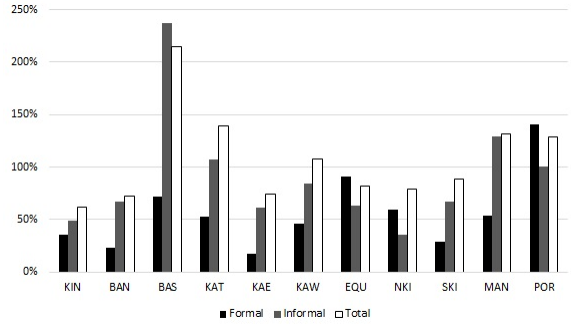
(b) Labor allocation of the skilled



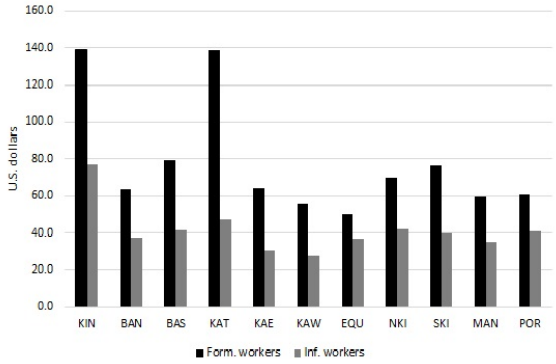
(c) Skill ratio by sector



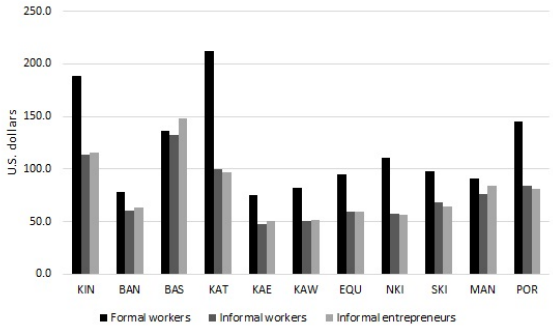
(d) Skill premium by sector



(e) Monthly earnings of the unskilled



(f) Monthly earnings of the skilled



the ownership of private property, but enforcement is virtually nonexistent. As a consequence, the Heritage Foundation assigns a property rights score of 30.1 (on a scale from zero to 100), which is far below the mean level observed in Central Africa and sub-Saharan Africa. In addition, the Heritage Foundation assigns a government integrity score of 13 (on a scale from zero to 100), which is the lowest score in central Africa and less than half of the sub-Saharan African average score. Lastly, the inflation rate in DRC is four times as large as the sub-Saharan African average (and six times as large as the world average). Between 2007 and 2012, the country experienced increasing economic growth, with a cumulative nominal growth of 33 percent (5.8 percent per year). However, the impact of economic growth on living standards has been very limited.

Table 1: DRC comparison with selected countries

Countries	HDI[a]	CPI[b]	GDP p.c. PPP value[c]	Property rights[d]	Gov. integrity[e]	Tax burden[f]	Inflation rate[g]
DR Congo	0.459	18	767.4	30.1	13.1	74.4	29.3
Angola	0.574	26	6814.3	36.9	15.1	87.3	19.6
Cameroun	0.563	25	3828.2	45.3	20.8	74.8	2.4
Gabon	0.702	31	18495.9	36.9	36.7	74.3	4.8
Equatorial Guinea	0.588	16	22709.7	38.1	15.1	75.1	1.3
Congo, Rep.	0.608	19	6798.9	40.7	23.1	63.3	1.1
Sao-Tomé & Principe	0.609	46	3324.0	41	37.4	88.3	7.9
Chad	0.401	20	2415.3	32.4	15.1	45.8	2.5
Central Africa	0.563	25.1	8144.2	37.7	22.0	72.9	8.6
Sub-Saharan Africa	0.541	32	5661.9	44.0	28.9	76.0	7
World	0.731	43	21385.6	56.6	43.8	77.3	4.8

Notes: Author's computation based on: [a] UNDP's 2019 Human Development Report; [b] Transparency International; [c,g] World bank indicator and IMF as summarized by Heritage Foundation; [d,e,f] Heritage Foundation. Data refer to the year 2019.

SF2. DRC provinces exhibit large differences in wages, skill supply and size of informality. DRC provinces are strongly heterogeneous in size and in labor market characteristics, as shown in Table 2 based on the *1.2.3* database. Looking at mean monthly wages, larger provinces exhibit higher average levels of earnings (the correlation between population size and monthly earnings equals 0.58). In particular, Kinshasa (10.5 million inhabitants) is 3.4 times wealthier than the poorest province of Kasai Oriental (7.1 million inhabitants), 3.1 times wealthier than the smallest province of Maniema (2.2 million inhabitants), and 2.1 times wealthier than the country's average. We consider that these nominal income disparities are reasonable proxies for variations in living conditions, as spatial differences in prices are relatively small in DRC. In fact, the poorest provinces (Kasai Oriental and Kasai Occidental) exhibit the highest average prices, indicating that the real poverty rate could be even higher than depicted by the monthly nominal wages.[8] Yet geographic mobility is low in DRC. The *1.2.3* database shows that the proportion of working-age individuals who have lived administratively in their province of residence for less than 10 years is 13.4 percent. Excluding those who moved for non-economic reasons (study, family reunification, forced displacement, etc.), this is reduced to 4.2 percent of the population. The group includes both within-province and between-province movers.

The size of the informal sector is greater than 80 percent in all provinces except Kinshasa, and is greater than 90 percent in three provinces (Kasai Oriental, Equateur, and Province Orientale). The correlation between average monthly wages and the size of the informal sector equals -0.88. The proportion of secondary-educated workers varies from 15 percent in Province Orientale to 59.9 percent in Kinshasa. The correlation between average monthly wages and the

[8]Data for the province-specific price index are not available. We use price data (per kg) for maize, rice, and wheat flour to compute an average province-specific price level. Such data are only available for the year 2019 and do not account for the price of housing, among other things.

proportion of secondary educated equals 0.86.

Table 2: Heterogeneity in labor market characteristics and prices across DRC Provinces

Province	Population (x 1,000)	Monthly wage	Price level	Informal job (as %)	Secondary+ (as %)
Kinshasa (KIN)	10,558	127,432	1169.73	62.5	59.9
Bandundu (BAN)	8,954	46,078	1387.96	87.6	28.9
Bas-Congo (BAS)	5,215	72,407	1035.08	82.9	29.4
Katanga (KAT)	12,240	93,735	1263.85	87.1	26.3
Kasaï Oriental (KAE)	7,190	37,147	1649.25	93.5	16.8
Kasaï Occidental (KAW)	5,757	37,151	1873.10	89.3	21.2
Equateur (EQU)	8,121	43,572	1212.60	91.5	16.7
Nord-Kivu (NKI)	6,240	54,681	1235.56	85.8	23.1
Sud-Kivu (SKI)	5,411	56,732	1115.63	88.9	16.5
Maniema (MAN)	2,187	40,672	1321.94	88.9	19.5
Province Orientale (POR)	8,589	45,137	1337.44	91.3	15.0
Unweighted mean	7,315	59,522	1327.47	86.3	24.8
Coef. of variation	0.363	0.452	0.174	0.093	0.487

Notes: Author's computation. Population data are from INS country's statistical report (2015). The price level is calculated averaging the per kg price of maize, rice and wheat flour available in "Indice de prix à la consommation des ménage," INS (2019). Wage, proportion of informal job and proportion of Secondary+ are computed from the *1.2.3* database.

SF3. Cross-province disparities in public infrastructure are large. The level of public infrastructure is low in DRC. The data taken from the INS statistical report (2015) for the country show that between 2010 and 2015, public capital spending amounted to 4.0 percent of total revenues, on average. Table 3 shows that access to drinkable water and electricity is limited (to 17.5 percent and 13.4 percent of the population, respectively). Only 5.4 percent of the road network is paved, the railways are poorly maintained, crowded, and dangerous, and less than one third of the provinces have an international airport. Furthermore, up to the end of 2015, there was no airline company, either public or private, serving the entire country. The low number of airports and their poor condition limit exchanges and transactions between provinces and countries. Combined with the insufficiency and poor condition of the road network, this hampers internal exchanges and the development of local potential in a country where only 20 percent of the national territory is covered by the telephone network and only about 7 percent of the population has access to the internet (INS, 2015). The coefficients of variation related to each infrastructure proxy and regional disparities in public infrastructure are larger (sometimes three times larger) than for the labor market characteristics reported in Table 2.

SF4. An overwhelming majority of unskilled workers are employed in the informal sector. The informal sector is overwhelmingly large in DRC. Since 1990, labor demand has been falling steeply, while rapidly expanding demography has continuously increased the demand for jobs. The high levels of poverty and inequality, and the absence of public provision for unemployment insurance have favored the emergence of the informal sector. According

Table 3: Heterogeneity in public infrastructure across provinces

Province	Capital spending per worker, USD	Acc. Electricity as % of HH	Acc. water as % of HH	Paved as % of road	Intern. airport	Pub. cap. index
KIN	958.8	74.0	89.0	90.1	Yes	84.4
BAN	217.2	2.2	5.6	5.2	No	4.3
BAS	1243.0	16.1	20.9	20.1	No	19.0
KAT	1669.1	13.0	20.6	5.5	Yes	13.0
KAE	240.3	0.5	8.8	3.1	No	4.1
KAW	160.6	0.4	3.1	0.8	No	1.4
EQU	413.0	7.0	2.3	0.6	No	3.3
NKI	655.0	5.2	8.3	20.5	Yes	11.3
SKI	703.2	10.8	19.8	7.9	No	12.8
MAN	1182.2	8.8	3.1	6.3	No	6.1
POR	379.3	9.0	11.5	2.3	Yes	7.6
Unweighted mean	711.1	13.4	17.5	14.8	0.272	15.2
Coef. of variation	0.664	1.479	1.345	1.674	1.633	1.474

Notes: Author's computation based on the INS statistical report (2015). The allocation of capital expenditure across the provinces is provided by the capital expenditure plan of the Ministry of Budget. The public capital index in the last column is the unweighted mean of columns. (2), (3), and (4).

to the (IMF, 2015), more than 80 percent of the active population operates outside of labor market regulations.

The *1.2.3* survey report of 2012 shows that the informal sector drains 88.6 percent of assets nationwide. It is seen as a key factor reducing the potential tax base, thereby minimizing the infrastructure spending that the country needs. The informal sector is particularly attractive for the low skilled. Figure 1a shows that more than 95 percent of them are employed in the informal sector in virtually all provinces. Two exceptions are Kinshasa (85 percent) and Bas-Congo (93 percent).

SF5. The majority of well-educated workers are in the informal sector. Although the phenomenon is less pronounced for holders of a state diploma, Figure 1b shows that the informal sector also drains a large number of skilled workers. The proportion of skilled workers employed in the formal sector is close to one third in Kinshasa, Bas-Congo, and Sud-Kivu. The highest proportion (38 percent) is found in Nord-Kivu; in the other provinces, it varies between 20 and 25 percent. These results are in line with other studies revealing that the informal economy is recognized for being low-skilled intensive, even though a non-negligible proportion of educated workers have jobs in the informal sector (Docquier and Iftikhar, 2019; Verick, 2008).

SF6. The formal sector is skill-intensive while the informal sector is not. As a corollary of the two previous stylized facts, the skill ratio — defined as the ratio of secondary-educated to lower-educated workers — varies drastically across sectors. The black bar in Figure 1c shows that the skill ratio is relatively large in the formal sector, varying between 5.6 in Kinshasa and 1.6 in Province Orientale. On average, there are three times as many skilled workers as low-skilled workers in the formal sector. This is substantially above the ratio found

for the national population, at around 0.5. Hence, the formal sector in DRC is clearly not representative of the national economy. By contrast, the skill ratio is very low in the informal sector, with the exception of Kinshasa. The country-wide average skill ratio in informal sector is around 0.4, but it falls to 0.3 when excluding Kinshasa. This is slightly smaller than observed for the national population (0.5).

SF7. For both skill groups, formal jobs are better remunerated. Looking at Figures 1e and 1f, the levels of monthly earnings are greater in the formal sector for both groups. On average, unskilled workers earn 1.9 times more in the formal sector than the informal sector, while secondary-educated workers earn 1.6 times more. These ratios are relatively stable across the provinces and are also representative of the situation in Kinshasa. There are a few exceptions, such as Equateur and Province Orientale, where unskilled formal employees (only) earn 40 percent more than informal employees, or Bas-Congo where skilled workers exhibit the same average levels of income in both sectors.

SF8. The skill premium varies across sectors and is sometimes larger in informal sector. Figure 1d shows that skill premiums are positive and fairly large in both sectors; however, they vary across provinces. On average, the largest skill premiums are observed in provinces with low levels of human capital, such as Bas-Congo, Maniema, and Province Orientale. The lowest levels are found in Kinshasa, Bandundu, and the two provinces of Kivu. Skill premiums are also correlated across sectors (0.3). What is remarkable is that the skill premium is on average larger in the informal sector (95 percent) than in the formal sector (59 percent). This is the case in all provinces except Province Orientale and the two provinces of Kivu.

SF9. The informal sector is governed by an entrepreneurial structure embedding land/capital owners and workers of both skill types. The Congolese informal sector consists of small-scale businesses that are characterized by precarious conditions. The *1.2.3* database shows that these activities are concentrated in the agricultural sector, mining industry, and small retail businesses. With the average size of establishments being 1.3 people, it is an atomized sector that mainly consists of micro-units. More than 50 percent of the informal production units in Congolese agglomerations operate without specific professional premises, and 31.2 percent carry out their activity from home (Makabu et al., 2006). The sector employs both skilled (15 percent) and unskilled (85 percent) individuals. Importantly, the sector follows an implicit (and sometimes explicit) entrepreneurial structure, which is mostly governed by the high heterogeneity in access to credit (Mushagalusa-Mudinga et al., 2014; Sara Geenen and Iragi-Mukotanyi, 2013).[9]

[9]The *1.2.3* database reveals that the lack of access to credit is the first obstacle encountered by informal workers, as 98.5% of such workers report that they do not have such access. See also https://www.farmlandgrab.org/post/view/26683.

In agriculture and mining, land ownership is concentrated in the hands of relatively wealthier people, local politicians, and churches. Land owners are not in a position to exploit their land directly (Mushagalusa-Mudinga, 2014), and instead rent out their farmland to peasants, in return for payments that are very rarely made in cash, but much more frequently made in kind or in labor hours. We consider it reasonable to assume that land owners have secondary education, and act as entrepreneurs. This is in line with Reyes et al. (2017), who show that skilled individuals have a low probability of operating alone in the informal sector; with the *1.2.3* database, which reveals that a large proportion of skilled people in informal sector declare themselves as entrepreneurs; and with Adoho and Doumbia (2018), who document that top-performing entrepreneurs in the informal sector are well educated. Most of them own large plots of land and plantations, and operate in agriculture using the abundant and available peasant workforce. Other workers (mostly unskilled), produce and return part of their sale revenues to land owners. The situation is very similar in the retail sector. Due to a lack of capital, small retailers fit into structures where they work for wholesalers. They obtain merchandise and small equipment from wholesalers, sell the merchandise, and pay back an agreed amount to the wholesalers.

As in many low-income countries, the informal sector also includes other odd jobs carried out on street corners and outside of any entrepreneurial structure. Such work can often be seen in the streets of large cities (shoe shining, repairing shoes, selling candy, etc.). However, most of these odd jobs are carried out by children. In 2000, the ILO estimated that nearly 2 million children aged 10 to 14 were economically active in DRC, with almost equal numbers of girls and boys.[10] The model we developed does not capture child labor as our data covers the adult population only.

SF10. In informality, skilled workers and entrepreneurs earn similar levels of income. As apparent from Figure 1f, skilled workers and entrepreneurs in the informal sector have similar levels of monthly earnings. This is the case in all provinces. Our model thus assumes that, in equilibrium, skilled people in informality are indifferent between acting as entrepreneur or wage earner. This being said, Mohammad (2014a) shows that although informal firms are smaller than their formal equivalents in DRC, some micro firms are highly productive. The author identifies an upper-tier segment of the informal economy in which firms are dynamic and efficient, and where entrepreneurs are well remunerated. Some of them are likely to prefer running their business as an informal operation rather than searching for alternative employment in the formal sector.[11] The same heterogeneity can be observed in the formal sec-

[10] See the ILO Committee of Experts on the Application of Conventions and Recommendations (CEACR), Reports, Individual Observations, General Observations and Direct Requests (2008-2010), published in 2000

[11] This can be reinforced by the fact that the low level of regulations, the weak enforcement of labor laws (Reyes et al., 2017), and the greater tolerance of informal activities observed in DRC can make the informal sector more attractive to some entrepreneurs (Garcia, 2017). Despite having job opportunities in the formal sector because of such skills, some individuals might prefer the combination of monetary rewards and greater flexibility (in

tor, where some jobs can be very well remunerated. On average, the level of monthly earnings of entrepreneurs in the informal sector is below the wage rate in the formal sector, implying that informal employment is largely not a choice.

3 Model

For all provinces of DRC ($p = 1, ..., P$), we develop a labor market model that is consistent with the stylized facts described above. Workers are treated as infinitely lived and risk neutral. They discount the future at the exogenous market rate r. There are two skill groups, the skilled (in number H_p), corresponding to individuals with at least a "state diploma degree" (12+ years of education), and the unskilled (in number L_p), corresponding to individuals who have not completed secondary education. The total population in province p is given by $N_p \equiv L_p + H_p$ and the skill ratio in the working-age population is defined as $Z_p \equiv \frac{H_p}{L_p}$. At each moment in time, a single homogeneous final good is produced in two different sectors, the formal and informal sectors (labeled F and I). The final good is the *numéraire* and its price is normalized to unity. Formal firms employ skilled and unskilled workers whereas in the informal sector, skilled entrepreneurs employ both skilled and unskilled workers (in line with SF9).

The informal labor market is competitive, whereas the formal labor market is characterized by search frictions, wage bargaining, and involuntary informal employment. The choice of a frictional formal labor market is justified by the fact that competitive labor markets and perfect mobility of workers between sectors fail to explain why a large income differential exists between the sectors. Although several mechanisms can be used to generate a wage differential between sectors in a competitive labor market setting (such as unobserved heterogeneity in workers' abilities, or differentials in risk, in exposure to rent-seeking, etc.), these mechanisms barely explain why the informal sector attracts workers from all skill groups. Search-and-matching models a la Pissarides (2000) are more compatible with SF7 and better account for endogenous job creation by formal firms and employment patterns observed in DRC (Docquier and Iftikhar, 2019).

In each province p, the workers from each skill group ($S = H, L$) are found in one of the two sectors. A fraction e_p^S of the type-S labor force is employed in the formal sector at a wage rate w_p^S, and produces intermediate goods for the final sector. Those who do not find a formal job are absorbed by the informal sector and keep searching for a job in the formal sector. Hence, a fraction $i_p^L = 1 - e_p^L$ of the unskilled labor force is employed in the informal sector out of necessity; these informal employees earn a competitive wage ω_p^L that is smaller than w_p^L, in line with SF7. Similarly, a share $i_p^H = 1 - e_p^H$ of the skilled labor force is employed in informality.

In line with SF9, we represent the informal sector as a set of high skilled entrepreneurs

terms of working hours, work relationships, responsibilities, etc.) in the informal sector (Mohammad, 2014b).

providing capital to workers (mostly unskilled, although the workforce also includes some skilled workers). The latter produce and/or sell the merchandise, return part of their sales revenue to the owners (assimilated to profit in our model) and keep the rest (assimilated to wages in our model). As unemployment benefits do not exist and wages are much higher in the formal sector, we assume that entrepreneurs and workers in the informality are queuing for a better job in the formal sector. With these assumptions, a fraction $b_p^H i_p^H$ of the high-skilled labor force acts as informal entrepreneurs and makes a business profit equal to π_p^H, whereas the others (i.e., a fraction $i_p^H(1-b_p^H)$ of the labor force) are employed as workers and earn a competitive wage ω_p^H. Skilled individuals in informality are perfectly mobile between the two occupations, ensuring that in equilibrium, the earnings of workers and entrepreneurs are equalized ($\omega_p^H = \pi_p^H$). This is in line with SF10 and implies that there is no incentive for high-skilled workers to move from one occupation to the other. Furthermore, SF7 suggests that $\omega_p^H < w_p^H$.

As a final remark, we have modeled the informal sector as a subsistence sector while it is possible that some workers choose to voluntarily work in informality for a number of reasons (e.g., women who are at their prime fertility age or older workers who want to take advantage of more flexible working hours in the informal sector). Nevertheless, the facts in Figures 1e and 1f suggest, that informality at large is not a choice despite the fact that some skilled entrepreneurs may find it optimal to operate in the informal sector (see discussion under SF10).

3.1 Technology

The **formal sector** F in province p produces a quantity Y_p of final good using a CES combination of intermediate inputs, Y_p^L and Y_p^H, given by:

$$Y_p = A_p \left[\alpha_p {Y_p^L}^{\frac{\sigma-1}{\sigma}} + (1-\alpha_p) {Y_p^H}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where A_p denotes the level of total factor productivity (TFP) in the formal sector, α_p is a province-specific parameter governing the preference for the two inputs and their income shares (reflecting the sectoral composition of the economy), and σ is the common elasticity of substitution between the two intermediate goods.

Intermediate inputs are produced by unskilled and skilled workers using a linear technology:

$$Y_p^H = e_p^H H_p \tag{2}$$

$$Y_p^L = e_p^L L_p, \tag{3}$$

where e_p^L and e_p^H are the employment rates of, respectively, unskilled and skilled workers in the formal labor market of province p.

The level of TFP in the formal sector is increasing in both infrastructure per worker g_p

and the skill ratio of intermediate inputs $z_p \equiv \frac{Y_p^H}{Y_p^L}$, which differs from Z_p, the skill ratio in the working-age population. We have:

$$A_p = \overline{A}_p z_p^{\eta} g_p^{\varphi}, \tag{4}$$

where $\overline{A}_p$ is an exogenous scale factor, η and φ are the elasticity of TFP w.r.t the skill ratio and the amount of infrastructure per capita, respectively. We assume $\eta + \varphi < 1$.[12]

The final good sector is perfectly competitive, implying that the price of each intermediate input equals its marginal product, which is given by:

$$y_p^L = \overline{A}_p z_p^{\eta} g_p^{\varphi} \alpha_p \left[\alpha_p + (1-\alpha_p) z_p^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}, \tag{5}$$

$$y_p^H = \overline{A}_p z_p^{\eta} g_p^{\varphi} (1-\alpha_p) z_p^{\frac{-1}{\sigma}} \left[\alpha_p + (1-\alpha_p) z_p^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}. \tag{6}$$

The modeling of the informal sector heavily relies on SF9 and SF10 described in Section 2. The final good is produced by skilled entrepreneurs with the help of unskilled and skilled employees. Production is governed by a Cobb-Douglas production function and all skilled entrepreneurs are homogeneous in terms of their productivity. The production function of each entrepreneur is given by:

$$\hat{y}_p = B_p h_p^{\psi_p} \ell_p^{\chi_p} \tag{7}$$

where B_p is the TFP level, h_p and ℓ_p represent the number of skilled and unskilled workers employed by each entrepreneur, respectively. It follows that total output in informality is given by $\hat{Y}_p = H_p i_p^H b_p^H \hat{y}_p$. Parameters ψ_p and χ_p represent the province-specific elasticities of output per entrepreneur with respect to unskilled and skilled labor, respectively. When calibrating the model without constraining parameter levels, it comes out that $\psi_p + \chi_p$ is almost constant across provinces, and well below the value 1. This decreasing returns to scale property ensures that profits are positive. However, the ratio $\frac{\psi_p}{\chi_p}$ varies with the share of educated workers in the economy. This reflects the heterogeneity of the informal sector. It comprises small-scale businesses run by entrepreneurs and employing a mix of unskilled and skilled workers in most advanced provinces; but comprises family-based, low productivity businesses with a very low demand for skilled labor in the least advanced provinces. We need $\psi_p + \chi_p = \varrho_p < 1$ in all provinces to ensure that profits are positive, and $\frac{\psi_p}{\chi_p} = \kappa_p Z_p^{\mu}$, so that:

$$\psi_p = \frac{\varrho_p \kappa_p Z_p^{\mu}}{1 + \kappa_p Z_p^{\mu}} \tag{8}$$

$$\chi_p = \frac{\varrho_p}{1 + \kappa_p Z_p^{\mu}}, \tag{9}$$

where ϱ_p is the share of labor income in total revenues of the informal sector of province p, and

[12] Bom and Ligthart (2014) find an average elasticity of output to core infrastructure of 0.17. See also IMF (2014). The upper bound of the range reported in Calderon and Serven (2014) equals 0.1.

μ is the elasticity of entrepreneurs' relative preference for skilled workers with respect to the province-wide supply of skilled labor.

The level of TFP in the informal sector is increasing in the level of infrastructure per worker g_p:

$$B_p = \rho_p \overline{A}_p g_p^{\phi}, \tag{10}$$

where $\rho_p \overline{A}_p$ is the exogenous scale factor (expressed as a fraction ρ_p of the TFP scale factor in the formal sector, without loss of generality), and ϕ is the elasticity of TFP with respect to the amount of infrastructure per capita such that $\phi \leq \varphi$. The latter condition implies that a rise in the level of public infrastructure increases the productivity gap between the formal and informal sectors.

The wage paid to unskilled workers in the informal sector is denoted by ω_p^L and that paid to skilled workers is denoted by ω_p^H. At each moment in time, the entrepreneur maximizes profit π_p^H and this determines the demand for unskilled labor, ℓ_p and skilled labor h_p per entrepreneur. The instantaneous profit is given as follows:

$$\pi_p^H = B_p h_p^{\psi_p} \ell_p^{\chi_p} - \omega_p^L \ell_p - \omega_p^H h_p. \tag{11}$$

The profit maximization conditions ($\frac{\partial \pi_p^H}{\partial \ell_p} = 0$ and $\frac{\partial \pi_p^H}{\partial h_p}$) implies that the demand for low- and high-skilled labor and the level of profit per entrepreneur are governed by:

$$\omega_p^H = B_p \psi_p h_p^{\psi_p - 1} \ell_p^{\chi_p}, \tag{12}$$

$$\omega_p^L = B_p \chi_p h_p^{\psi_p} \ell_p^{\chi_p - 1}, \tag{13}$$

$$\pi_p^H = B_p (1 - \psi_p - \chi_p) h_p^{\psi_p} \ell_p^{\chi_p}. \tag{14}$$

In line with SF10, the skilled workers are perfectly mobile between the two occupational states, informal employment and entrepreneurship. In equilibrium $\omega_p^H = \pi_p^H$, there is no incentive for skilled agents to move from one state to the other. This implies:

$$h_p^* = \frac{\psi_p}{1 - \psi_p - \chi_p}, \tag{15}$$

which in turn implies that the number of skilled employees in informality ($i_p^H H_p$) divides into a fraction

$$b_p^H = \frac{1}{1 + h_p^*} \tag{16}$$

of entrepreneurs, and a fraction $(1 - b_p^H) = h_p^*(1 + h_p^*)^{-1}$ of workers. As h_p^* is a province-specific constant from Eq. (15), the level of earnings of skilled individuals depend on the equilibrium level of ℓ_p, which will be determined below.

3.2 Labor Market

Utility is an increasing function of net income. As earnings are greater in the formal sector (in line with SF7), individuals employed in the informality (both workers and entrepreneurs) search for formal jobs. At each moment in time, some are matched with open vacancies through a matching function $F(i_p^S, v_p^S)$, where v_p^S is the total number of vacancies available per type-S worker in the formal sector. The matching function exhibits constant returns to scale and is increasing in both arguments. The job finding rate for agents in each period is given by $\lambda(\theta_p^S) = \frac{F(i_p^S, v_p^S)}{i_p^S}$ where $\theta_p^S \equiv \frac{v_p^S}{i_p^S}$ is defined as the market tightness. The hiring rate is defined as $q(\theta_p^S) \equiv \frac{F(i_p^S, v_p^S)}{v_p^S}$ such that $\frac{\partial q(\theta_p^S)}{\partial \theta_p^S} < 0$ and $\frac{\partial \lambda(\theta_p^L)}{\theta_p^S} > 0$. Workers in the formal sector can lose their job and return to the informal sector at an exogenous (job destruction) rate δ_p^S; this is the rate at which workers lose their jobs and go back into the pool of informally employed workers or entrepreneurs.

We first characterize the **Asset Value Functions**. In the formal labor market, firms post vacancies ν_p^S at each moment in time. We assume each firm can post one vacancy and pays a cost c_p^S per moment in time for maintaining a vacancy. The costs are skill-specific and such that $c_p^H > c_p^L$. The cost includes, among other things, advertising expenditure, interview arrangements, initial training, and the time and resources invested by the firms to find a worker as well as the forgone output while maintaining the vacancy. For simplicity, we assume job search costs for workers and costs for creating a vacancy to be nil. Remember that we denote by w_p^S the wage rate paid by formal firms. From the firm's perspective, the lifetime value of a vacancy (V_p^S) and of a filled job (J_p^S) that require a skill type S are given as follows:

$$rV_p^S = -c_p^S + q(\theta_p^S)(J_p^S - V_p^S), \tag{17}$$

$$rJ_p^S = y_p^S - w_p^S - \delta_p^S(J_p^S - V_p^S). \tag{18}$$

In the steady state equilibrium, the free entry condition implies $V_p^S = 0$. This implies:

$$J_p^S - V_p^S = \frac{y_p^S - w_p^S}{r + \delta_p^S}, \tag{19}$$

$$J_p^S - V_p^S = \frac{c_p^S}{q(\theta_p^S)}. \tag{20}$$

Hence, the job creation conditions are given by:

$$\frac{y_p^L - w_p^L}{r + \delta_p^L} = \frac{c_p^L}{q(\theta_p^L)}, \tag{21}$$

$$\frac{y_p^H - w_p^H}{r + \delta_p^H} = \frac{c_p^H}{q(\theta_p^H)}. \tag{22}$$

The job creation equation sates that in equilibrium the marginal cost of opening a vacancy equals the marginal profit from a filled job. With regard to workers, let W_p^S and U_p^S represent the lifetime value of formal employment and informal employment for type-S individuals, respectively. The wage in the formal sector is taxed at the national tax rate τ, and government revenues are used to finance public infrastructure, education, and other types of public expenditures. We ignore the government budget constraint here as (i) it is not province-specific, (ii) the model is static and we disregard the dynamic implications of running a public deficit, and (iii) part of the revenue can be redirected to corruption.

Keeping in mind that $\omega_p^H = \pi_p^H$, the lifetime value of formal and informal employment for type-S workers are given as follows:

$$rW_p^S = w_p^S(1-\tau) - \delta_p^S(W_p^S - U_p^S), \tag{23}$$

$$rU_p^S = \omega_p^S + \lambda(\theta_p^S)(W_p^S - U_p^S). \tag{24}$$

This yields:

$$W_p^S - U_p^S = \frac{(w_p^S(1-\tau) - \omega_p^S)}{r + \delta_p^S + \lambda(\theta_p^S)}, \forall S = (L, H). \tag{25}$$

We can now characterize the conditions governing the **labor allocation and wage rates**. In steady state, the flows into and out of informal employment balances out each other, we have

$$\frac{\dot{I_p^L}}{I_p^L} = \delta_p^L(\frac{L_p}{I_p^L} - 1) - \lambda(\theta_p^L) = 0,$$

$$\frac{\dot{I_p^H}}{I_p^H} = \delta_p^H(\frac{H_p}{I_p^H} - 1) - \lambda(\theta_p^H) = 0.$$

Denoting $\frac{I_p^S}{S_p} = i_p^S$, we have:

$$i_p^L = \frac{\delta_p^L}{\delta_p^L + \lambda(\theta_p^L)}, \tag{26}$$

$$i_p^H = \frac{\delta_p^H}{\delta_p^H + \lambda(\theta_p^H)}, \tag{27}$$

which implies that $e_p^S = \frac{\lambda(\theta_p^S)}{\delta_p^S + \lambda(\theta_p^S)}, \forall S = (L, H)$ determines the share of type-S individuals employed in the formal sector. The allocation of workers determines the skill ratio in the formal sector:

$$z_p \equiv \frac{e_p^H H_p}{e_p^L L_p} = \frac{\frac{\lambda(\theta_p^H)}{\delta_p^H + \lambda(\theta_p^H)}}{\frac{\lambda(\theta_p^L)}{\delta_p^L + \lambda(\theta_p^L)}} Z_p. \tag{28}$$

In the informal sector, the labor market is competitive and the wage rate of unskilled workers

is such that the demand for labor equals the supply:

$$\frac{H_p i_p^H \ell_p^*}{1+h_p^*} = L_p i_p^L, \tag{29}$$

which, together with Eq. (13), determines ω_p^L and ℓ_p^*. As explained above, once ℓ_p^* is determined, $\omega_p^H = \pi_h^H$ can be computed from Eq. (12), or alternatively from Eq. (14). In other words, there is no need to equalize the supply and demand of skilled labor to determine the equilibrium level of earnings in informality as the latter can be obtained by plugging the perfect mobility conditions Eq. (15) and the equilibrium value ℓ_p^* into Eq. (12) or (14).

In the formal sector, once the workers are matched with firms they bargain over wage and the wage rate is determined through Nash bargaining as following:

$$(1-\beta^L)(W_p^L - U_p^L) = \beta^L(J_p^L - V_p^L)(1-\tau), \tag{30}$$

$$(1-\beta^H)(W_p^H - U_p^H) = \beta^H(J_p^H - V_p^H)(1-\tau), \tag{31}$$

where β^S is the bargaining power of the type-S workers in the formal sector. Keeping in mind that $\omega_p^H = \pi_p^H$, the wages rates are then given as follows:

$$w_p^L = \frac{y_p^L \beta^L (r+\delta_p^L+\lambda(\theta_p^L)) + (1-\beta^L)\frac{\omega_p^L(r+\delta_p^L)}{(1-\tau)}}{r+\delta_p^L+\beta^L\lambda(\theta_p^L)}, \tag{32}$$

$$w_p^H = \frac{y_p^H \beta^H (r+\delta_p^H+\lambda(\theta_p^H)) + (1-\beta^H)\frac{\omega_p^H(r+\delta_p^H)}{(1-\tau)}}{r+\delta_p^H+\beta^H\lambda(\theta_p^H)}. \tag{33}$$

3.3 General Equilibrium

We consider public interventions (τ), the skill composition of the labor force (Z_p), and the level of infrastructure per inhabitant (g_p) as exogenous. We also assume a standard Cobb-Douglas matching function with symmetric elasticities in the formal labor market,

$$F(i_p^S, v_p^S) \equiv \epsilon_p^S \sqrt{I_p^S \nu_p^S}, \tag{34}$$

where $\nu_p^S = v_p^S L_p$ is the total number of vacancies available for type-S workers. The job finding rate $\lambda_p^S(\theta_p^S)$ is given as follows

$$\lambda_p^S(\theta_p^S) \equiv \frac{\epsilon_p^S \sqrt{I_p^S \nu_p^S}}{I_p^S} = \epsilon_p^S (\theta_p^S)^{0.5}, \tag{35}$$

We can now define the steady state, general equilibrium of our model as following:

Definition 1. For a set of common parameters $\{\sigma, \eta, \varphi, \phi, \tau, r, \delta^S, \beta^S, \kappa\}$ and a set of province-

specific parameters $X_p \equiv \{L_p, H_p, g_p, \overline{A}_p, \alpha_p, \rho_p, \varrho_p, \kappa_p, \epsilon_p^L, \epsilon_p^H, c_p^L, c_p^H\}$, the general equilibrium is a set $\Gamma_p \equiv \{A_p, B_p, y_p^L, y_p^H, \theta_p^L, \theta_p^H, i_p^L, i_p^H, b_p^H, z_p, w_p^L, w_p^H, \omega_p^L, \omega_p^H, \pi_p^H, \ell_p^*, h_p^*, \psi_p, \chi_p\}$ of endogenous variables satisfying the following 19 conditions, $\Gamma_p = f(X_p)$: (i) definition of technological externalities (4), (10), (8) and (9); (ii) profit-maximization conditions (5) and (6) in the formal sector; (iii) job creation conditions (21) and (22) in the formal labor market; (iv) labor market equilibrium conditions (12), (13), (14) and the equilibrium condition (29) in the informal sector; (v) equilibrium informal employment shares (26) and (27) for both skill groups; (vi) optimal allocation of high-skilled workers between informal employment and entrepreneurship (15) and (16); (vii) equilibrium skill ratio (28) in the formal sector; and (viii) wage formation conditions (32) and (33) in the formal labor market.

The other endogenous variables (e.g., asset values, z_p, e_p^S or π_p^H) can be computed as a transformation of the parameters or as by-products of the endogenous variables. For the purpose of our numerical experiments, we divide the set of province-specific parameters into five categories:

Definition 2. The set of province-specific parameters $X_p \equiv \{X_p^Z, X_p^G, X_p^F, X_p^I, X_p^L\}$ consists of five subsets of parameters, namely the human capital structure, $X_p^Z = \{Z_p\}$, the level of public infrastructure, $X_p^G = \{g_p\}$, technological characteristics of the formal sector, $X_p^F = \{\overline{A}_p, \alpha_p\}$, the technological characteristic of the informal sector, $X_p^I = \{\rho_p, \varrho_p, \kappa_p\}$, and labor market frictions, $X_p^L = \{\epsilon_p^L, \epsilon_p^H, c_p^L, c_p^H\}$.

We now explain how we calibrate common and province-specific parameters to exactly match the data and stylized facts described in Section 2.

3.4 Parameterization

The parameter values are summarized in Table 4. Alternative parameters values are considered in the robustness analysis (see Appendix 6.4).

In line with the definition of the general equilibrium, we consider eight parameters as common to all provinces, and we assign them a consensus value from the existing empirical literature. With regard to the elasticity of substitution between intermediate goods, we use the elasticity of substitution between high-skilled and low-skilled workers estimated by Ottaviano and Peri (2012) for a one-sector model. This gives $\sigma = 2$. For the interest rate, we follow Satchi and Temple (2009), setting real interest rate at 4 percent per year and computing the monthly rate; this gives $r = 0.003$. In line with Gong and van Soest (2012) and Satchi and Temple (2009) on Mexico, the job destruction rates are set to $\delta = 0.060$ for both skill groups. For the bargaining power of workers, most existing literature uses a value of 0.500. We thus use $\beta^S = 0.500$ for all provinces.[13]

[13] Satchi and Temple (2009) recommends a value of 0.700 when the informal sector represents more than 30%

For η, the existing empirical literature suggests that quantitatively large aggregate schooling externalities are unlikely to exist in developing countries (Acemoglu and Angrist, 2000; Moretti, 2004). Caselli and Ciccone (2013) argue that for a typical poor country, increasing college attainment to the level of the US in 1990 would add less than 4 years to the average years of schooling, inducing a 30 percent increase in TFP. Transposing this to the share of secondary educated means that when the share of skilled workers in developing countries increases to the US level, the TFP increases by 30 percent. To calculate the lower bound on η, we take the average share of high school graduates of DRC (30 percent). Increasing this share to the US level (90 percent) in the year 2010 involves an increase by 300 percent. In line with Caselli and Ciccone (2013), we assume that this shock induces a 30 percent rise in TFP, which implies that $\eta = 0.100$.

Last, hundreds of papers have estimated the elasticity of aggregate output (usually proxied by the GDP per capita or by measurements of private output) to public infrastructure using cross-country regressions (Bom and Ligthart, 2014; Dufflo and Pande, 2007; Irmen and Kuehnel, 2009; Wang and Wu, 2015). Using a synthetic index of infrastructure to assess its impact on GDP, Calderon and Serven (2014) obtain a long-run elasticity varying between 0.05 and 0.10. However, Calderon and Serven (2010) find, that the largest contributions of infrastructure development to growth were attained in South-Asia. In sub-Saharan countries, the contribution of infrastructure is smaller. We thus assume a lower-bound elasticity $\varphi = 0.050$ for the formal sector, and we halve this value in the informal sector ($\phi = 0.025$).

As far as the 12 province-specific parameters are concerned, three of them, $\{L_p, H_p, g_p\}$, are directly obtained from the data described in Section 2. In particular, Table 3 shows that the amount of capital investment per capita in Col. (1) exhibits low variability across provinces, while the other columns show that the actual level of infrastructure is substantially greater in Kinshasa and varies a great deal across province. We proxy g_p with the public capital index reported in Col. (6) of Table 3. This index ranges from 1.4 in Kasai Oriental to 84.4 in Kinshasa. The parameters $(\epsilon_p^L, \epsilon_p^H, \overline{A}_p, \alpha_p, \rho_p, \psi_p, \chi_p)$ in X_p are calibrated to match the informal employment shares by skill groups (i_p^L, i_p^H), the structure of earnings by skill group and by sector $(w_p^L, w_p^H, \omega_p^L, \omega_p^H, \pi_p^H)$ and the number/share of skilled entrepreneurs in the informality (b_p^H). μ is estimated by regressing $\log(Z_p)$ on $\frac{\psi_p}{\chi_p}$ and is common across provinces. Last, the parameters (κ_p, ϱ_p) can be computed using relations (9) and (8). We assume that $c_p^S = 0.4 w_p^L$ in all provinces, in line with Docquier and Iftikhar (2019).

In Appendix 6.1 we discuss the identification of our parameters. Appendix 6.2 discusses the validity of our parameters and presents a broad categorization of provinces based on the values of province-specific parameters.

of the workforce.

Table 4: Parameters – Summary

Prm.	Definition	Source/Target	Mean	CV
Common to all provinces				
σ	Elast. of subst. btw intermediates	Ottaviano and Peri (2012)	2.000	-
η	Elast. of TFP to human capital in F	Caselli and Ciccone (2013)	0.1	-
φ	Elast. of TFP to infrastructure in F	Calderon and Serven (2014)	0.050	-
ϕ	Elast. of TFP to infrastructure in I	Calderon and Serven (2014)	0.025	-
μ	Elast. of $\frac{\psi_p}{\chi_p}$ to z_p	Calibration outcome	2.000	-
τ	Income tax rate in F	Direction Générale des Impôts (RDC)	0.132	-
r	Monthly interest rate	Satchi and Temple (2009)	0.003	-
δ^S	Monthly job destruction rate	Satchi and Temple (2009)	0.060	-
β^S	Bargaining power	Petrongolo and Pissarides (2001)	0.500	-
Province-specific				
$\overline{A}_p$	TFP scale factor in F	Wages in the formal sector	193.2	0.380
α_p	Income share parameter in F	Wages in the formal sector	0.313	0.141
ρ_p	Relative TFP scale factor in I	Wages and entrepreneurship in the informal sector	0.589	0.292
ϱ_p	Sum of ψ_p and χ_p	Wages and entrepreneurship in the informal sector	0.852	0.242
κ_p	Scale factor in $\frac{\psi_p}{\chi_p}$ function	Wages and entrepreneurship in the informal sector	0.886	0.194
ψ_p	Elast. of output to HS labor in I	Wages and entrepreneurship in the informal sector	0.235	0.468
χ_p	Elast. of output to LS labor in I	Wages and entrepreneurship in the informal sector	0.616	0.223
ϵ_p^L	Scale factor in LS matching fct.	Informality rate high skilled workers	0.014	0.342
ϵ_p^H	Scale factor in HS matching fct.	Informality rate low skilled workers	0.054	0.369
c_p^L	Cost of posting a LS vacancy	Equal to 0.4 times w_p^L	35.2	0.383
c_p^H	Cost of posting a HS vacancy	Equal to 0.4 times w_p^H	54.1	0.368

Notes: CV = coefficient of variation of province-specific parameters, defined as the ratio of standard deviation to the mean value.

4 Quantitative Experiments

In our numerical experiments, we consider the wealthiest province of Kinshasa (indexed by *KIN*) as a benchmark, simulate the counterfactual general equilibrium $\overline{\Gamma}_p = f(X_{KIN})$ obtained when province-specific parameters are in totality or partially equalized with those of Kinshasa, and compare this with the observed equilibrium, $\Gamma_p = f(X_p)$. We take notice of the structure of income, as described by sector-specific and skill-specific income levels $(w_p^H, w_p^L, \omega_p^H, \omega_p^L)$, the average income level of unskilled workers $(\overline{w}_p^L \equiv (1-i_p^L)w_p^L(1-\tau)+i_p^L\omega_p^L)$, and the average level of income per capita in the province $(\overline{w}_p \equiv (H_p\overline{w}_p^H + L_p\overline{w}_p^L)/(H_p+L_p)$. In our experiments, we refer to variations in the set of province-specific parameters as "policy changes" because our structural parameters corresponds to intermediate targets of public policies. For example, improving the human capital structure is the main objective of public education policies, reducing labor market frictions is an important intermediate objective of labor policies, etc. Assuming that raising per-capita income and reducing inequalities are the ultimate policy goals, we shed light on the relevance of targeting one or several intermediate objectives without being able to identify the most efficient policy actions. This is because we disregard (and lack information about) the costs of implementing such policies.

4.1 One-At-A-Time Policy Changes

Let us first consider policy reforms targeting one specific part of the economy at a time. Building on the subsets of parameters in Definition 2, we simulate five counterfactuals:

- Education policies (Z): they lead to a counterfactual equilibrium obtained after replacing X_p^Z by the level observed in Kinshasa, X_{KIN}^Z. This gives $\overline{\Gamma}_p^Z = f(X_{KIN}^Z, X_p^G, X_p^F, X_p^I, X_p^L)$;
- Infrastructure policies (G): they lead to a counterfactual equilibrium obtained after replacing X_p^G by X_{KIN}^G. This gives $\overline{\Gamma}_p^G = f(X_p^Z, X_{KIN}^G, X_p^F, X_p^I, X_p^L)$;
- Policies influencing the technology of the formal sector (F): they lead to a counterfactual equilibrium defined as $\overline{\Gamma}_p^F = f(X_p^Z, X_p^G, X_{KIN}^F, X_p^I, X_p^L)$;
- Policies influencing the technology of the informal sector (I): they lead to a counterfactual equilibrium defined as $\overline{\Gamma}_p^I = f(X_p^Z, X_p^G, X_p^F, X_{KIN}^I, X_p^L)$;
- Policies influencing labor market frictions (L): they lead to a counterfactual equilibrium defined as $\overline{\Gamma}_p^L = f(X_p^Z, X_p^G, X_p^F, X_p^I, X_{KIN}^L)$.

We use a radar-plot representation to describe the effect of the each policy on the region-wide average level of income per capita. The results are depicted by the blue curves in Figure 2, representing the effect of each of these policy reforms expressed as percentage of the income gap with Kinshasa, measured on the vertical axis. The closer to the 100 percent reference level, the greater the explained share of the income gap with Kinshasa. The red curves are discussed in the next section. The top panel shows the unweighted average of the province-specific results. The bottom panel shows the effect obtained in nine provinces of DRC.[14]

The first key message of our analysis is that the technological characteristics in both sectors (X_p^F and X_p^I) are the key determinants of spatial inequalities, followed by human capital and infrastructure. Labor market frictions taken in isolation play a negligible role. The results by province are in line with the broad classification presented in Figure 9. In line with existing literature on cross-country disparities (Hall and Jones, 1999; Klenow and Rodríguez-Clare, 1997), improving the technology in the formal sector (X_p^F) – mostly involving increasing the TFP level ($\overline{A}_p$) – is the most effective policy by far in BAN and MAN, but also in the poorest provinces (KAE and KAW) and in EQU. However, improving the technology in the informal sector (X_p^I), is the most effective policy in the most productive provinces (BAS and POR). In the two provinces of Kivu, acting on both sectors is desirable. This does not mean that pushing people into informality is a desired option as income levels are smaller in this sector.

The role of technology is mostly governed by the role of the exogenous TFP scale factor in both sectors. Table 5 in Appendix 6.2 shows that TFP in the formal sector is correlated

[14]Katanga is excluded, as it is a clear outlier in terms of the amount of natural resources and level of income.

with the share of the manufacturing in output and employment. TFP partly relates to the quality of local institutions and mineral resource endowment. Good and stable institutions are instrumental to creating an enabling environment for socioeconomic growth. The institutional context in Kinshasa relies on a system called *Branchement* which directly connects economic actors to higher-level authorities and bypasses the role of the provincial government (Nkuku and Titeca, 2018). These alliances between economic actors and high-level political actors can be fragile in periods of turmoil; however, they are more stable than in less developed provinces. Although the provincial governor of Kinshasa remained in post from 2007 to 2017, other provinces are characterized by chronic instability, which is reflected in a high turnover of provincial leaders. From 2007 to 2017, four governors succeeded each other in South Kivu,and three in Equateur, Kasai Occidental and Bandundu. A large number of reshuffles in provincial executive governments were observed for all provinces in general, even in the relatively highly productive Province Orientale (Gérard, 2014). This instability prevents political leaders from carrying out ambitious reconstruction or development programs.

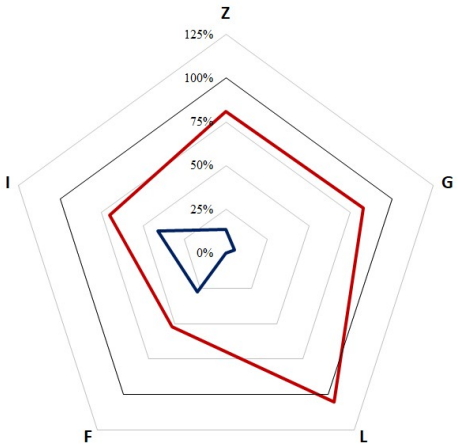
Another key aspect is corruption, particularly with regard to natural resource endowments. On the one hand, these endowments serve as a catalyst for the provision of public services. It is not unusual for mining companies to finance projects in the electricity and transport sectors, which benefit local communities in some provinces.[15] Sometimes, they also contribute to the provision of local public services, such as healthcare, agriculture extension services, water supply, and education. On the other hand, well-endowed provinces are prone to corruption, fraud, and interventionism, and rely on armed groups to control mining sites (Global Witness, 2006). This contributes to perpetuating extreme poverty and political instability.

The second major finding is that the effectiveness of each policy taken in isolation is relatively small compared with the average income gap of 60 percent. This can be better understood if one looks at their effect on the distribution of income. Figure 3 shows the effects of the shocks on the income structure. The background gray area highlights the relative change in the key parameter affected by each policy (as measured on the right-hand scale), while the bars show the relative change in income for the four types of workers, skilled vs. unskilled in the formal vs. the informal sector (as measured on the left-hand scale).

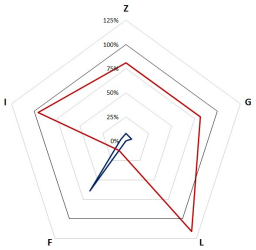
[15]Examples of such projects include (i) the development of a power station by Randgold in Kibali (Province oriental), (ii) the construction of roads and bridges by Banro in Twangiza (South Kivu), (iii) the construction of four hydroelectric plants, and (iv) a transmission line by Tenke Fungurume Mining in the Katanga province.

Figure 2: Effect of one-at-a-time and quadruple policy changes on income per worker ($\overline{w}_p$)

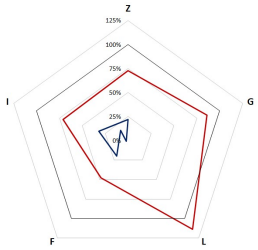
(a) Unweighted mean



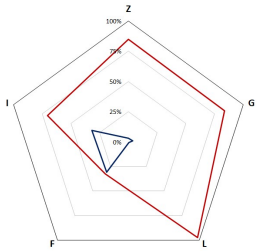
(b) Bandundu



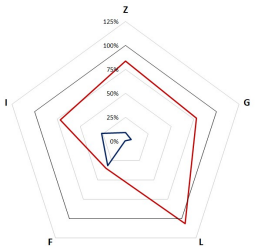
(c) Bas-Congo



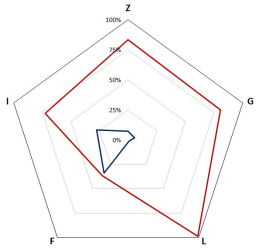
(d) Kasaï Oriental



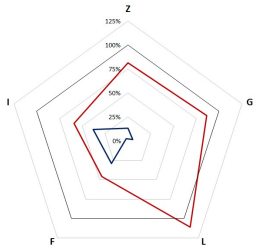
(e) Kasaï Occidential



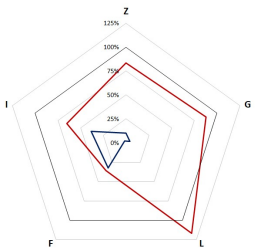
(f) Equateur



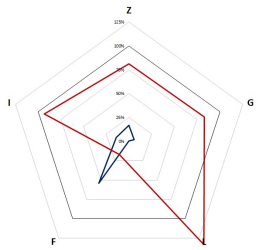
(g) Nord-Kivu



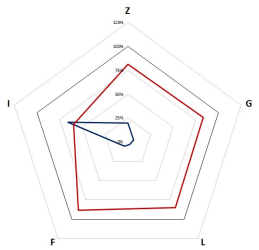
(h) Sud-Kivu



(i) Maniema



(j) Province Orientale



Notes: The blue curve is the fraction of the income gap between each province and Kinshasa that is filled when a single policy $P = (Z, G, F, I, L)$ is implemented. The red curve is the fraction of the gap that is filled when all policies but $P = (Z, G, F, I, L)$ are implemented.

In Figure 3a, we set the technological parameters of the formal sector to the level of Kinshasa (X_p^F). Note that this implies that productivity increases in both sectors, as the productivity in the informal sector is proportional to the TFP of the formal sector as implied by Eq. (10). Under a competitive labor market, a similar increase in the TFP of the two sectors would not change the allocation of the labor force. However, in the case of a labor market with frictions, the change in TFP induces job creation in the formal sector, which in turn attracts both types of workers. Given larger frictions for the unskilled, more-educated workers move to the formal sector and the skill ratio increases in this sector. By contrast, the skill ratio decreases in the informal sector, thereby attenuating the gains for unskilled workers. Hence, although the role of market frictions taken in isolation is negligible, the functioning of the labor market governs the size and distribution of the gains from improving the quality of the technology. Improving the technology in the formal sector benefits all types of workers, but has greater effects on the skilled.

Figure 3b shows that improving the technology in the informal sector (X_p^I) has less inegalitarian effects. It induces similar benefits for skilled and unskilled workers in the informal sector. By attracting entrepreneurs and unskilled workers into informality, this policy has a negative effect on the skill ratio in the formal sector. However, despite the decline in the skill ratio, low-skilled workers in the formal sector observe an increase in wages in six provinces. This is due to the fact that wages are determined via bargaining, and an increase in the informal TFP improves the outside options of all workers, resulting in higher wages for workers in the formal sector. This effect dominates the negative effect of a reduced skill ratio on the wages of low-skilled workers in the formal sector. Both types of workers exhibit large income gains in the informal sector. In five provinces (BAN, BAS, KAW, MAN, and POR), increasing relative productivity in the informal sector is more beneficial to unskilled workers than to entrepreneurs. In six provinces (BAS, KAE, KAW, NKI, SKI, and POR), this is the most effective policy to combat extreme poverty.

Figure 3c shows the effects of setting the proportion of skilled workers to the level observed in Kinshasa (X_p^Z). The shocks are large: the province-wide skill ratio (Z_p) increases by a factor that ranges from 4 in Bas-Congo to 8 in Maniema, as measured on the right-hand scale in Figure 3c. A rise in the skill ratio would stimulate the TFP gap between the formal and informal sectors due to technological externalities, but increases the competition between educated workers in both markets. With regard to skilled workers, the competition effect dominates in all provinces, as profits from informal businesses decrease. For unskilled workers, their wage rate in the formal sector increases drastically in all provinces. Due to strong labor market frictions, more than 90 percent of the unskilled remain in informality, where their wage rate decreases. This is because entrepreneurship decreases. The majority of unskilled workers are adversely affected by this policy.

In Figure 3d, we depict the effect of decreasing labor market frictions (X_p^L). This leads to small effects in most provinces. Reducing frictions reduces the skill ratio in the formal sector in all provinces except POR, and reduces the productivity gap between the two sectors due to human capital externalities. This effect dominates the positive effect of a decline in the skill ratio on the productivity of high-skilled workers, and attenuates the positive effects of job creation arising from smaller frictions. This policy taken in isolation has very limited effects on the income level of the unskilled workers in the informal sector, who marginally gain due to an increase in the skill ratio in this sector.

Last, Figure 3e shows the effects of setting the level of public infrastructure to the level observed in Kinshasa (X_p^G). The shocks are large: the (g_p) increases by a factor that ranges from 6 in Bas-Congo to 57 in Kasai Occidental, as measured on the right-hand scale of the Figure 3e. Given the low elasticity of TFP to infrastructure found in relevant literature, and the fact that infrastructure matters even less in the informal economy, we find small effects on income. A rise in infrastructure increases TFP in both sectors but also increases the productivity gap between the two sectors. The rise in the productivity gap worsens the outside options of workers, as this attenuates the positive effect of infrastructure on wages. Overall, the effect is more beneficial for the skilled (who are more mobile across sectors), and for the unskilled who are employed in the formal sector. The effect on the majority of unskilled workers employed in the informal sector is small.

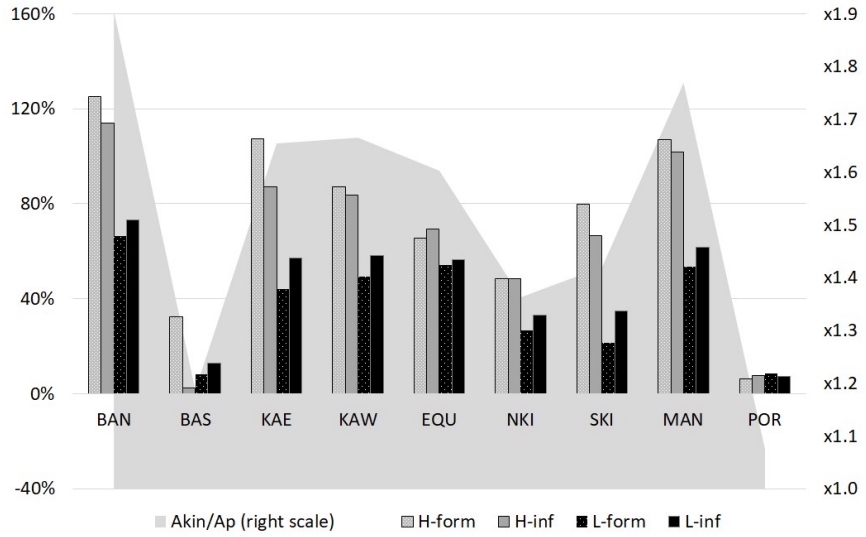
4.2 Complementarities Between Policies: O-ring Patterns

The main findings of the previous section are that (i) each policy taken in isolation has moderate effects on spatial inequality and has potential undesirable effects on the distribution of income (and in turn, on within-province inequalities and extreme poverty), and (ii) most of these undesirable effects are linked to the friction-driven, imperfect mobility of workers across sectors. By construction, if all province-specific parameters were equalized with those of Kinshasa, spatial inequality would disappear. This clearly suggests that reducing spatial inequality is a multifaceted challenge, requiring a combination of favorable conditions. Below, we illustrate the strong interactions between policies in two ways.

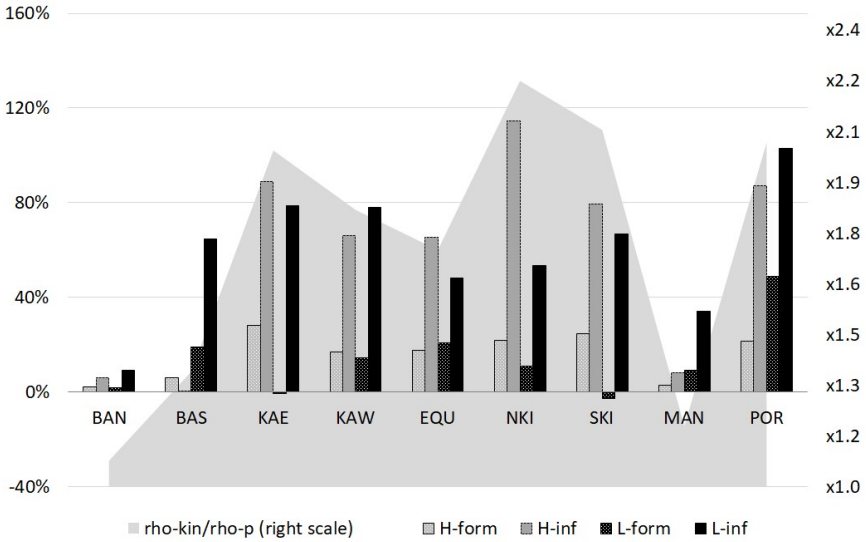
First, the role of complementarities between policy actions appears clearly when summing up the effect of the five policies taken in isolation, and quantifying the role of the interactions (capturing complementarities) between them. The results by province are shown in Figure 4. In general, although the role of technological parameters is important, each individual effect (represented by the black and gray areas) accounts for a small part of the total income gap with Kinshasa, illustrated by the total length of the bar. The residual interaction term (represented by the red area) accounts for about one fifth of the total effect in three provinces (BAN, NKI, and SKI), and one third of the total in three provinces (KAE, KAW, and EQU). These are

Figure 3: Income responses ($\frac{dw_p^S}{w_p^S}$, $\frac{d\omega_p^S}{\omega_p^S}$) to policy reforms

(a) Technology in the formal sector (X_p^F)



(b) Technology in the informal sector (X_p^I)



(c) Skill ratio in the population (X_p^Z)

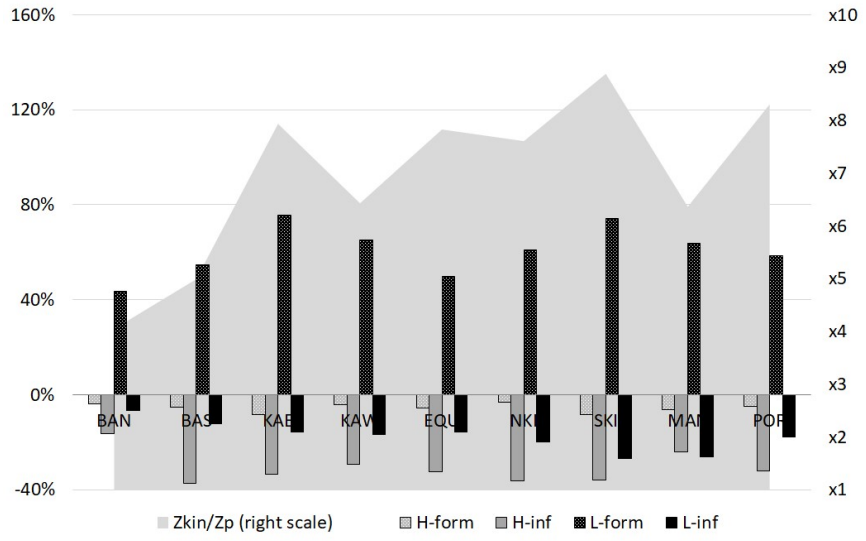
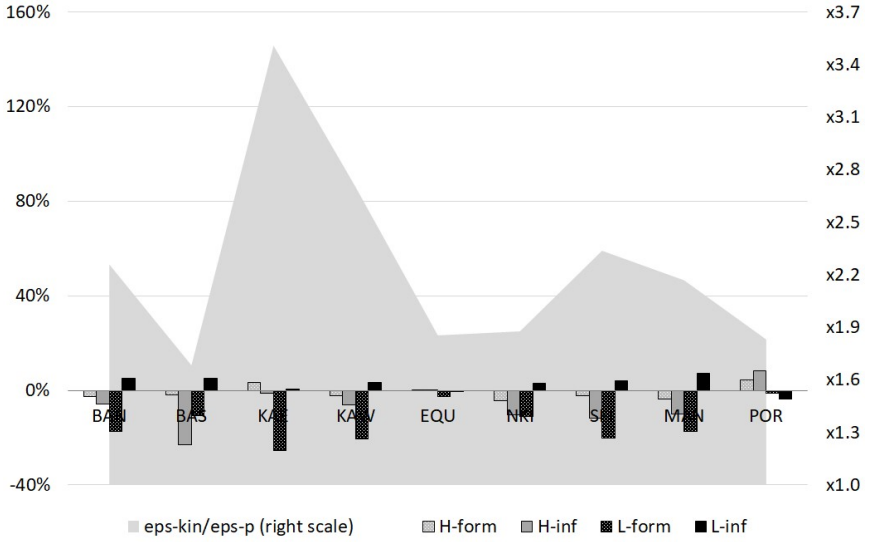
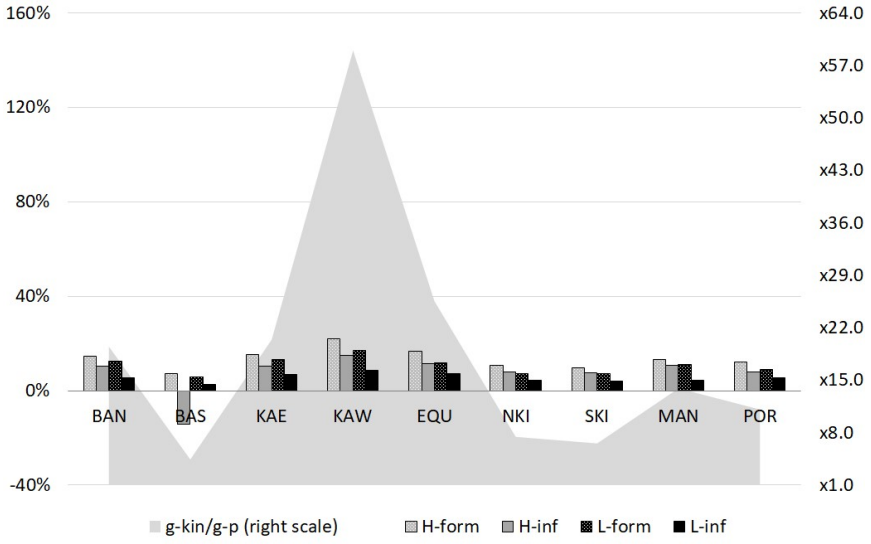


Figure 3: Income responses ($\frac{dw_p^S}{w_p^S}$, $\frac{d\omega_p^S}{\omega_p^S}$) to policy reforms (cont'd)

(d) Labor market frictions (X_p^L)



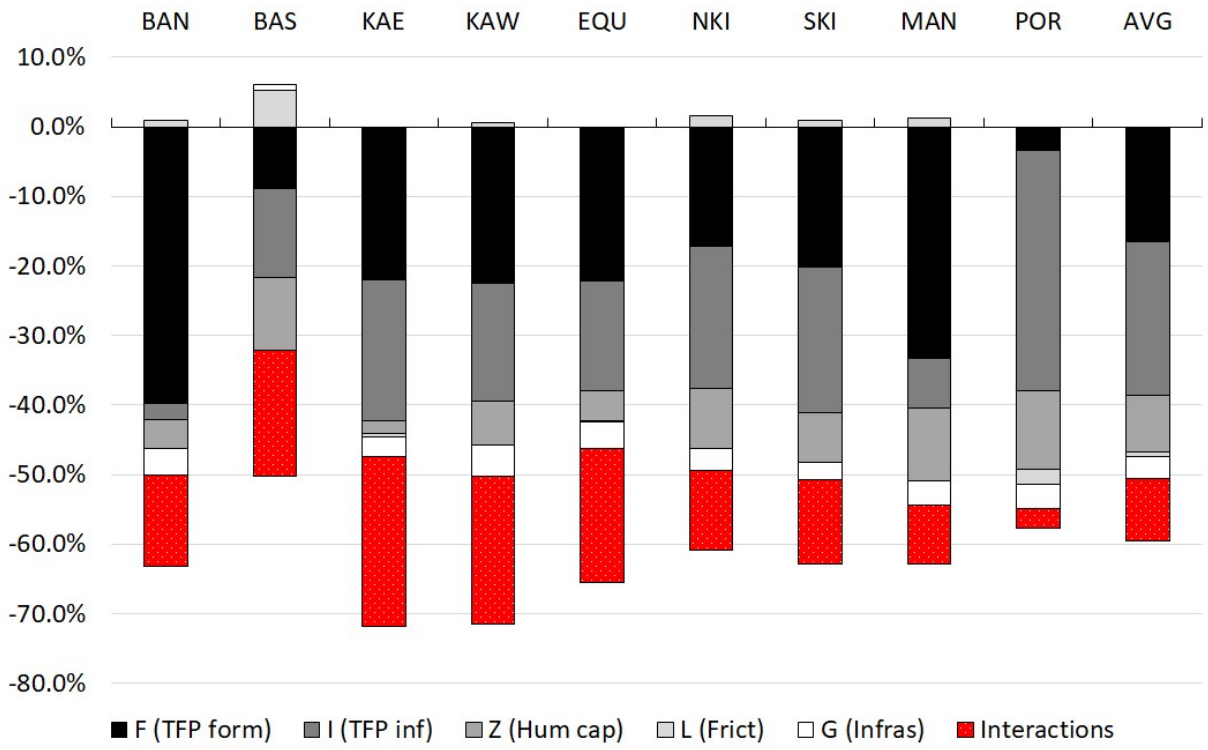
(e) Public infrastructure (X_p^G)



provinces where TFP in the formal sector is low. The residual term reaches its maximum of 41 percent of the observed income gap with Kinshasa in the highly productive province of Bas-Congo. Smaller interactions are found in Maniema and Province Orientale.

Overall, our results are compatible with the O-ring theory of development (Kremer, 1993). This theory implies that there are strategic complementarities between ingredients of the development process. These complementarities are important in explaining the development gap between provinces.[16]

Figure 4: Average income gap with Kinshasa:
Effect of isolated policies and interactions between them



Second, we return to Figure 2 however, instead of considering one policy at a time (as depicted by the blue curves), we now turn to the opposite exercise, which consists of combining four policies at a time. The results are depicted by the red curves, which represent the effect of leaving aside one policy at a time,[17] and expressing the income change as a percentage of the observed gap with Kinshasa. The effects are greater than 100 percent when one characteristic is on average more detrimental to growth in Kinshasa than in other provinces. Policies targeting the technology parameters of the formal sector are key to increasing the average level of income. On average, only half of the gap can be filled if the TFP of the formal sector is not affected

[16]The original O-ring theory focuses more on the micro aspects of production such as workers' skills, type of capital, and the nature of tasks in a firm's production process. We extend the O-ring concept to the macro ingredients of the development machinery.

[17]Remember that, by construction, combining the five policies would lead to the same equilibrium as in Kinshasa.

(with greater losses in BAN, KAE, KAW, EQU, SKI, and MAN). Taken in isolation, the TFP of the formal sector only fills 25 percent of the income gap with Kinshasa. This suggests that interactions between TFP and other factors are of utmost importance. It should be recalled that the TFP scale factor in the formal sector is also associated with governance and institutional stability. In the same vein, only 70 percent of the gap can be addressed if the technology in the informal sector is not improved (with larger effects in NKI, SKI, and POR). Lastly, a gap of 15 to 20 percent remains if the levels of education and infrastructure are left unchanged. Yet working on each of these factors separately and ignoring complementarities between them cannot entirely boost the development process and eradicate poverty.

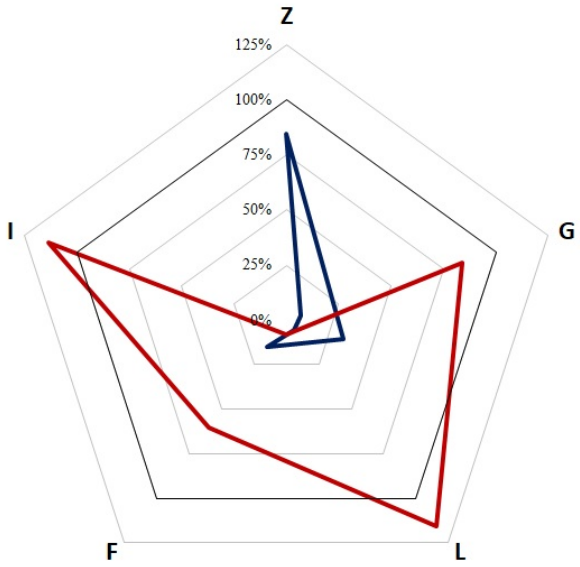
Before we proceed to the next section, we should briefly discuss the effects of one-at-a-time and quadruple sets of policies on the average informality rate in DRC. Figure 5 shows that improving human capital reduces the average informality gap between Kinshasa and other provinces by more than 80 percent. Our results are in line with (Gong and van Soest, 2012; Gong et al., 2004; Mondragon and Pena, 2008; Quiroga-Martínez and Fernández-Vázquez, 2021), who all find a negative association between the size of the informal sector and human capital. Quiroga-Martínez and Fernández-Vázquez (2021) further deduce that by decreasing informality, human capital also reduces spatial inequalities in Argentina. These authors' conclusion regarding the size of informality and spatial inequality is based on the paper by Binelli (2016), which provides empirical evidence from Mexico, suggesting inequality and informality move together. However, Binelli (2016) does not link human capital to the informality rate. Our findings reveal that though human capital reduces the size of the informal sector, it does not reduce spatial inequalities (see Figure 2). This suggests that putting in place policies focusing on reducing the size of the informal sector without also implementing policies that increase labor demand in the formal sector for the unskilled will have little or no effect on spatial inequalities. Such policies would instead reduce the size of the informal sector at the cost of a reduction in the wages for some skill groups. Our findings are consistent with the dual view of informality (Harris and Todaro., 1970; La Porta and Shleifer, 2014; Lewis, 1954; Rauch, 1991), which suggests that informality is a subsistence sector, and that development comes from the growth of formal employment for both types of workers.

We perform several other counterfactual experiments to identify the pairs of policies with the largest impact on per capita income. The details are provided in Appendix 6.3.

4.3 Are Labor Market Frictions Irrelevant?

Although labor market frictions prevent unskilled people from moving massively to the formal sector when it becomes more attractive, policies targeting frictions alone (see Figure 3d) or targeting the technology and frictions jointly (see Figure 10b) have minor or even negative effects on the average income of unskilled workers. Does this mean that frictions are irrelevant?

Figure 5: Effect of one-at-a-time and quadruple policy changes on informality ($\bar{i}_p$)



Notes: The effect is expressed as a fraction of the gap with Kinshasa in the average informality rate.

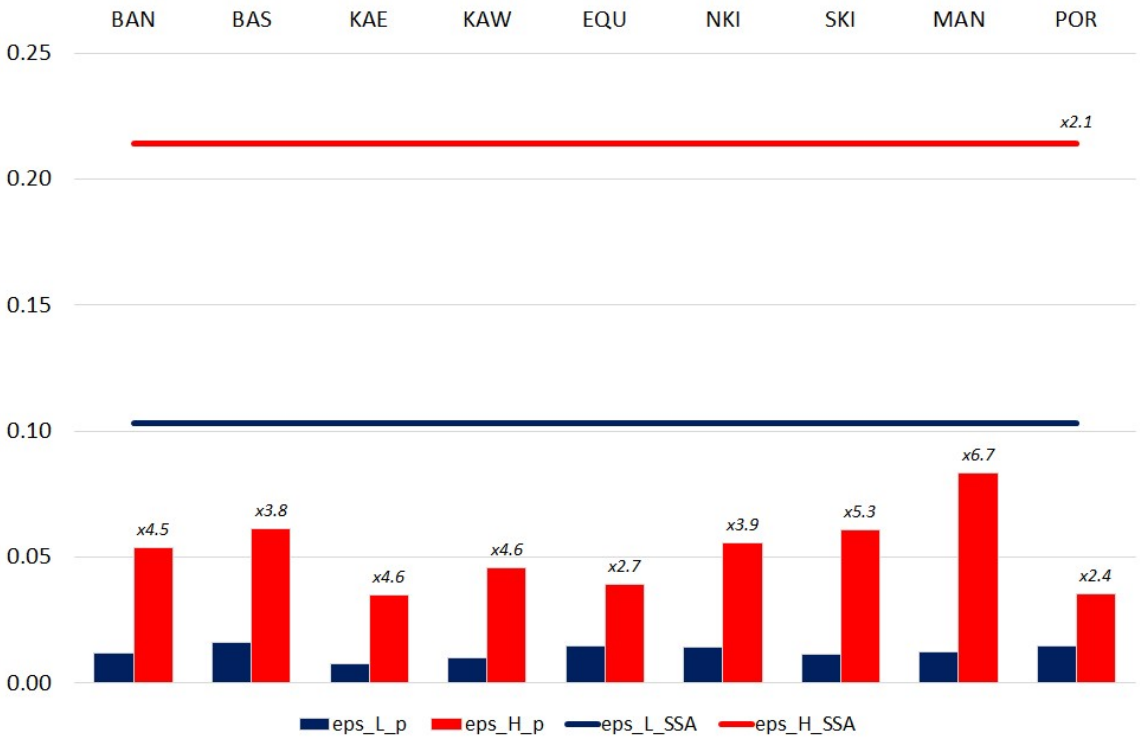
The answer is no. Remember that our X_p^L counterfactual mostly consists of equalizing the levels of ϵ_p^S, the scale factor in the skill-specific matching functions, with those observed in Kinshasa (i.e., $\epsilon_p^L = 0.027$ and $\epsilon_p^H = 0.056$). These levels are greater than in the rest of DRC, but are still very low compared with the levels estimated in other countries. For example, Docquier and Iftikhar (2019) obtain average levels of $\epsilon_p^L = 0.103$ and $\epsilon_p^H = 0.214$ in a sample of 34 sub-Saharan African countries that, by mere chance, implies a ratio $\epsilon_p^H/\epsilon_p^L$ equal to that of Kinshasa.

In Figure 6, we simulate the effect of applying the average sub-Saharan levels of ϵ_p^S to all provinces. Panel 6a shows the calibrated levels of ϵ_p^L (blue bar) and ϵ_p^H (red bar); the number above the red bar gives the ratio $\epsilon_p^H/\epsilon_p^L$ calibrated for the province, which ranges from 2.4 in Province Orientale to 6.7 in Maniema. The blue and red lines are the average levels observed in sub-Saharan Africa, taken from Docquier and Iftikhar (2019). Panel 6b presents the effect of such a drastic policy on the average income of the unskilled ($\overline{w}_p^L$ in black) and on the province-wide average income ($\overline{w}_p$ in gray). This Panel shows that a dramatic reduction in labor market frictions has small but positive effects on $\overline{w}_p^L$ in five out of the nine provinces. The largest gains are obtained in Bas Congo, Kasai Oriental, and South Kivu. An adverse effect is obtained in Equateur, North Kivu and Province Orientale where the current levels of ratio ϵ_p^L are the greatest (albeit small). When focusing on $\overline{w}_p$, the effect is positive and large in all provinces, evidencing substantial gains for the skilled.

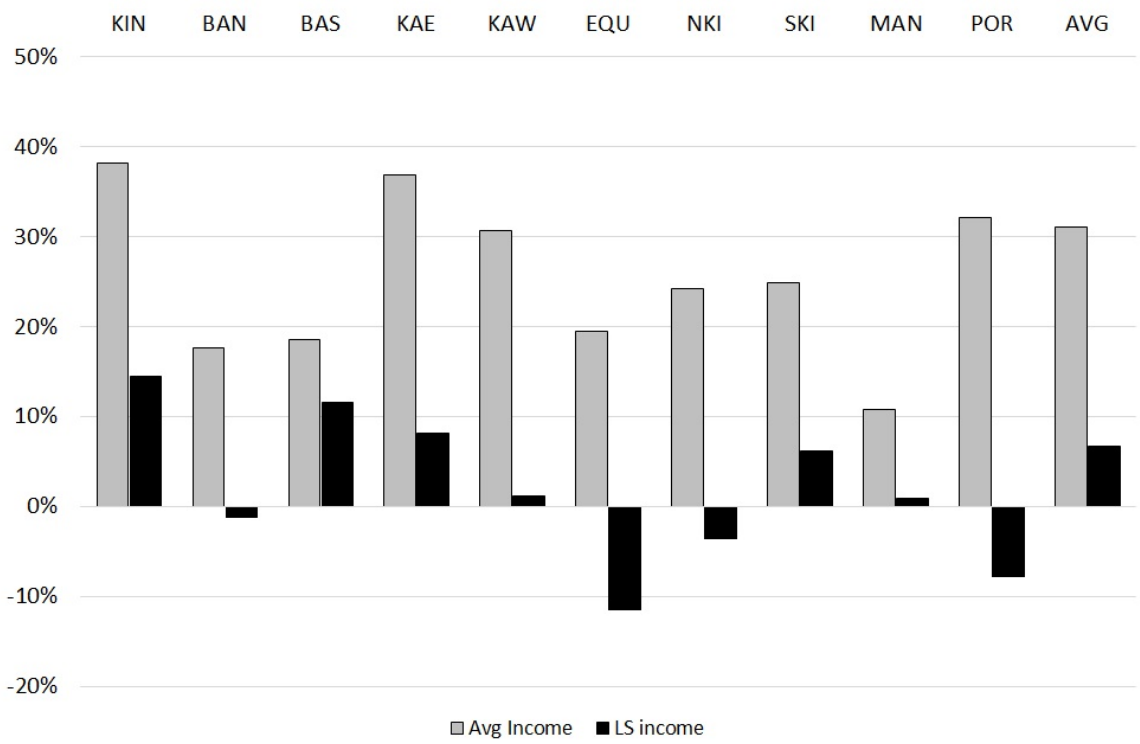
Figure 6b shows that the average income rises for both skilled and unskilled workers in

Figure 6: Effect of a dramatic decrease in labor market frictions

(a) Effect on income per capita



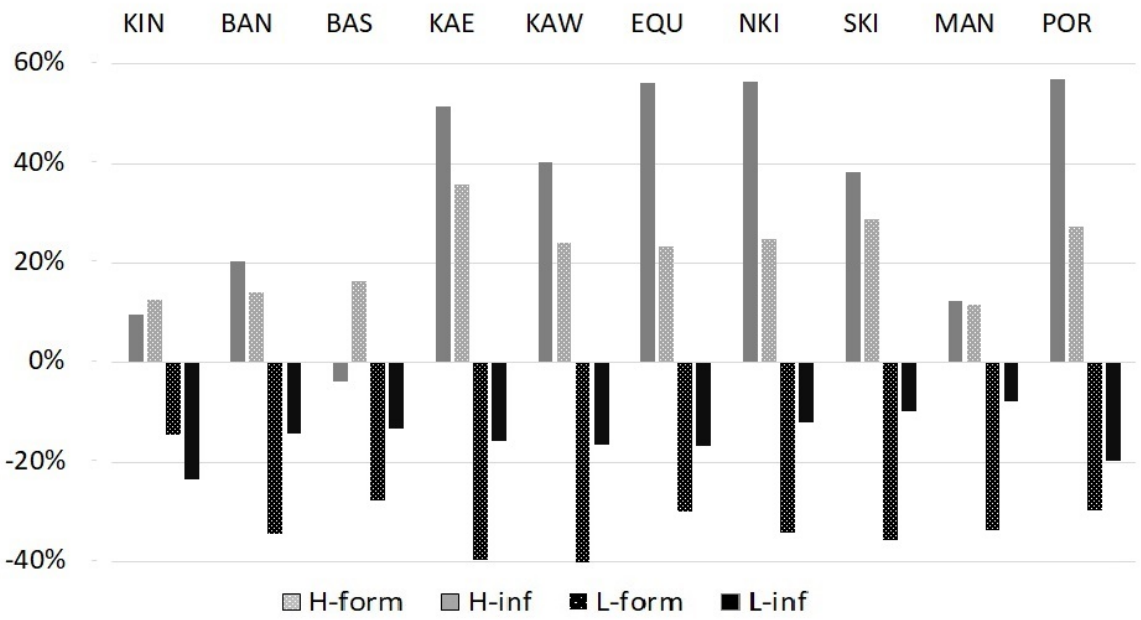
(b) Average effect on unskilled workers



DRC. This implies that reducing labor market frictions could reduce poverty and be welfare enhancing. However, looking at the wages of the workers in the two sectors reveals some

interesting details. Figure 7 shows that in both sectors, the wages increase for skilled workers in all provinces, including Kinshasa. By contrast, income levels decrease in both sectors for the unskilled workers. How do we reconcile this result with the one presented in Figure 6b? Reducing frictions allows the mobility of workers from the informal to the formal sector, thereby reducing the informality rate in all provinces for both skill groups. Average wages increase in most of the provinces due to a decline in the informal rate in all provinces. However, the opportunities in the formal sector do not respond greatly to the changes in labor market frictions. Hence, the mobility of workers reduces the skill ratio in both sectors (on average by 70 percent in the formal sector compared with 36 percent in the informal sector) and leads to a reduction in the wages of unskilled workers and a rise in the wages of skilled workers in both sectors. This brings us to the interesting conclusion that combatting informality by reducing frictions, but without expanding opportunities in the formal sector, reduces poverty along the extensive margin but increases it along the intensive margin. Once more, this provides additional evidence that reducing informality alone is not the cure to poverty and inequality if the formal sector is not attractive enough.

Figure 7: Effect of a dramatic decrease in labor market frictions on wages



5 Conclusion

This paper focuses on the causes of spatial and within-province inequalities in DRC, one of the world's poorest countries. We build a two-sector model with labor market frictions to explain income disparities between provinces, sectors (formal vs. informal), and skill groups.

We parameterize this model to exactly match the observed labor allocation of workers and distribution of income. The calibration reveals large differences across provinces, both in observed characteristics and identified parameters. We then conduct a set of policy experiments to analyze the roles of technology in the formal and informal sectors, human capital, public infrastructure, and labor market frictions in explaining spatial and within-province inequalities.

We highlight the high level of complementarity between policies, identify strong O-ring patterns of spatial inequality, and shed light on the role of labor market frictions. Income disparities are mostly determined by the technological characteristics, reflecting endowments in mineral resources, geographic position, and institutional quality. A development policy that disregards the situation of the informal sector can have small or even detrimental effects on inequality and extreme poverty. In particular, policies targeting education, labor market frictions, or public infrastructure in isolation have little effect, as they mostly impact on productivity in the formal sector, and reduce the skill ratio and productivity in the informal sector, where many unskilled workers are trapped.

Our paper sheds light on the most relevant policy areas in terms of achieving higher income in a province and combating extreme poverty. We also highlight how different policies have heterogeneous effects across provinces and skill groups. The follow-up research question is to identify which of these policy actions are more feasible in terms of cost effectiveness. The answer to this question is greatly hindered by the availability of data on the levels of public investment in the drivers of growth and human development.

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6 Appendix

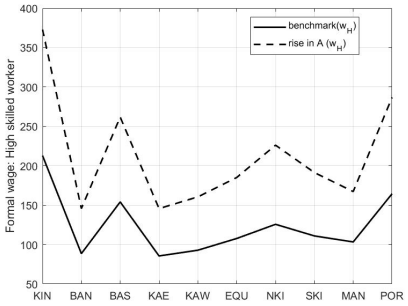
6.1 Parameter Identification

We calibrated ten province specific parameters $(\overline{A}_p, \alpha_p, \rho_p, \varrho_p, \kappa_p, \psi_p, \chi_p, \epsilon_p^H, \epsilon_p^L)$ and μ. We now discuss that each of these parameters has a unique effect on the wages and informality patterns that help identify these parameters independently. We calibrate $\overline{A}_p, \alpha_p$ by matching w_p^L, w_p^H simultaneously. Figures 8a, 8b, 8c and 8d show that while a rise in $\overline{A}_p$ increases the wage for both skill groups, a rise in α_p reduces w_p^L and increases w_p^H.

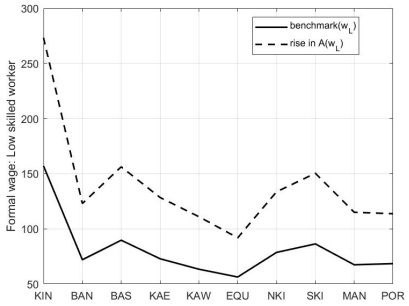
We target $(\omega_p^L, \omega_p^H, \pi_p^H)$ to calibrate (ψ_p, χ_p, ρ_p). Recall that we have $\omega_p^H = \pi_H$ based on SF10, giving us two wage targets and one entrepreneurship rate (b_p^H) to calibrate the three parameters. Figures 8e and 8f show that a rise in ρ_p increases the wages/profits in the informal sector, but the effect of a rise in ψ_p or χ_p is not homogeneous across all groups of workers. A rise in ψ_p, χ_p increases wages but reduce the profits of the high skilled entrepreneurs (Figures; 8g, 8h, 8i, and 8j). Note that, ψ_p has a larger effect on ω_p^H while χ_p has a more pronounced effect on ω_p^L. It is clear from Eqs. (15) and (16) that a rise in ψ_p, χ_p reduces entrepreneurship (b_p^H) while increasing the employment of low skilled workers in the informal sector (Eq. 29). Once ψ_p, χ_p are known, we regress $\frac{\psi_p}{\chi_p}$ on $log[Z_p]$ to estimate μ. This is then used in Eqs. (8) and (9) to obtain κ_p. The parameter ϱ_p is the sum of ψ_p, χ_p.

Figure 8: Identification of the parameters

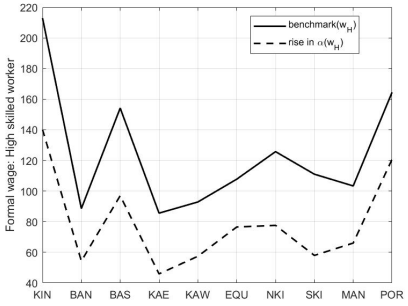
(a) Effect of a rise in $\overline{A_p}$ on w_p^H



(b) Effect of a rise in $\overline{A_p}$ on w_p^L



(c) Effect of a rise in $\overline{\alpha_p}$ on w_p^H



(d) Effect of a rise in $\overline{\alpha_p}$ on w_p^L

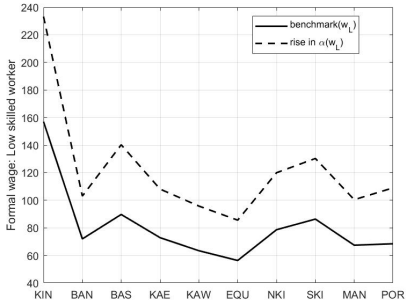
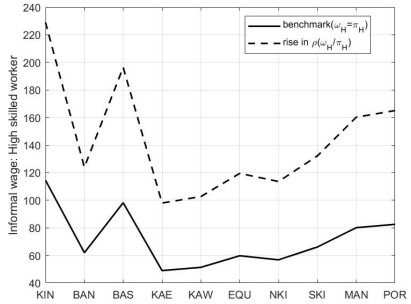
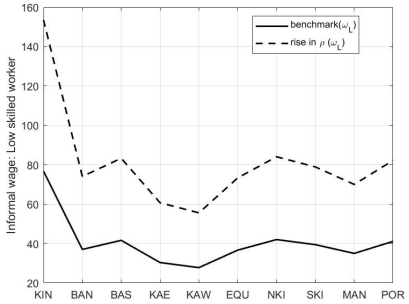


Figure 8: Identification of the parameters (cont'd)

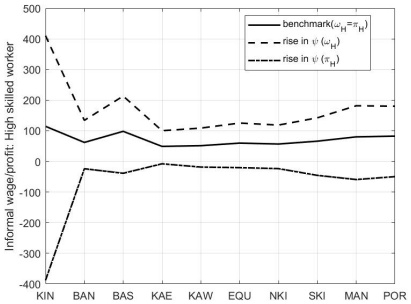
(e) Effect of a rise in $\overline{\rho_p}$ on ω_p^H



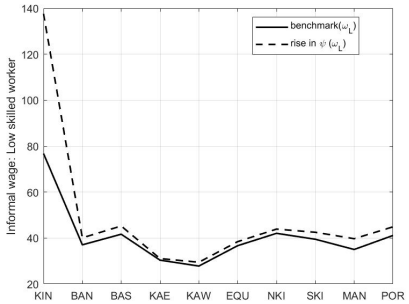
(f) Effect of a rise in $\overline{\rho_p}$ on ω_p^L



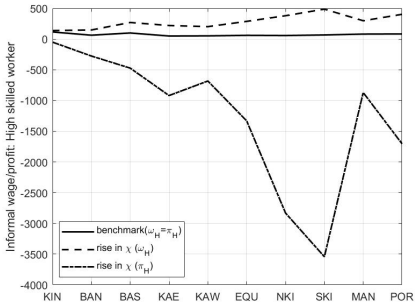
(g) Effect of a rise in ψ_p on ω_p^H, π_p^H



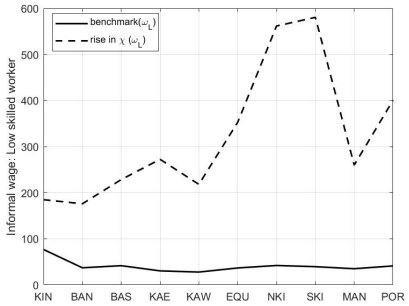
(h) Effect of a rise in ψ_p on ω_p^L



(i) Effect of a rise in χ_p on ω_p^H, π_p^H



(j) Effect of a rise in χ_p on ω_p^L



In order to calibrate ϵ_p^S we target the informality rate i_p^S. It is straightforward to see from Eq. (35) that an increase in ϵ_p^S will reduce the informality rate for the skill group S with no effect on the other group, ceteris paribus.

6.2 Parameter Validation

As we used all the degrees of freedom in the data to identify the needed coefficients, our model is exactly identified and we cannot produce a test of its assumptions. In order to establish the relevance of our parameterization method, we examine whether our province-specific parameters exhibit realistic correlations with the traditional explanatory variables used in relevant econometric literature.

The coefficients of correlation between province-specific parameters and potential correlates are shown in Table 5. The TFP scale factor in the formal sector ($\overline{A}_p$) is significantly correlated with the proportions of the manufacturing industry in terms of output and employment. Importantly, the correlation between $\overline{A}_p$ and population density is non-significant, which suggests that cross-province differences in productivity are not correlated with urbanization and market size once TFP is deflated by infrastructure and human capital. It should be noted that as $\overline{A}_p$ a residual scale factor, the absence of correlation with Z_p and g_p suggests that the size of technological externalities (φ and η) makes sense. In addition, $\overline{A}_p$ is not correlated with the number of people displaced due to conflicts, which is a proxy for political stability and governance quality in a province. As conflicts mostly arise in resource abundant provinces, this also suggests that the benefits of natural wealth and the resulting costs of instability may cancel out in the aggregate.

The relative productivity in informal sector (ρ_p) is negatively correlated with internal displacements. It is uncorrelated with the other indicators, which supports our assumptions that TFP in the informal sector is less affected by the level of infrastructure per capita and uncorrelated with human capital. The elasticity of informal output to high-skilled employment (ψ_p) is positively correlated with most indicators, in contrast to the elasticity to low-skilled employment (χ_p). In particular, the greater the skill ratio in the population (Z_p), the greater is the elasticity of informal output to high-skilled labor (ψ_p). This suggests that a skill-biased externality is more likely to operate in the informal sector than in the formal sector (as α_p is uncorrelated with the skill ratio). The sum $\varrho_p = \chi_p + \psi_p$ is uncorrelated with our indicators. In other words, the informal sector is heterogeneous across provinces; its technology is more skill-intensive in provinces where human capital is less scarce. With regard to labor market frictions, the efficiency of the matching function for low-skilled workers is positively correlated with most indicators, whereas the scale parameter of the matching function for skilled workers is not.

We identify four groups of provinces, as illustrated in Figure 9, and we use a radar-plot representation to highlight disparities along the five dimensions of Definition 2.[18] The values of the parameters in each province are shown as a part of the value of the parameter in Kinshasa. The first group includes Bas-Congo (BAS) and Province Orientale (POR), which exhibit

[18]We exclude Katanga, which is almost as wealthy as Kinshasa due to its abundant mineral resources.

Table 5: Parameters – Validation

Correlate	$\overline{A}_p$	α_p	ρ_p	ψ_p	χ_p	ϱ_p	ϵ_p^L	ϵ_p^H
Population density	0.343	-0.400	0.471	0.882*	-0.791*	-0.331	0.890*	0.063
Value added in Manufacturing	0.630*	-0.450	0.284	0.859*	-0.781*	-0.362	0.846*	-0.143
Workers in Manufacturing	0.943*	-0.258	-0.043	0.658*	-0.630*	-0.398	0.571	-0.278
Good roads (as %)	0.458	-0.292	0.168	0.680*	-0.557	-0.052	0.788*	0.018
Nb. business projects	0.594	-0.154	0.317	0.828*	-0.754*	-0.351	0.827*	0.189
Nb. vacancies to be filled	0.520	-0.193	0.209	0.687*	-0.613*	-0.245	0.789*	0.166
Urban population share	0.490	-0.276	0.267	0.832*	-0.768*	-0.395	0.790*	-0.156
People displaced	0.345	0.038	-0.623*	-0.382	0.462	-0.257	0.157	-0.273
Infrastructure per capita	0.447	-0.343	0.457	0.900*	-0.819*	-0.382	0.911*	0.140
Skill ratio in population	0.367	-0.371	0.575	0.947*	-0.886*	-0.492	0.874*	0.069

Notes: Data are obtained from the INS country's statistical report (INS, 2017). Population density is the average number of inhabitants in a given area per square kilometer in the year 2013. Proportion of the manufacturing sector in formal output and formal employment in the year 2013, respectively. Good roads (%) represents the proportion of paved road (2016). No. of business projects and No. of vacancies to be filled are an annual mean value from 2012 to 2015. Urban population proportion represents the percentage of the population living in urban areas. People displaced represents the number of internal displacements due to conflicts and instability (2014). * means significant at the 5% level.

relatively high levels of productivity in the formal sector. Bas-Congo takes advantage of its geographic position as the only gateway through which the country has access to the ocean. This allows BAS to trade more with other countries, and to benefit from greater tax revenues from trade. A large proportion of the products imported and exported by the DRC transit through this province. Province Orientale benefits from its subsoil assets, which are abundant in gold minerals. POR has benefited from the settlement of multinational mining companies (e.g., Kibali Mining) that have contributed to shifting the exploitation from *artisanal* to industrial, and to improving institutions. The province also benefits from revenues generated by dynamic cross-border trade with the *Eastern African Community* countries.

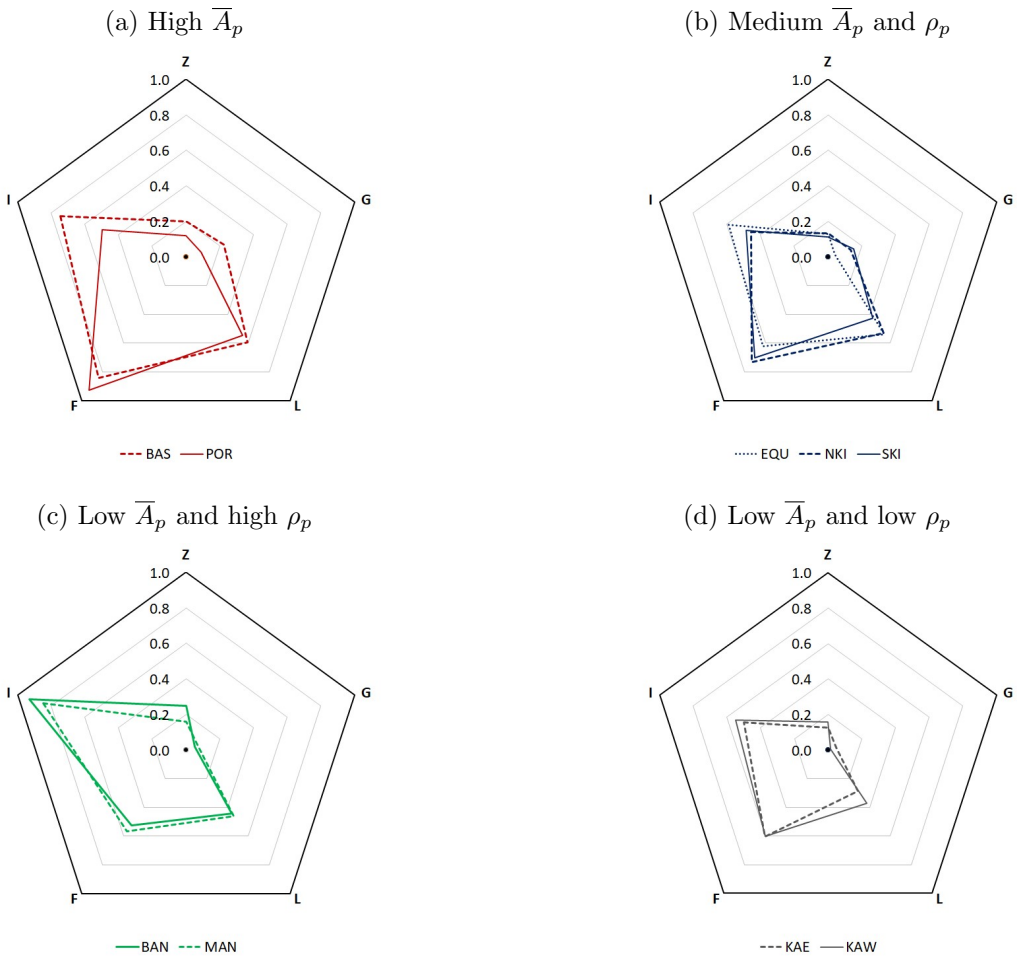
The second group includes three provinces, North and South Kivu (NKI, SKI) and Equateur (EQU), that exhibit medium levels of productivity in both sectors. In particular, the Kivu provinces are well endowed in mineral resources and represent the world reservoir of *columbo-tantalite*, as well as of other minerals. They have the advantage of sharing borders with countries experiencing increasing economic growth rates (i.e., Rwanda and Tanzania). However, they have been experiencing violent conflicts for decades, fueled by both national and regional tensions. This permanent instability has generated huge costs in terms of human lives and social and economic development.

The third group includes two provinces, Bandundu (BAN) and Maniema (MAN), with low productivity in the formal sector, but with a relatively successful informal sector. Maniema is handicapped by being *landlocked*, as it does not share borders with any of the nine countries surrounding DRC. Bandundu has limited mineral resources, and has suffered from the disorganized exploitation of rubber. Lowes et al. (2017) show that greater exposure to extraction-oriented institutions has significantly affected BAN in terms of education, wealth, and health outcomes.

Historically, the severe rationing of formal jobs in these two provinces has contributed to the development of a relatively dynamic informal sector.

Lastly, the two provinces of Kasai (KAE and KAW) combine many shortages (infrastructure, health, education, sanitation, etc.) and substantial labor market frictions. They are the most rural provinces in DRC, with low productivity levels in both sectors. Although they have significant mineral resources, such as diamonds, their economies are dominated by small-scale and sparse *artisanal* mining and farms. The IMF (2015) report ranks these two provinces as the poorest in DRC, with an average poverty rate of 76.5 percent.

Figure 9: Broad classification of provinces



Notes: Broad classification based on calibrated parameters from Table 4, expressed as a fraction of the value obtained for Kinshasa.

6.3 Most Effective Policy Pairs

In line with the O-ring theory of development, working on the single source of under-development is poorly effective on the aggregate, and can even be detrimental when focusing on poverty and inequality. We now consider pairs of policies, identifying the most effective ones, as well as pairs that are better or worse for the economy. For each province, we set one pair of policy targets at

a time at the Kinshasa levels, while leaving other subsets of parameters at their baseline level. We only consider pairs involving the technological parameters of the formal sector (X_p^F).

The results are depicted in Figure 10. Panel 10a gives the effect on the province-wide average level of income ($\overline{w}_p$), while Panel 10b gives the effect on the average income/welfare of unskilled workers, defined as $\overline{w}_p^L = (1 - i_p^L)w_p^L(1 - \tau) + i_p^L\omega_p^L$. The first bar in black depicts the observed income gap with Kinshasa. The second bar in pixelated black gives the income gap obtained under the X_p^F counterfactual (referred to as "With $\overline{A}$ only" in the legend). Then, the bars in dark red, red, green and yellow show the effect of combining X_p^F with X_p^G, X_p^Z, X_p^L and X_p^I, respectively. The order of these policy pairs is correlated with their average effectiveness when focusing on $\overline{w}_p^L$.

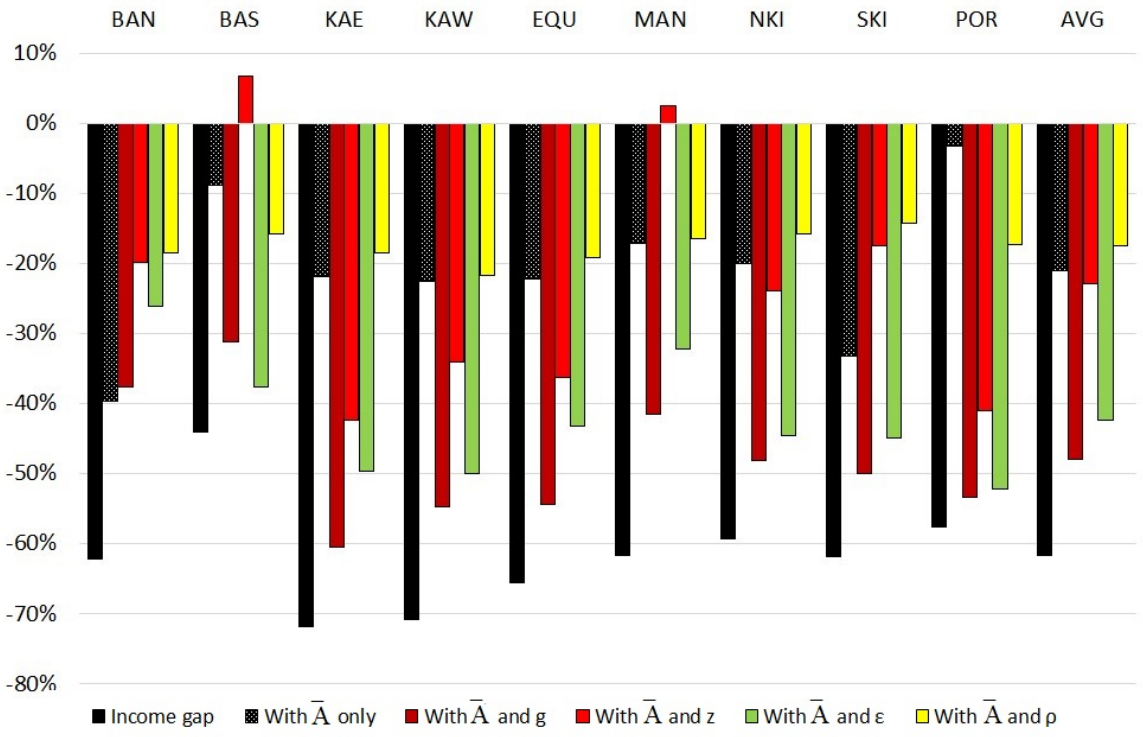
The first key result is that policy pairs targeting X_p^F and X_p^I jointly are always the most effective ones. They drastically reduce the income gap with Kinshasa for the unskilled in the provinces of Kasai, Kivu and Equateur. In Province Orientale, this even takes $\overline{w}_p^L$ to a higher level than in Kinshasa. A significant gap persists in Bandundu and Maniema, where the observed informal sector is highly productive. The effect on the province-wide average income $\overline{w}_p$ is smaller, because improving productivity in the informal sector attracts skilled workers into it (as entrepreneurs), where income levels are lower. In a very poor country such as DRC, a development policy that disregards the situation of the informal sector has small, or even detrimental, effects on inequality and extreme poverty.

The second key result is that whatever the outcome variable (province-wide average income or average income of the unskilled), combining X_p^F with policies targeting infrastructure (dark red) or education (red) can be counterproductive. These policy pairs are less effective than improving the technology in the formal sector alone. In line with Figure 3, this is due to the fact that infrastructure and education policies stimulate the attractiveness of the formal sector, and labor market frictions are larger for unskilled workers. Hence, these policies reduce the skill ratio in the informal sector, where most of the unskilled are employed. Combining X_p^F with policies targeting labor market frictions has similar effects on $\overline{w}_p^L$ than X_p^F alone, except in Bandundu and Maniema. However, they adversely affect the income of the skilled, as well as the province-wide average income in most provinces. In a poor economy with huge labor market frictions, traditional development policies can induce a smoother transition to formal work for the wealthiest part of the labor force, and generate a detrimental effect for the overwhelming part of the unskilled population trapped in informality.[19]

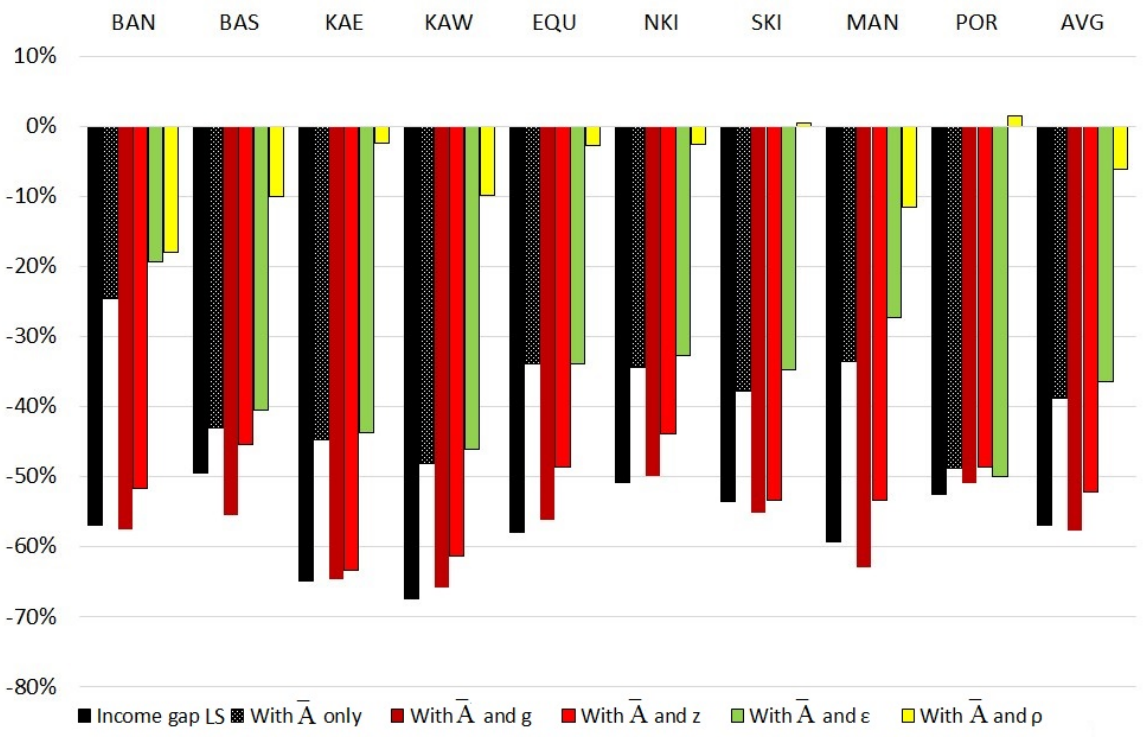
[19]Several effects are at work when policy pairs change making it difficult to disentangle different channels and explain why X_p^F alone is more effective than a policy pair. For example consider the policy pair combining X_p^F and X_p^G. Improving X_p^F improves both marginal product and outside options of the worker however, combining X_p^F and X_p^G increases the productivity in both sectors but also increases the productivity gap between the formal and informal sector ($\varphi < \phi$) thus reducing the outside options of workers. This effect attenuates the positive effects of improving X_p^F and X_p^G on wages. We thus have a smaller effect of this policy pair on inequality than improving X_p^F alone. Similarly, improving X_p^F and X_p^L has a smaller effect on the average per capita income

Figure 10: Effectiveness of policy pairs

(a) Effect on income per capita



(b) Average effect on unskilled workers



than from X_p^F alone, but for the low-skilled workers this policy pairs out performs improving X_p^F alone. This is because removing frictions improves the skill ratio in the formal sector. This attenuates the positive effects

6.4 Robustness Checks

In this section, we check the robustness of our results to the value of parameters. We first consider a monthly job destruction rate of 0.04 (instead of 0.06 in the baseline). Second, there is an existing group of studies suggesting that quantitatively large aggregate schooling externalities are unlikely to exist in developing countries. We consider a variant with $\eta = 0.0$ (Acemoglu and Angrist, 2000), instead of 0.10. Third, Angrist (1995) recommends a value of σ above 2 to explain the trends in the college premium in developing countries. Our third variant assumes $\sigma = 3.0$, instead of 2.0. Lastly, we consider the upper bound of the range of elasticity of TFP to public infrastructure, as $\varphi = 0.10$ instead of 0.05, as suggested by Calderon and Serven (2014).[20]

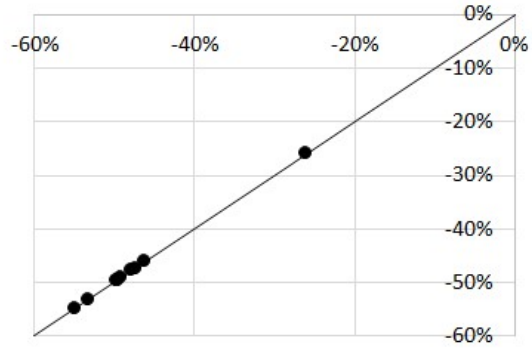
Our variable of interest is the province-wide average level of income under the five policy experiments. Focusing on the sum of isolated policies and interactions terms in Figure 4, Figure 11 compares the baseline results with those obtained after changing these elasticities.

The results are robust to the parameters δ, σ and η thereby suggesting our results in the baseline scenario are not driven by the values of these parameters. However, the results appear to be sensitive to the value of φ. The sum of isolated effects is smaller while the interaction term is much larger with a higher value for φ. Nonetheless, our measure of public infrastructure is uncorrelated with $\bar{A}_p$ and ρ_p meaning that we are able to isolate the effect of g_p on income from the scale factors of TFP in the two sectors. Hence, the baseline level of φ does a good job of capturing the effects of g_p on productivity. However, with the higher elasticity of TFP to public infrastructure, this implies stronger O-ring patterns of economic development. The value of φ governs the size of the complementaries between policies.

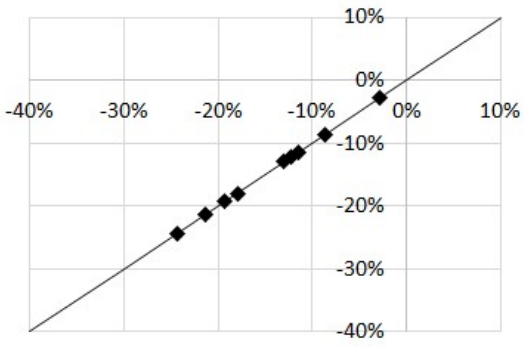
of X_p^F on high-skilled workers. However, the low skilled workers gain from this rise in the skill ratio in the formal sector. Thus this policy pair is more effective for low-skilled workers than improving X_p^F alone. Similar mechanisms are also involved in other policy pair experiments. The key message is that different policies affect different skill groups and production sectors in heterogeneous ways.

[20]The elasticity of TFP to public infrastructure in the informal sector ϕ is always set at half of φ.

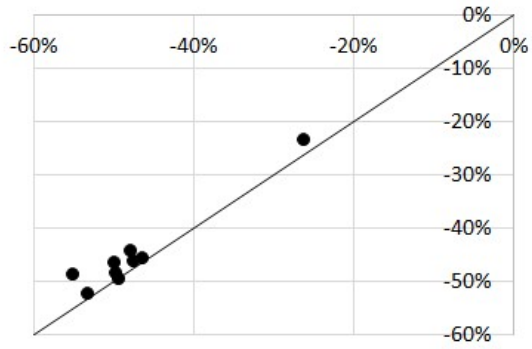
Figure 11: Robustness checks - Sum of isolated effects and residual interaction term



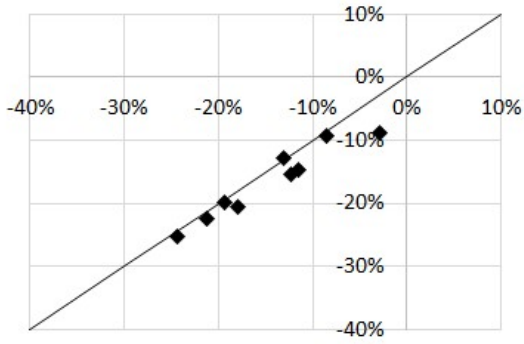
(a) Sum of isolated effects ($\delta = 0.04$)



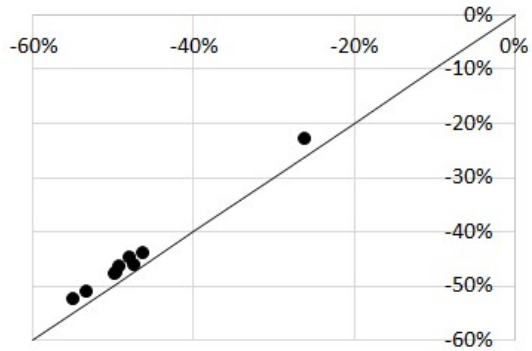
(b) Interaction term ($\delta = 0.04$)



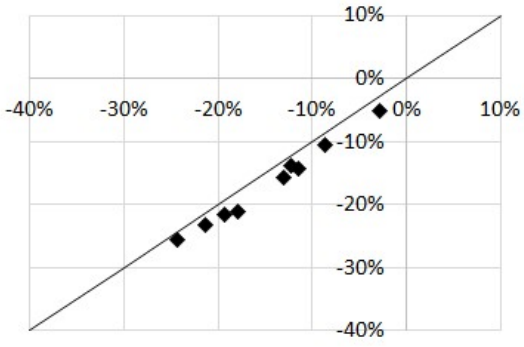
(c) Sum of isolated effects ($\eta = 0$)



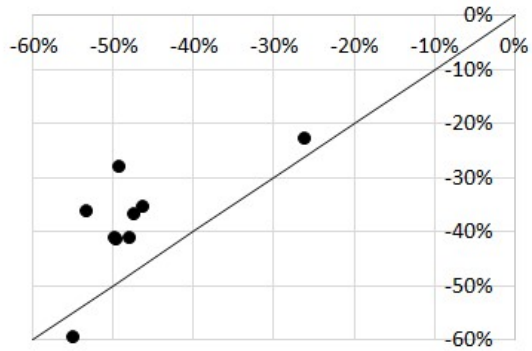
(d) Interaction term ($\eta = 0$)



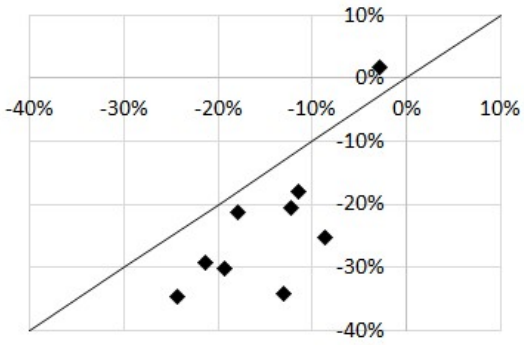
(e) Sum of isolated effects ($\sigma = 3.0$)



(f) Interaction term ($\sigma = 3.0$)



(g) Sum of isolated effects ($\varphi = 0.1$)



(h) Interaction term ($\varphi = 0.1$)