Spatial Inequality, Labor Market Frictions and Informality in the Democratic Republic of the Congo*

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Abstract

We build a two-sector model with labor market frictions to explain income disparities between provinces, sectors (formal vs. informal) and skill groups in the Democratic Republic of the Congo. We parameterize the model and conduct a set of counterfactual "policy" experiments to analyze the role of technologies, human capital, infrastructure and labor market frictions in explaining spatial and within-province inequalities. We first quantify the high level of complementarity between policies and identify O-Ring inequality patterns. Second, we show that spatial inequalities are mostly determined by technological disparities. Third, we find that a development policy that disregards the informal sector has low or even detrimental effects on inequality. In particular, policies targeting education, labor market frictions, or public infrastructure in isolation have little effects as they mostly impact productivity in the formal sector, and reduce the skill ratio and productivity in informality, where many unskilled workers are trapped.

Keywords: Informality; Inequality; Labor market frictions; O-Ring theory of development.
JEL codes: O15, F22, I11, C23, J61.

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1 Introduction

Despite some timid progress toward the Sustainable Development Goals (SDGs), Africa continues to lag behind when it comes to per capita income growth and economic convergence. More than half of the global poor (i.e., people earning less than USD 1.90 PPP per day) live in Africa, and the region of Central Africa is especially struggling to improve its SDG indicators. Income inequality also remains persistently high in the region. According to the World Inequality Database WID (2020), there are large variations within and between African countries when it comes to income inequality. Central Africa, in particular, has observed an increase in income inequality between 1990-2015 while other parts of Africa have witnessed a marginal decline. Africa has the human and natural resources to yield inclusive growth and eradicate poverty WDI (2021). African nations have experimented with diverse approaches to economic development, prioritizing infrastructure and capital accumulation, fight against corruption and poor governance, trade and economic integration, human development, etc. In majority of the countries these actions have failed, possibly because achieving sustainable development is a multifaceted challenge requiring a combination of favorable conditions that are difficult to reconcile.

In this paper, we take a different approach to understand the underlying reasons for persistent stagnation in economic growth and high income inequality within and between regions. Unlike most of the growth and development literature that focuses on the role of a single determinant of economic development, we develop an approach that formalizes the interaction between several ingredients of economic development (public infrastructure, human capital, production technology, labour market frictions). We propose that the O-Ring model of development is likely to apply to many African countries. Although the original theory focuses more on micro aspects (Kremer, 1993),[1] a macroeconomic generalization of the O-Ring theory implies that policies targeting a specific part of the economy have low value if other complementary components of the development machinery are not working properly. We aim to evaluate the strength of interaction between different factors of development while assessing the relative importance of each factor in isolation as well. With our quantitative analysis, we identify the most effective areas for policy interventions for per capita income growth and reducing spatial inequality in the Democratic Republic of Congo (DRC, henceforth). Our findings are in line with theories showing that the extremely poor need a "big multidimensional push" to escape from the poverty trap (Banerjee et al., 2015). We illustrate the difficulty of reducing income inequalities in the DRC using a two-sector model with labor market frictions.

Our focus on DRC is justified by two facts. First, DRC is among the world's poorest countries and suffers from weak levels of public infrastructure and human capital, poor governance, and an overwhelmingly large informal sector. Like many other African countries, it is abundant

[1] e.g. the importance of firm-level interactions between tasks

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). Despite greater monthly wage levels in the formal sector, one-third of the skilled and ninety percent of the unskilled are employed informally. These numbers potentially reflect a labor market with large frictions. The informal sector is defined as the part of an economy that is not taxed or monitored by any form of government. It drains a large proportion of both skilled and unskilled workers in developing countries (Docquier and Iftikhar, 2019; Jütting and De Laiglesia, 2009; Schneider, 2012). Second, microdata are available to characterize both levels of 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. In particular, the *1.2.3* household survey is unique in the sense that it documents the level of income of Congolese working age people by education level, by sector of activity (formal vs. informal), by type of activity (entrepreneurship vs. employment) and by province. The database provides a unique opportunity to analyze interactions between sectors and the functioning of the labor market. It reveals that DRC provinces are strongly heterogeneous in labor market characteristics and productivity levels. Spatial inequalities are important and account for approximately fifty percent of the Theil index between broad groups of income earners. In all provinces, the informal sector employs large share of both skilled and unskilled workers. On average, workers in informality have low levels of earnings compared to similarly skilled workers in the formal sector.

We build a one good, two-sector (formal and informal), two-class (low and high skilled worker) model, and use it to quantify the effect of different types of "policies" on per capita income and inter(intra)-provincial income inequality. In each province, the same final good is produced by formal and informal firms, using different technologies. The formal sector is characterized by labor market frictions. The informal sector is characterized by small businesses run by entrepreneurs who hire informal workers on a competitive labor market. In line with observed data, we ignore inter-provincial trade and migration flows; they are almost inexistent between provinces.[2] The economy of each province is characterized by five sets of parameters, namely (i) socio-demographic indicators (say, the share 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 data reveals large differences across provinces in observed characteristics (i.e., the education structure of the population and the level of public infrastructure per worker). We

[2]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. To put it in perspective, only 5.4% of the road network over the country is asphalted. This also significantly limits the mobility of labor. Indeed, Using the 1.2.3 database, the proportion of migrants accounts for 4.2% of the working aged population only. These include both intra- and inter-province labor mobility. The inter-province mobility itself is likely to be significantly lower.

parameterize the model to exactly match employment patterns and income disparities between groups, and conduct a set of numerical experiments. We find disparities across provinces in identified parameters (i.e., total factor productivity scale factors in both sectors, labor market frictions). These differences explain the average income gap with the richest province of Kinshasa as well as within-province inequality. We use counterfactual simulations to analyze the role of these province-specific characteristics in explaining the income gap with the richest province and within-province inequality. Somewhat unsurprisingly, we show that income disparities are mostly determined by technological characteristics, reflecting both endowment 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 informality induces larger aggregate gains by generating greater benefits for the low-skilled. Acting on both sectors is desirable to increase the average income of both types of workers.

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 productivity in the formal sector, and reduces the skill ratio and productivity in informality, where many unskilled workers are trapped. These policies taken in isolation 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 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 ask whether informality hampers growth in a developing economy? The literature provides support for different views on the answer to this question. On one hand, we have De Soto (1989, 2000) that considers informality plays an important role in economic growth and development and on the other hand, we have (McKinsey, 2004a,b, 2015) that suggest boosting economic growth is possible by reducing informality. Nonetheless, our findings are in line with the dual view of informality, which suggests that informality is a subsistence sector, and that development comes from the growth of formal employment (see (Harris and Todaro., 1970; 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 have little or no effect on spatial inequalities and may increase inequality within a region by reducing wages for some groups of workers.

The low mobility across sectors is due to large labor market frictions. Reducing frictions at the levels observed in Kinshasa alone or combined with a policy targeting productivity in the formal sector can be worse than targeting the technology only as it mainly benefits skilled workers. A main conclusion of our analysis is that even a dramatic reduction of labor market

frictions does not benefit unskilled workers. This is because a drastic reduction in labour market frictions does not induce an increase in job creation (given other complementary policies are not in place) of comparable magnitude, it only allows a more free worker mobility across sectors. This increase in worker mobility reduces the skill ratio in both the formal and the informal sector leading to a decline in the wage of low-skilled workers. Hence, reducing labour market friction reduce 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 wage offered in the formal sector.

Our paper relates to the literature on the effectiveness of development policies. In the discussion of William Estearly's "Elusive Quest for Growth," Wacziarg (2002) 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." Most of these miracle growth policies have proven disastrous or ineffective, which might 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 investments in physical and human capital) requires a supportive environment with political stability and sound governance, a good 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 dysfunctioning 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 odds of finding productive employment on the labor market are 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 informality. Job creation was not fast enough to meet the demand from a growing working-age population between 2005 and 2012.

Second, we account for the role of infrastructure.[3] There is evidence that public infrastruc-

[3]Not that informality can generate vicious circles as the difficulty to raise fiscal revenues is one of the main reasons why investments in infrastructure are small in developing countries. Besley and Persson (2014) report that low-income countries have small tax rates (varying between 10 and 20% of GDP), while in developed

ture – transport infrastructure, electricity, sanitation, water and sewer lines, 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; La Porta and Shleifer, 2014; Wang and Wu, 2015). Yet, a deficit in 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 are outdated, maintenance levels are insufficient, and new investments are low.[4]

Third, human capital is usually seen as a key determinant of development potential through its effects on health, knowledge, skills, the resilience of people (Bloom et al., 2004; Hanuschek, 2013). On this basis, the World Bank has 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 high among the population (Gyimah-Brempong, 2011). Furthermore, public spending in education is unevenly redirected towards less developed regions (IMF, 2015).[5]

Finally, it has long been recognized that good institutions and stability are needed to enable growth miracles. Good institutions provide secure property rights and relatively equal access to resources (Acemoglu et al., 2005). DRC is rich in mineral resources. 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 incentives to invest for formal and informal firms.

The rest of this paper is organized as follows. Section 2 describes the *1.2.3* and highlights ten stylized facts characterizing the economy of DRC, and helping us motivate the specification and parameterization of our model. In Section 3, we develop a labor market model which is consistent with the stylized facts and anecdotal evidence. Results of our numerical experiments are presented in Section 4. Finally, Section 5 concludes.

2 Stylized Facts

Our study focuses on the Democratic Republic of Congo (DRC), which is the most populous francophone nation of the world (about 100 million inhabitants) and among the world's poorest

countries the average level of taxation is close to the 40% of GDP; they 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.

[4]As shown by Herderschee et al. (2012), only four out of 10 province capitals are linked by road to the national capital (Kinshasa), and shipping costs by rail transport are substantially greater than in other countries. Access to electricity and telecommunication are low.

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

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 that are illustrated in the tables 1-3 and Figure 1 below. 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 (hereafter INS) in partnership with different actors (including Afristat and the World Bank).

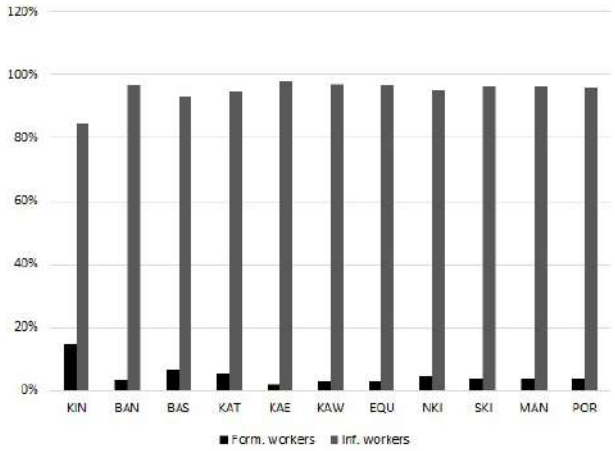
The *1.2.3* data were collected in three phases. Each of these numbers refers to a collection phase. Phase 1 provides detailed information on employment, unemployment, household and individual socio-demographic characteristics. Phase 2 focuses on the informal sector and gathers information on the characteristics of firms and firm owners in informality. 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 informality, productivity and income distribution.

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

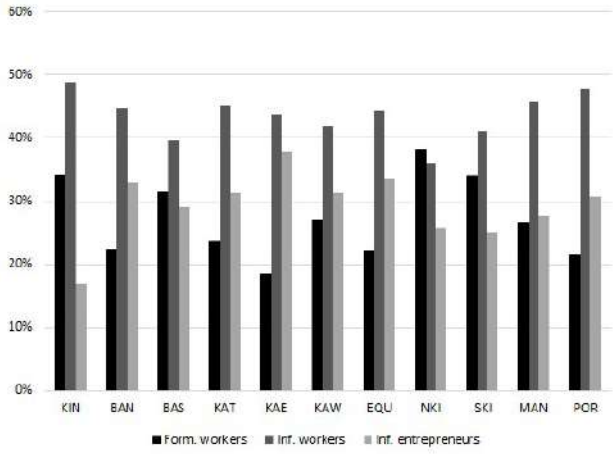
SF1. DRC is one of the least developed countries of the world. – Despite an abundance of natural resources, DRC has one of the world's lowest GDP per capita and is characterized by low institutional quality, as illustrated in Table 1. For many decades, the majority of the population has lived in extreme poverty. In 2019 (Human Development Report of the United Nations), DRC showed a HDI index of 0.459 and ranked 179 out of 189 countries included in the database. Almost 64% of the Congolese population live below the national poverty line, and 76% live with less than USD 1.90 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 Gini index of 0.45 in 2012 and a per capita GDP level of USD 767.4 (in PPP value), i.e. 13.5% of the sub-Saharan African mean, 9.4% of the Central African mean... and 3.6% of the worldwide average level.

The Corruption Perception Index (CPI), which ranges from 0 to 100, scores and ranks countries based on how corrupt is the public sector. In 2019, the CPI score of DRC was equal to 18, one-half the average level of sub-Saharan African countries and 41.8% of the world average. This ranks DRC in the 168th position out of 180 countries included in the database. It is worth emphasizing that DRC has lowered its CPI rank for the recent years, which suggests that corruption is continuously increasing. Although the DRC constitution protects the ownership of private property, enforcement is virtually nonexistent. As a consequence, the Heritage Foundation assigns a property right score of 30.1 (on a scale from zero to 100) which

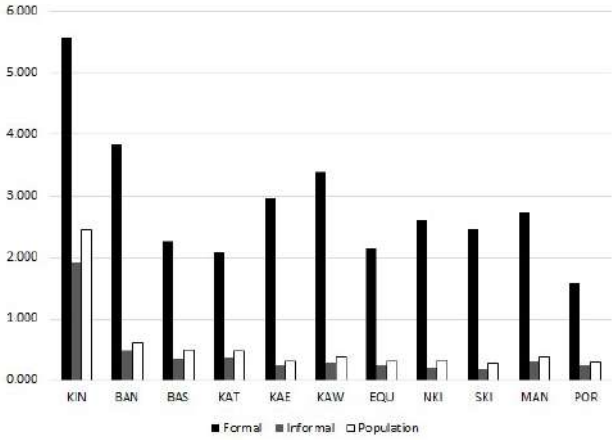
Figure 1: Labor market characteristics by sector and by skill group



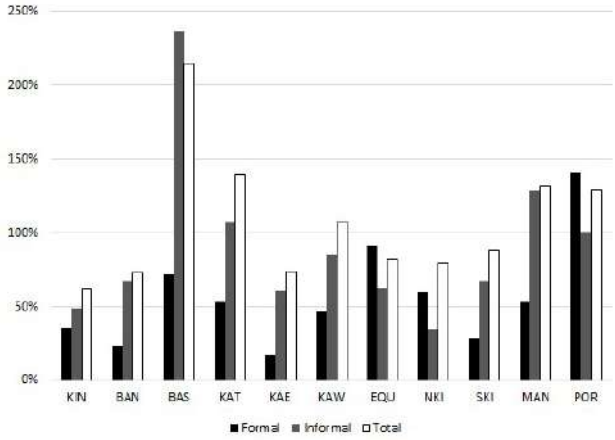
(a) Labor allocation of the unskilled



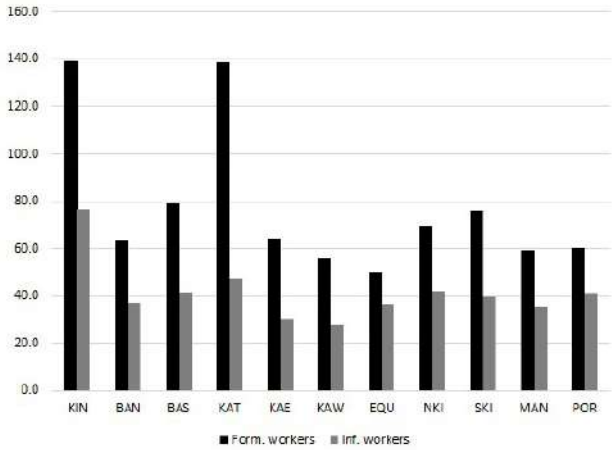
(b) Labor allocation of the skilled



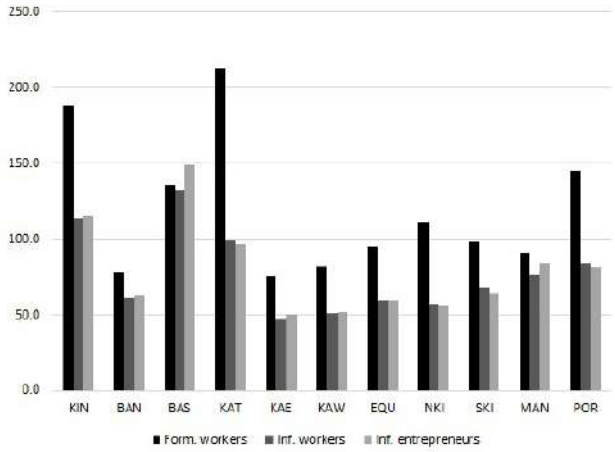
(c) Skill ratio by sector



(d) Skill premium by sector



(e) Monthly earnings of the unskilled



(f) Monthly earnings of the skilled

is way 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 one-half the sub-Saharan African

average level. Although the tax burden is high in the country, public revenues are mostly fed by taxes on mineral extraction industries. Many of these payments fail to reach the government budget for a variety of reasons. Finally, the inflation rate is four times as large as the sub-Saharan African average (and 6 times as large as the world average). This reflects a high level of political and economic turmoil.

Hence, DRC suffers large social and economic disparities which are usually perceived as resulting from a strongly embedded culture of corruption and the lack of appropriate economic reform. Between 2007 and 2012, the country experienced an increasing economic growth with a cumulative nominal growth of 33% (5.8% 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 informality. – Until 2015, the country was divided into 11 provinces. We use data for 2012, our model focuses on these 11 provinces and Table 2 relies on the *1.2.3* database to shed light on their labor market characteristics. A random stratification technique has been implemented to guarantee that each of the eleven provinces of DRC has at least one thousand household-level observations.

DRC provinces are strongly heterogeneous in size and in labor market characteristics. Differences in resources endowments are huge, and translate into different business opportunities, productive capacity and labor market composition. Looking at mean monthly wages, larger provinces exhibit larger average levels of earning (the correlation between population size and monthly earning equals 0.58). In particular, Kinshasa (10.5 million inhabitant) is 3.4 times richer than the poorest province of Kasai Oriental (7.1 million inhabitant), 3.1 times richer than the smallest province (Maniema with 2.2 million inhabitant), and 2.1 times richer than the country's average. Yet, geographic mobility is low in DRC. Unreported results from the

1.2.3 database show that the fraction of working aged individuals who have lived administratively in their province of residence for less than 10 years equals 13.4%. And subtracting those who moved for non-economic reasons (study, family reunification, war displaced, etc.), this fraction is reduced to 4.2% of the population. This group of movers include both within-province and between-province movers. The latter group itself is likely to be significantly lower. Our model will disregard the geographic mobility across provinces.

The size of the informal sector is above 80% in all provinces except Kinshasa; it is even greater than 90% 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. In this study, we define skilled individuals as workers with at least a "state diploma degree" (12+ years of education), while the unskilled are those who have not completed secondary education. Education is low as around one quarter of the population has completed secondary education. The share of secondary-educated workers varies between 15% in Province Orientale and 59.9% in Kinshasa. The correlation between average monthly wages and the share of secondary educated equals 0.86. Due to these disparities and their potential impact on the creation of wealth, the constitution of February 18, 2006 in its article 181, instituted a common equalization fund so that the richest provinces participate in the development of the poorest provinces through the payment of 10% of their national revenue.

Table 2: Heterogeneity in labor market characteristics across DRC Provinces

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

Notes: Author's computation. Population data are from INS country's statistical report (2015). Wage, Share of informal job and share of Secondary+ are computed from 1.2.3 database.

SF3. Cross-province disparities in public infrastructure is large. – The level of public infrastructure is extremely low in DRC. Our data by province are taken from INS country's statistical report (2015). From 2010 to 2015, the public capital spending amounted to 4.0% of total revenues, on average. As shown in Table 3, access to drinkable water and electricity is limited (17.5% and 13.4% of the population). Of a hydropower potential of 106,000 MW,

only 2,417 MW of hydropower capacity is installed and only 42.1% of it is available for use. Ground transport in DRC has always been difficult. Only 5.4% 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, until the end of 2015, there was no airline company, neither public nor private, serving the whole country. The low number of airports and their deplorable state 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% of the national territory is covered by the telephone network and about 7% of the population has access to internet (INS, 2015).

Remarkably, looking at the coefficients of variation related to each infrastructure proxy, regional disparities in public infrastructure are larger (sometimes three times larger) than disparities in labor market characteristics (reported in Table 2). In Equateur, only 7% of the population has access to electricity and 2.3% has access to drinkable water. Eight provinces have no international airport. The percentage of paved roads is below 1% in Equateur and Kasai Occidental, and smaller than 10% in eight provinces. In general Kinshasa has much better infrastructure than the rest of the country.

Table 3: Heterogeneity in public infrastructure across provinces

Province	Capital spending per worker	Acc. Electricity as % of HH	Acc. water as % of HH	Paved as % of road	Intern. airport	Pub. cap. index
Kinshasa	958.8	74.0	89.0	90.1	Yes	84.4
Bandundu	217.2	2.2	5.6	5.2	No	4.3
Bas-Congo	1243.0	16.1	20.9	20.1	No	19.0
Katanga	1669.1	13.0	20.6	5.5	Yes	13.0
Kasaï Oriental	240.3	0.5	8.8	3.1	No	4.1
Kasaï Occidental	160.6	0.4	3.1	0.8	No	1.4
Equateur	413.0	7.0	2.3	0.6	No	3.3
Nord-Kivu	655.0	5.2	8.3	20.5	Yes	11.3
Sud-Kivu	703.2	10.8	19.8	7.9	No	12.8
Maniema	1182.2	8.8	3.1	6.3	No	6.1
Province Orientale	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 INS statistical report (2015). The allocation of capital expenditure across 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 Cols. (2), (3) and (4).

SF4. An overwhelming majority of unskilled workers are employed informally. – Turning out attention to the labor market, the informal sector is overwhelmingly large in DRC. As a consequence of favoritism, looting, wars and other shocks to the economy, the country's labor market is badly out of balance. Since 1990, labor supply has been falling steeply while galloping demography is continuously increasing the demand for jobs. Associated with high levels of poverty and inequality, absence of public provisions for unemployment insurance has

favored the emergence of the informal sector. According to IMF (2015), more than 80% of the active population operates outside the labor market regulations and the World-Bank (2005) reports that 78.4% of formal firms are competing with informal firms.

The *1.2.3* survey report of 2012 shows that the informal sector drains 88.6% of assets nationwide, and is likely to constitute an obstacle to faster development. 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% of them are employed in the informal sector in virtually all provinces. Two exceptions are Kinshasa (85%) and Bas-Congo (93%).

SF5. A majority of well-educated workers is in the informal sector. – Although the phenomenon is less pronounced for holders of a state diploma, Figure 1b show that informality also drains a large fraction of skilled workers. The share of skilled workers employed in the formal sector is close to one third in Kinshasa, Bas-Congo and sud Kivu. The highest share (38%) is obtained in Nord-Kivu. In the other provinces, it varies between 20% and 25%. These results are in line with other studies revealing that the informal economy is recognized for being low-skilled intensive, even if a non negligible fraction of educated workers has informal jobs (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 less educated workers, varies drastically across sectors. The black bar in Figure 2c show that the skill ratio is rather large in the formal sector. It varies 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 way above the skill ratio obtained in the national population, which is 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 informality is around 0.4, but it falls to 0.3 when excluding Kinshasa. This is slightly smaller than what we observed in the national population (0.5).

SF7. For both skill groups, formal jobs are better remunerated. – Looking at Figures 2e and 2f, 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 informal employees, while secondary-educated workers earn 1.6 times more. These ratios are rather stable across provinces and are also representative of the situation of Kinshasa. There are a few exceptions such as Equateur and Province Orientale where unskilled formal employees earn 40% more than informal employees only, or Bas-Congo where skilled workers exhibit the same average levels of income in both sectors.

Some workers choose to voluntarily work in the informal economy for a host of reasons (e.g.,

women who are in their prime fertility age or older workers who would like to take advantage of more flexible working hours in the informal sector). In addition, several mechanisms can be used to generate a wage differential between sectors in the competitive labor market setting (such as unobserved heterogeneity in workers' abilities, or a differential in risk, in exposure to rent-seeking, etc.). The facts in Figures 2e and 2f suggest, however, that informality at large is not a choice despite the fact that some skilled entrepreneurs may find it optimal to operate in informality (see discussion under SF10). Some models assume competitive labor markets and perfect mobility of workers between sectors. Such models fail to explain why a large income differential exists between sectors and why informality 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 (Docquier and Iftikhar, 2019).

SF8. The skill premium varies across sectors and is sometimes larger in informality. – A related issue concerns the levels of the skill premium in both sectors. Figure 2d show that skill premia are positive and rather large in both sectors. They vary, however, across provinces. On average, the largest skill premia are observed in provinces with low levels of human capital such as Bas-Congo, Maniema or Province Orientale, which is in line with a standard neo-classical production function with decreasing marginal productivity of skilled labor. The lowest levels are obtained in Kinshasa, Bandundu and the two provinces of Kivu. Skill premia are also correlated across sectors (0.3). What is remarkable is that in the skill premium is on average larger in the informal sector (95%) than in the formal sector (59%). This is the case in eight provinces. Exceptions are Province Orientale and the two provinces of Kivu. The gap between secondary-educated and unskilled workers is larger in informality. Hence, assuming that the informal sector offers a subsistence level to all workers is wrong. This is defendable for unskilled workers, but not for the skilled.

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 easy to launch, require relatively few specific skills, and 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 business. With an average size of establishments of 1.3 people, it is an atomized sector which mainly consists of micro-units. More than 50% of the informal production units in Congolese agglomerations operate without specific professional premises, and 31.2% carry out their activity at home (Makabu et al., 2006). The sector employs both skilled (15%) and unskilled (85%) individuals, who declare themselves as self-employed, entrepreneurs, unemployed, or searching for a job. 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).[6]

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). Land owners rent out their farmland to peasants, in return for payments which are very rarely made in cash, but much more frequently made in kind or in labor hours. We find it reasonable to assume that land owners have secondary education, and act as entrepreneurs. This is in line with Reyes et al. (2017), who shows 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 fraction of skilled people in informality declare themselves as entrepreneurs, and with Adoho and Doumbia (2018), who documents that top-performer 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 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 the agreed amount to wholesalers.

We thus represent the informal sector as a set of skilled entrepreneurs providing capital to workers (mostly unskilled but include some skilled). The latter produce and/or sell the merchandise, return part of their sales revenue to the owners (assimilated to profit in our model) and live with the rest (assimilated to wages in our model). As unemployment benefits do not exist and wages are way greater in the formal sector, we assume that entrepreneurs and workers in informality are queuing for a better job in the formal sector.

As in many low-income countries, informality also includes other odd jobs carried out at the corner of the street and outside any entrepreneurial structure. One often sees them in the streets of big cities (shining of shoes, repairing shoes, selling candy, etc.). However, most of these odd jobs are done by children. In 2000, the ILO estimated that nearly 2 million children aged 10 to 14 were economically active in the DRC, with almost equal numbers of girls and boys.[7] 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. – On average, as apparent from Figure 2f, skilled workers and entrepreneurs in informality 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

[6]The *1.2I3* database reveals that the lack of access to credit is the first obstacle encountered by informal workers, as 98.5% of informal workers report that they do not have access to credit. See also https://www.farmlandgrab.org/post/view/26683.

[7]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

acting as entrepreneur or wage earner. This being said, Mohammad (2014a) has shown that, although informal firms are smaller than formal firms in DRC, some micro firms are highly productive. The author identifies a upper-tier segment of the informal economy where firms are dynamic and efficient, and where entrepreneurs are well remunerated. Some of them are likely to prefer running their business in informality to searching for alternative employment in the formal sector.[8] The same heterogeneity can be observed in the formal sector where some jobs can be very well remunerated. On average, the level of monthly earnings of informal entrepreneurs is below the formal wage rate, which implies that informality at large is not a choice.

3 Model

For all provinces of DRC ($p = 1, ..., P$), we develop a labor market model which is consistent with the stylized facts described above. Workers are 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 low skilled, 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. 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; these informal employees earn a competitive wage ω_p^L which 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 distinguish two types of occupation for them. 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

[8] 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 higher tolerance for 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 terms of working hours, work relationships, responsibilities, etc.) in the informal sector (Mohammad, 2014b).

$i_p^H(1-b_p^H)$ 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, which ensures 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 $\omega_p^H < w_p^H$.

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), 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 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 $\eta + \varphi < 1$.[9]

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

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

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

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

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. 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. If 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 one. 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; it is made of 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 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 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:

$$\begin{aligned} \omega_p^H &= B_p \psi_p h_p^{\psi_p - 1} \ell_p^{\chi_p}, & (12) \\ \omega_p^L &= B_p \chi_p h_p^{\psi_p} \ell_p^{\chi_p - 1}, & (13) \\ \pi_p^H &= B_p (1 - \psi_p - \chi_p) h_p^{\psi_p} \ell_p^{\chi_p}. & (14) \end{aligned}$$

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 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 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 V_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 others, advertising costs, interview arrangements, initial training, 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 says that in equilibrium the marginal cost of opening a vacancy equals the marginal profit from a filled job. As for 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 employment 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 follows:

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

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

where β^S is the bargaining power of the worker of 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,

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

where $V_p^S = v_p^S L_p$ is the total number of vacancies available for type-S workers.

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, N_p, 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, $X_p^I = \{\rho_p, \varrho_p, \kappa_p\}$, 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.

In line with the definition of the general equilibrium, we consider 8 parameters as common to all provinces, and we assign them a consensus value from the existing empirical literature. As far as the elasticity of substitution between intermediate goods is concerned, 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% per year and compute 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. As for the bargaining power of workers, most of the literature uses a value around 0.500. We use $\beta^S = 0.500$ in all provinces.[10]

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 average years of schooling, inducing a 30% 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%. To calculate the lower bound on η, we take the average share of high school graduates of DRC (30%). Increasing this share to the US level (90%) in the year 2010 involves an increase by 300%. Following Caselli and Ciccone (2013), we assume that this shock induces a 30% rise in TFP, which implies that $\eta = 0.100$.

Finally, hundreds of papers have estimated the elasticity of aggregate output (usually proxied by the GDP per capita or by measures 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

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

GDP, Calderon and Serven (2014) obtain a long-run elasticity varying between 0.05 and 0.10. Calderon and Serven (2010) find, however, 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 assume a lower-bound elasticity $\varphi = 0.050$ in 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 way greater in Kinshasa and varies a lot 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 others parameters in X_p are calibrated to match the same number of moments, namely the informal employment shares by skill groups (i_p^L, i_p^H), the structure of earnings by skill group and by sector $(w_p^L, w_p^H, \omega_p^L, \omega_p^H, \pi_p^H)$, the number/share of skilled entrepreneurs in informality (b_p^H) and the number of unskilled employees per entrepreneur (ℓ_p^*). We assume that $c_p^S = 0.4 w_p^L$ in all provinces, in line with Docquier and Iftikhar (2019).

Table 4: Parameters – Summary

Prm.	Definition	Source	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	Calibration outcome	193.2	0.380
α_p	Income share parameter in F	Calibration outcome	0.313	0.141
ρ_p	Relative TFP scale factor in I	Calibration outcome	0.589	0.292
ϱ_p	Sum of ψ_p and χ_p	Calibration outcome	0.852	0.242
κ_p	Scale factor in $\frac{\psi_p}{\chi_p}$ function	Calibration outcome	0.886	0.194
ψ_p	Elast. of output to HS labor in I	Calibration outcome	0.235	0.468
χ_p	Elast. of output to LS labor in I	Calibration outcome	0.616	0.223
ϵ_p^L	Scale factor in LS matching fct.	Calibration outcome	0.014	0.342
ϵ_p^H	Scale factor in HS matching fct.	Calibration outcome	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.

As we used all the degrees of freedom of the data to identify the needed coefficients, our model is exactly identified and 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 traditional explanatory variables used in the econometric literature.

The coefficients of correlation between province-specific parameters and potential correlates are provided in Table 5. The TFP scale factor in the formal sector ($\overline{A}_p$) is significantly correlated with the shares of the manufacturing industry in formal output and employment. Importantly, the correlation between $\overline{A}_p$ and population density is insignificant, 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. Remember $\overline{A}_p$ is 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 the province. As conflicts mostly arise in resource abundant provinces, this also suggests that benefits of natural wealth and resulting instability costs may cancel out on the aggregate.

The relative productivity in informality (ρ_p) is negatively correlated with internal displacements. It is uncorrelated with the other indicators, which comforts our assumptions that TFP in informality 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 with the elasticity to low-skilled employment (χ_p). In particular, the greater the skill ratio in population (Z_p), the greater is the elasticity of informal output to high-skilled labor (ψ_p). This suggests that a skilled-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. As far as labor market frictions are concerned, 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 2.[11] We use a radar-plot representation to highlight disparities along the five dimensions of Definition 2. The values of the parameters in each province are shown as a fraction of the value of parameter in Kinshasa. The first group includes Bas-Congo (BAS) and Province Orientale (POR), which exhibit relatively high levels of productivity in the formal sector. Bas-Congo takes advantage of its geographic position as the only gate 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 portion of the products imported and exported by the DRC transits through this province. Province Orientale benefits from its subsoil assets, which are abundant in gold mineral. POR has benefited from the settlement of multinational mining companies (e.g., Kibali Mining) that

[11] We exclude Katanga, which is almost as rich 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. Share of the manufacturing sector in formal output and formal employment in the year 2013, respectively. Good roads (%) represents the share of paved road (2016). Nb. business projects and Nb. vacancies to be filled are an annual mean value from 2012-2015 and represent the number of business projects and vacancies to be filled. Urban population share represents the percentage of 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.

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), which exhibit medium levels of productivity in both sectors. In particular, the provinces of Kivu are well endowed in mineral resources and represent the world reservoir of *columbo-tantalite* as well as of other minerals. They have an 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, social and economic development.

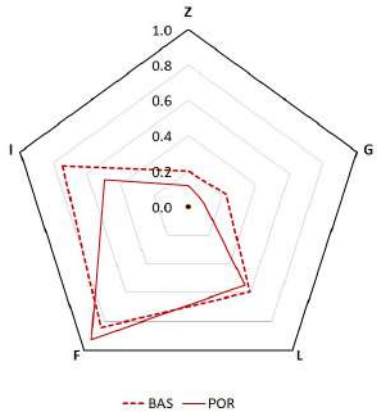
The third groups includes two provinces, Bandundu (BAN) and Maniema (MAN), with low productivity in the formal sector, but with a relatively successful informal sector. Maniema is handicapped by its *landlockedness* as it does not share borders with any of the 9 countries surrounding DRC. Bandundu has limited mineral resources, and suffered from the disorganized exploitation of rubber. Lowes et al. (2017) show that the 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.

Finally, the two provinces of Kasai (KAE and KAW) combine many shortages (infrastructure, health, education, sanitation, etc.) and high 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

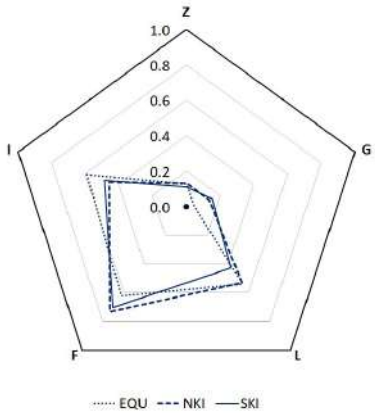
sparse *artisanal* mining and farms. The IMF (2015) report ranks these two provinces as the poorest of DRC, with an average poverty rate of 76.5%.

Figure 2: Broad classification of provinces

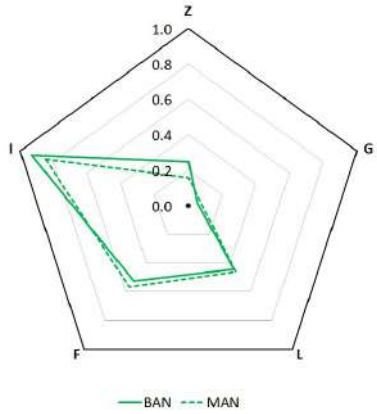
(a) High $\overline{A}_p$



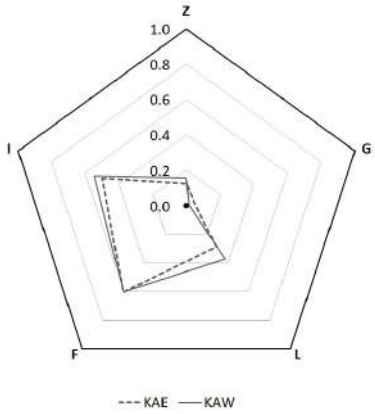
(b) Medium $\overline{A}_p$ and ρ_p



(c) Low $\overline{A}_p$ and high ρ_p



(d) Low $\overline{A}_p$ and low ρ_p



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

4 Quantitative Experiments

In our numerical experiments, we consider the richest province of Kinshasa (indexed by KIN) as a benchmark, simulate the counterfactual general equilibrium $\overline{\Gamma}_p = f(X_{KIN})$ when province-specific parameters are in totality or partially equalized with those of Kinshasa, and compare it with the observed equilibrium, $\Gamma_p = f(X_p)$. We care about the structure of income, as described by sector- and skill specific levels of income before taxes $(w_p^H, w_p^L, \omega_p^H, \omega_p^L)$, 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 $(\overline{w}_p \equiv (H_p\overline{w}_p^H + L_p\overline{w}_p^L)/(H_p + L_p)$.

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 $\overline{\Gamma}_p^L = f(X_p^Z, X_p^G, X_p^F, X_p^I, X_{KIN}^L)$.

First, we use the same radar-plot representation as above to describe the effect of the each policy on the region-wide average level of income per capita. Results are depicted by the blue curves in Figure 3, which represent the effect of each of these policy reforms expressed as percentage of the income gap with Kinshasa, measured on the vertical axis. The closer from the 100% reference level, the higher the explained share of the income gap with Kinshasa. Red curves will be discussed in the next section. The bottom panel shows the effect obtained in nine provinces of DRC (Katanga is excluded, as it is richer than Kinshasa). The top panel shows the unweighted average of the province-specific effects.

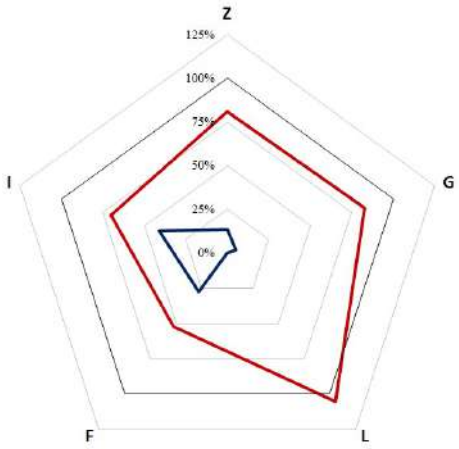
The first key message of our analysis is that the technological characteristics in both sectors (X_p^F and X_p^I) are the key determinants of spatial inequalities, somewhat unsurprisingly, followed by human capital and infrastructure. Labor market frictions taken in isolation play a negligible role. The results by province are in line with the broad classification presented in Figure 2. In particular, improving the technology of the formal sector (X_p^F) – which mostly consists of 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. Improving the technology of 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.

The role of the technology is mostly governed by the role of the exogenous TFP scale factor in both sectors. Remember that Table 5 shows that TFP in formality is correlated 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

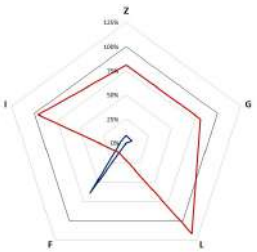
to creating an enabling environment for socioeconomic growth. The institutional context in Kinshasa relies on a system called *Branchement* which directly connects economic actors to higher-level authorities and bypasses the role of the provincial government (Nkuku and Titeca, 2018). These alliances between economic actors and high-level political actors can be fragile in turmoil periods; they are, however, less unstable 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 by a high turnover of provincial leaders. From 2007 to 2017, four governors succeeded each other in South Kivu, three in Equateur, Kasai Occidental and Bandundu. A high number of reshuffles in provincial executive governments were observed in all provinces in general, even in the relatively highly productive Province Orientale (Gérard, 2014). This instability prevents political leaders to carry out ambitious reconstruction or development programs.

Figure 3: Effect of one-at-a-time and quadruple policy changes on income-per-worker levels ($\overline{w}_p$)

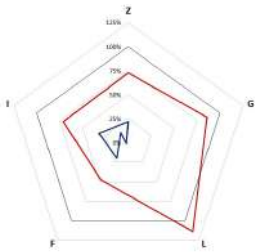
(a) Unweighted mean



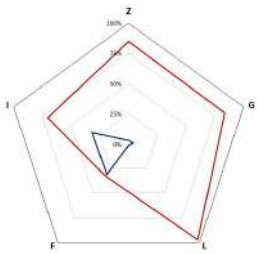
(b) Bandundu



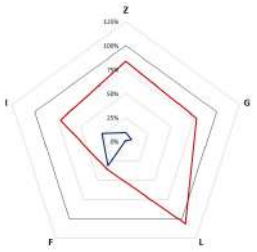
(c) Bas-Congo



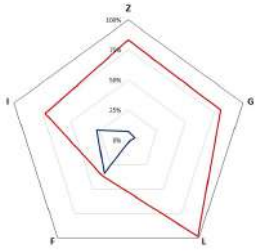
(d) Kasaï Oriental



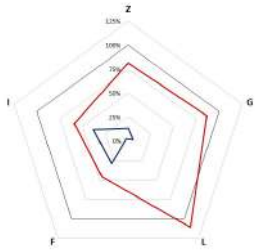
(e) Kasaï Occidential



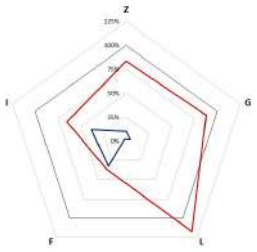
(f) Equateur



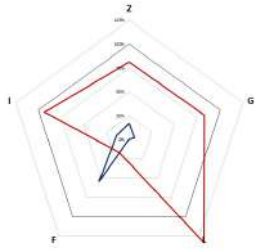
(g) Nord-Kivu



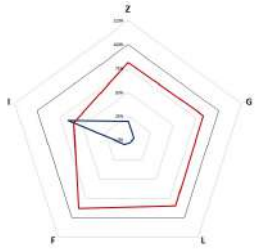
(h) Sud-Kivu



(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.

Another key aspect is corruption. Political leaders have strong incentives to manage mineral wealth in their own interest. Hence, natural resource endowments have their pros and cons. On the one hand, they serve as a catalyst for the provision of public services. It is not unusual that mining companies finance projects in the electricity and transport sectors, which benefit local communities in some provinces.[12] 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, interventionism, and rely on armed groups for the control of 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 to the average income gap of 60 percent. This can be better understood if one looks at their effect on the distribution of income. Figure 4 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 scale), while the bars show the relative change in income for the four types of workers, skilled vs unskilled in the formal vs. informal sector (as measured on the left scale).

In Figure 4a, 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 informality 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. In case of a labor market with frictions, however, 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 formality and the skill ratio increases in this sector. On the contrary, the skill ratio decreases in the informal sector, which attenuates 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 of the formal sector benefits all types of workers, but has greater effects on the skilled.

Figure 4b shows that improving the technology of the informal sector (X_p^I) has less inegalitarian effects. It induces similar benefits on skilled and unskilled workers in the informal sector. By attracting entrepreneurs and unskilled workers in informality, this policy has negative effects on the skill ratio in the formal sector. However, despite the decline in skill ratio, low-skilled workers in the formal sector observe an increase in wage in six provinces. This is due to the fact that wages are determined via bargaining, and an increase in the informal TFP

[12]Examples of such projects include: (i) the development of 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.

improves outside options of all workers, which results in higher wage for workers in the formal sector. This effect dominates the negative effect of reduced skill ratio on the wage of low-skilled workers in the formal sector. Both types of workers exhibit large income gains in the informal sector. In 5 provinces (BAN, BAS, KAW, MAN and POR), increasing relative productivity in informality is more beneficial to unskilled workers than to entrepreneurs. In 6 provinces (BAS, KAE, KAW, NKI, SKI, POR), this is the most effective policy to combat extreme poverty.

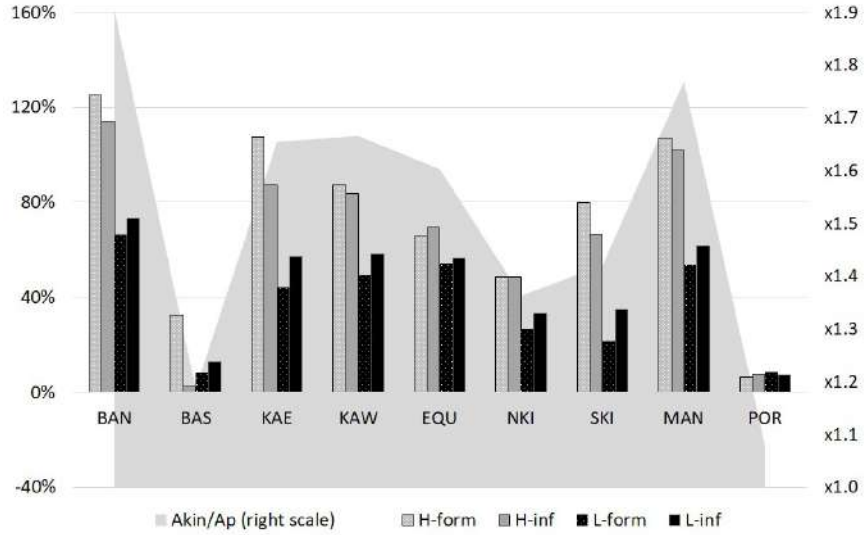
Figure 4c shows the effects of setting the proportion of skilled workers to the level observed in Kinshasa (X_p^Z). The shocks are large: the province-wide skill ratio (Z_p) increases by a factor that ranges from 4 in Bas-Congo to 8 in Maniema, as measured on the right scale. A rise in the skill ratio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

In Figure 4d, we depicts the effect of decreasing labor market frictions (X_p^L). This leads to small effects in most provinces. Reducing frictions reduce skill ratio in both sectors, and reduces productivity gap between the two sectors due to human capital externalities. This effect dominates the positive effect of a decline in skill ratio on the productivity of the 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 a decline in the skill ratio in the informal sector.

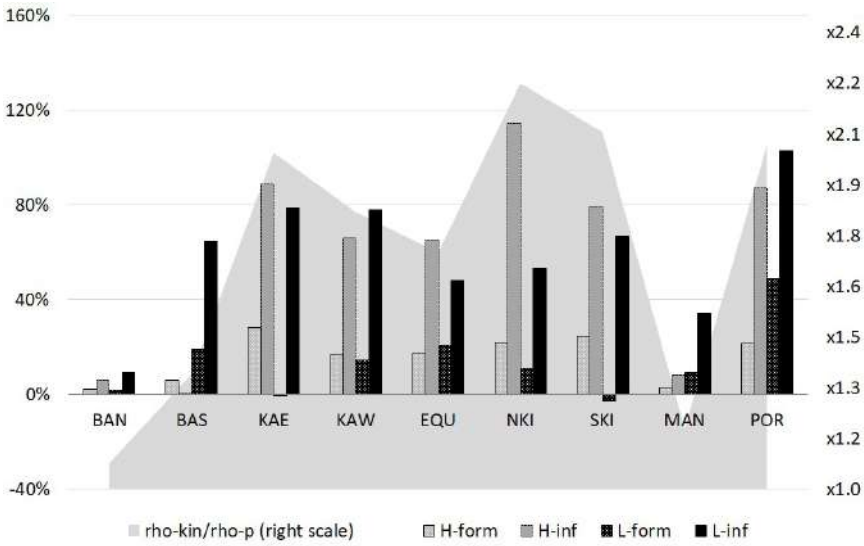
Finally, Figure 4e shows the effects of setting the level of public infrastructure to the level observed in Kinshasa (X_p^G). The shocks are large: the province-wide level of infrastructure per capita (g_p) increases by a factor that ranges from 6 in Bas-Congo to 57 in Kasai Occidental, as measured on the right scale. Given the low elasticity of TFP to infrastructure found in the 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 productivity gap worsen the outside options of workers 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 informality is small.

Figure 4: 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)

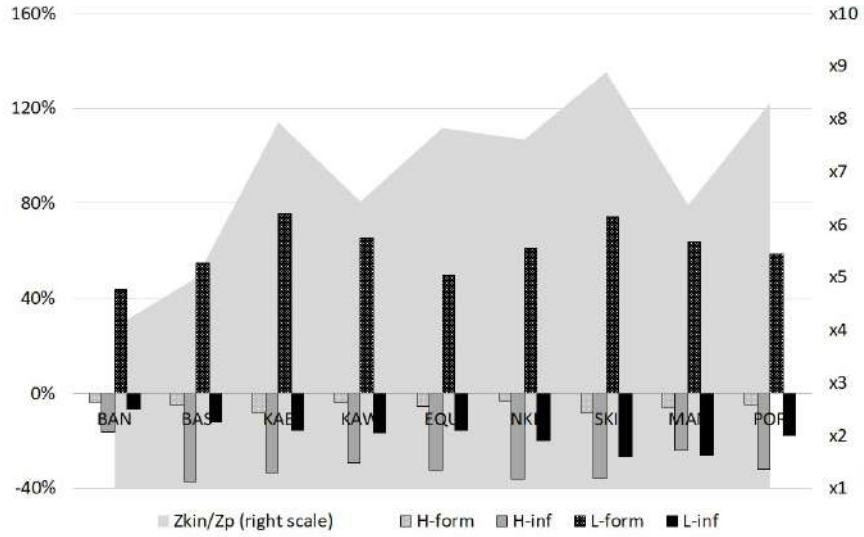
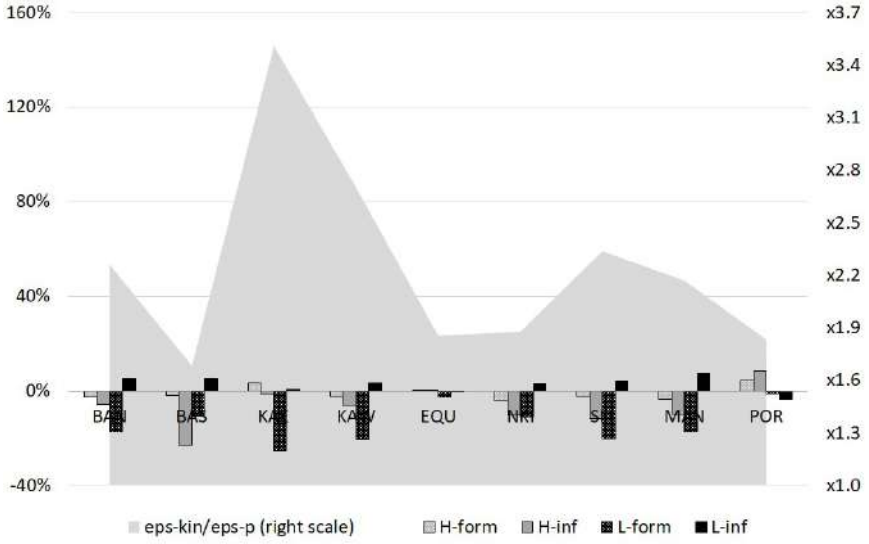
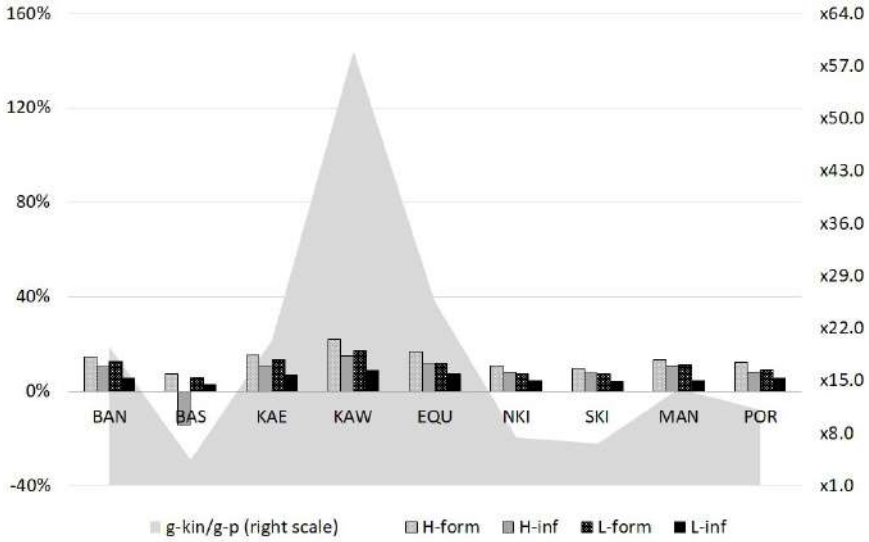


Figure 4: Income responses ($\frac{dw_p^S}{w_p^S}$, $\frac{d\omega_p^S}{\omega_p^S}$) to policy reforms (cont'd)

(d) Labor market frictions (X_p^L)



(e) Public infrastructure (X_p^G)



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 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 suggest that reducing spatial inequality is 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. Results by province are shown in Figure 5. In general, although the role of technological parameters is important, each individual effect (represented by the black and gray areas) accounts for a small portion of the total income gap with Kinshasa, captured 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), one third of the total in three provinces (KAE, KAW and EQU). These are Provinces where TFP in the formal sector is low. The residual term reaches its maximum of 41% of the observed income gap with Kinshasa in the highly productive province of Bas-Congo. Smaller interactions are found in Maniema and Province Orientale.

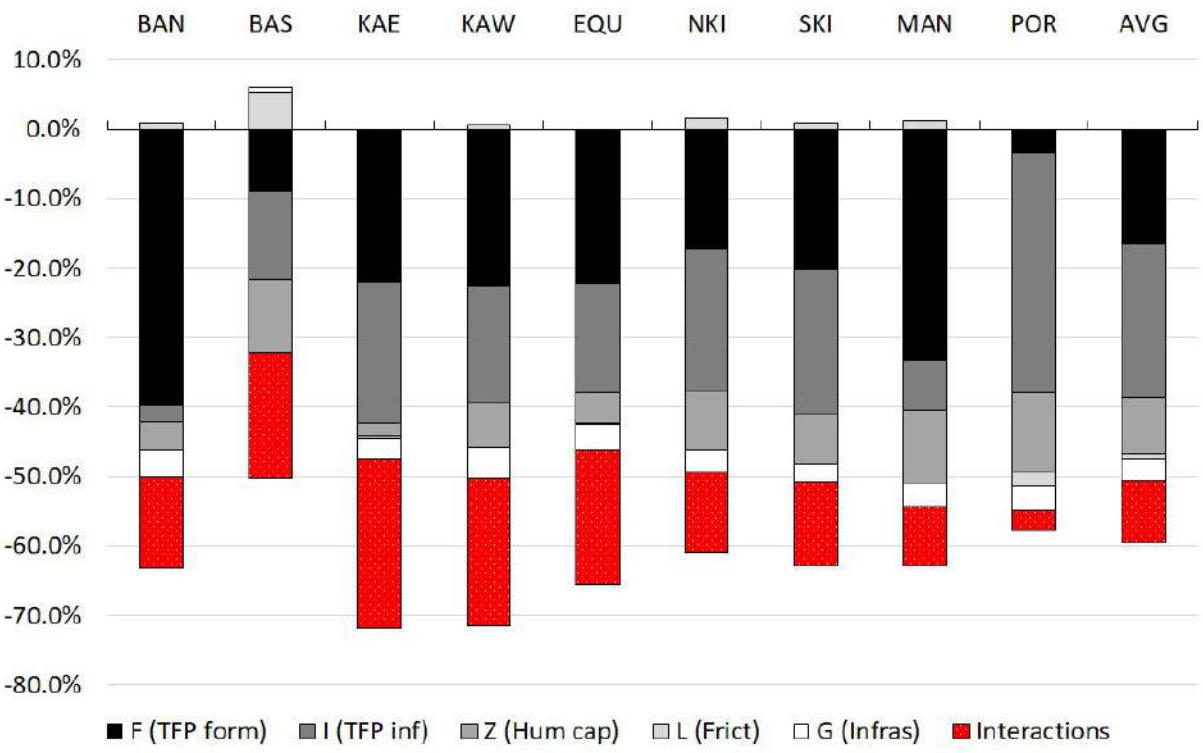
Overall, our results are compatible with the O-Ring theory of development (Kremer, 1993). The O-Ring theory implies that there are strategic complementarities between ingredients of the development process. These complementarities are important in explaining the development gap between provinces.[13]

Second, we get back to Figure 3 but 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. Results are depicted by the red curves, which represent the effect of leaving aside one policy at a time,[14] and expressing the income change as percentage of the observed gap with Kinshasa. Effects are larger than 100% when one characteristics 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 increase 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 (with bigger losses in BAN, KAE, KAW, EQU, SKI and MAN). In isolation TFP of the final sector only

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

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

Figure 5: Isolated policies and interactions between them ($\overline{w}_p$)

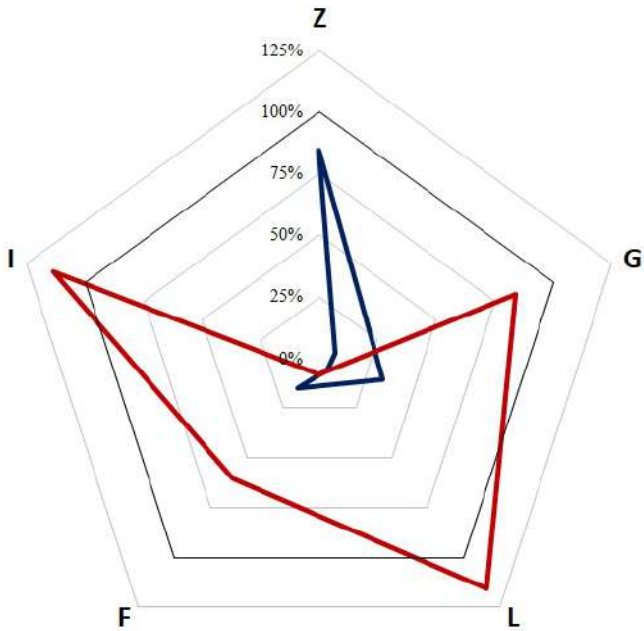


fills 25% of the income gap with Kinshasa. This reveals the interaction of TFP with other factors is of utmost importance. Recall that the TFP scale factor in the formal sector is also associated with governance and institutional stability. In the same vein, only 70% of the gap can be addressed if the technology of the informal sector is not improved (with bigger effects in NKI, SKI and POR). Finally, a gap of 15 to 20% subsists 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 next section, let us briefly discuss the effects of one-at-a-time and quadruples of policies on the average informality rate in DRC. Figure 6 shows that improving human capital reduces the average informality gap between Kinshasa and other provinces by more than 80%. 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 find a negative association between the size of the informal sector and human capital. Quiroga-Martínez and Fernández-Vázquez (2021) further deduce that by reducing informality, human capital will also reduce spatial inequalities in Argentina. Their conclusion regarding the size of informality and spatial inequality is based on the paper by Binelli (2016), which provides empirical evidence from Mexico that inequality and informality move together. However, the latter does not link human capital to the informality rate. Our findings reveal that though human capital reduces the size of informality, it does not reduce spatial inequalities (recall

Figure 3). This suggests that policies that focus on reducing the size of informal sector without implementing policies that increase labour demand in the formal sector for the unskilled have little or no effect on spatial inequalities. Such policies would rather reduce the size of informality at the cost of reduction in the wage 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.

Figure 6: Effect of one-at-a-time and quadruple policy changes on informality ($\bar{i}_p$)



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

4.3 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, identify the most effective ones, and identify pairs that can be detrimental for the economy. To this purpose, 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).

Results are depicted in Figure 7. Panel 7a gives the effect on the province-wide average level of income ($\overline{w}_p$), while Panel 7b 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 Ao 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 $\overline{w}_p^L$.

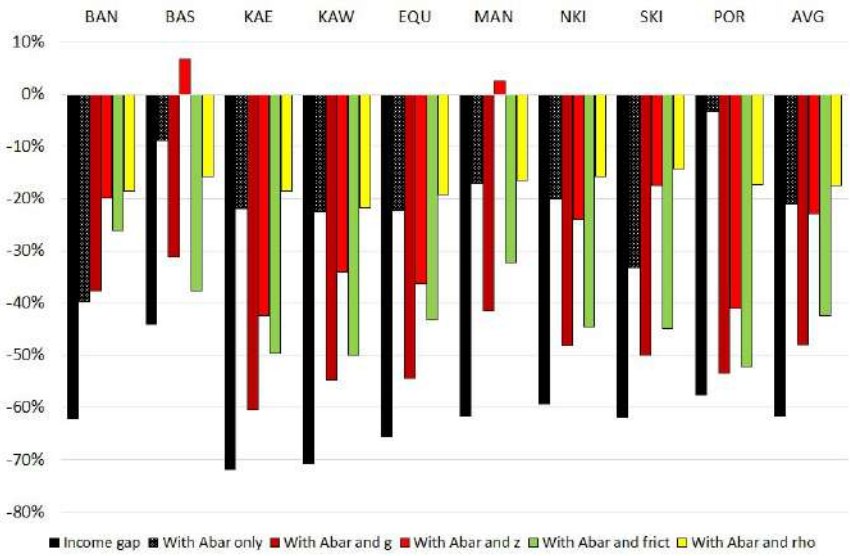
The first key result is that policy pairs targeting X_p^F and X_p^I jointly are always the most effective ones. They drastically reduce the income gap with Kinshasa for the unskilled in the provinces of Kasai, Kivu and Equateur. In Province Orientale, it even brings $\overline{w}_p^L$ at a higher level than in Kinshasa. A significant gap persists in Bandundu and Maniema, where the informal sector is (relatively) 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 in this sector (as entrepreneurs), where income levels are lower. In a very poor country like DRC, a development policy that disregards the situation of the informal sector has low 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 of the formal sector alone. In line with Figure 4, 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 deteriorate the income of the skilled and 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 formality for the richest part of the labor force, and generate detrimental effect for the overwhelming part of the unskilled population trapped in informality.[15]

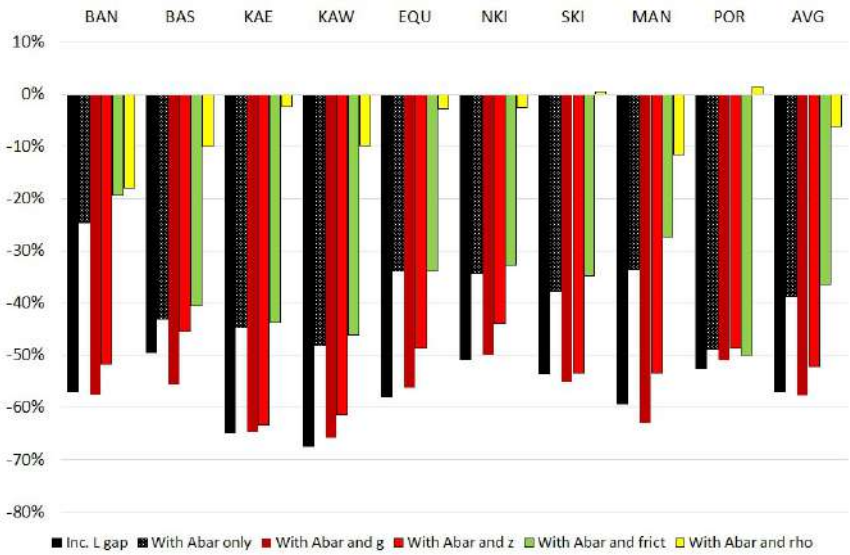
[15]Several effects are at work when policy pairs change which makes it difficult to disentangle different channels and explain why X_p^F alone is more effective than a policy pair. For example consider the policy pair combining X_p^F and X_p^G, improving X_p^F improves both marginal product and outside 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 deteriorating the outside options of workers. This effect attenuates the positive effects of improving X_p^F and X_p^G on the 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 than 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 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. This is why this policy pair is more effective on 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.

Figure 7: Effectiveness of policy pairs

(a) Effect on income per capita



(b) Average effect on unskilled workers



4.4 Are Labor Market Frictions Irrelevant?

Although labor market frictions prevent unskilled people from moving massively to formality when this sector becomes more attractive, policies targeting frictions alone (see Figure 4d) or targeting the technology and frictions jointly (see Figure 7b) have little or negative effects on the average income of unskilled workers. Does it mean that frictions are irrelevant? The answer is negative. 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 to 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 which, by mere chance, implies a ratio $\epsilon_p^H/\epsilon_p^L$ equal to that of Kinshasa.

In Figure 8, we simulate the effect of applying the average sub-Saharan levels of ϵ_p^S to all provinces. Panel 8a 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 in 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 8b 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 5 out of the 9 provinces. The largest gains are obtained in Bas Congo, Kasai Oriental, 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 large gains for the skilled.

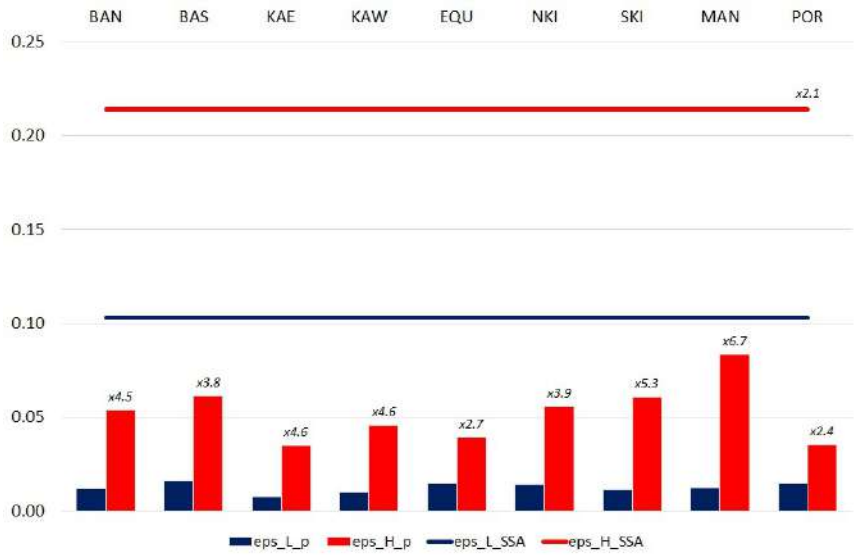
Figure 8b shows that the average income increases for both skilled and unskilled workers in DRC. This implies that reducing labour market frictions could reduce poverty and be welfare enhancing. However, looking at the wages of the workers in the two sectors reveals interesting information. Figure 9 shows that wages increases for skilled workers in all provinces including Kinshasa in both sectors. By contrast, income levels decrease in both sectors for the unskilled workers. How do we reconcile this result with one presented in Figure 8b? Reducing frictions allows mobility of workers from informal to the formal sector, thereby reducing informality rate in all provinces for both skill groups. Average wages increase in most of the provinces due to a decline in the informality rate in all provinces. But the opportunities in the formal sector do not respond much to the changes in labor market frictions. Hence, the mobility of workers reduces the skill ratio in both sectors (on average by 70% in the formal sector while by 36% in the informal sector) and leads to a decline in the wage of unskilled workers and a rise in the wage of skilled workers in both sectors. This brings us to an interesting conclusion that combatting informality by reducing frictions and 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.

4.5 Robustness Checks

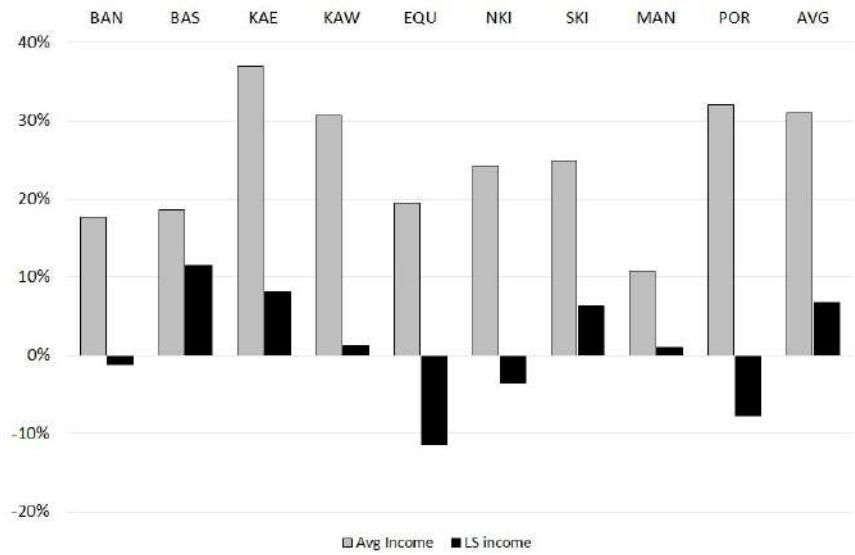
In this section, we check the robustness of our results to the value of parameters. We first consider a monthly job destruction rate of 0.04 (instead of 0.06 in the baseline). Second, there is bunch of studies suggesting that quantitatively large aggregate schooling externalities are unlikely to exist in developing countries. We consider a variant with $\eta = 0.0$ (Acemoglu and

Figure 8: Effect of a dramatic decrease in labor market frictions

(a) Effect on income per capita



(b) Average effect on unskilled workers



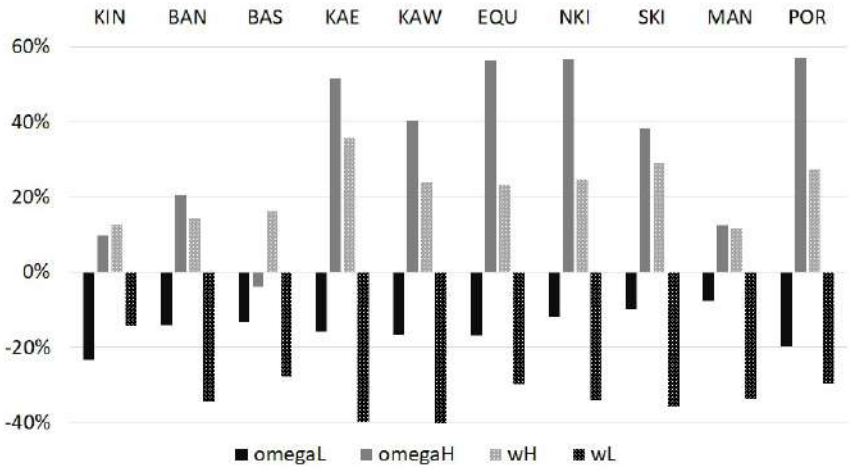
Angrist, 2000), instead of 0.10. Third, Angrist (1995) recommends a value of σ above 2 to explain the trends in the college premium in developing countries. Our third variant assumes $\sigma = 3.0$, instead of 2.0. Finally, we consider the upper bound of the range of elasticity of TFP to public infrastructure, $\varphi = 0.10$ instead of 0.05, as suggested by Calderon and Serven (2014).[16]

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 as in Figure 5, Figure 10 compares the baseline results with those obtained after changing these elasticities.

The results are robust to the parameters δ, σ and η ensuring our results in the baseline

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

Figure 9: Effect of a dramatic decrease in labor market frictions on wages



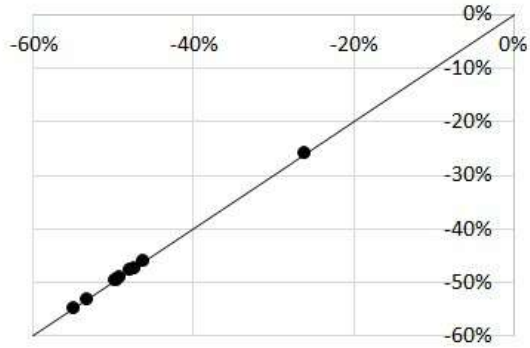
scenario are not driven by the values of these parameters. However, the results appear to be sensitive to the value of φ. The sum of isolated effects are smaller while the interaction term is much bigger with a higher value of φ. Nonetheless, our measure of public infrastructure is uncorrelated with $\bar{A}_p$ and ρ_p which means 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 at capturing the effects of g_p on productivity. However, this implies, with the higher elasticity of TFP to public infrastructure, the stronger the O-Ring patterns of economic development. The value of φ governs the size of the complementaries between policies.

5 Conclusion

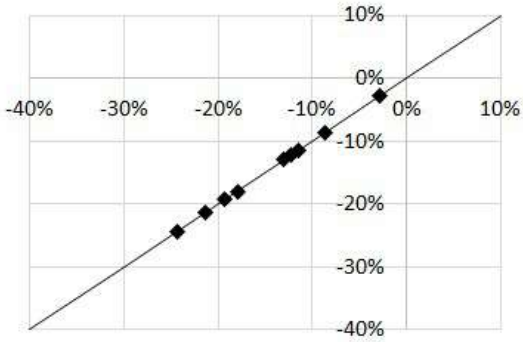
This paper focuses on the causes of spatial and within-province inequalities in DRC, one of the world's poorest countries. We build a two-sector model with labor market frictions to explain income disparities between provinces, sectors (formal vs. informal) and skill groups. We parameterize it to exactly 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 role of technologies 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 both endowment in mineral resources, geographic position and institutional quality. 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, labor market frictions, or

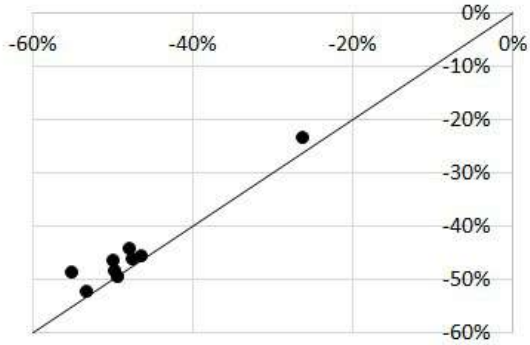
Figure 10: Robustness checks - Sum of isolated effects and residual interaction term



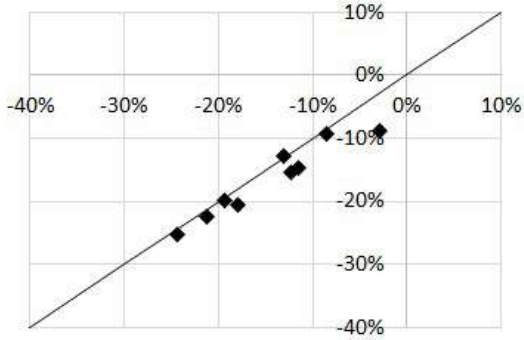
(a) Sum of isolated effects ($\delta = 0.04$)



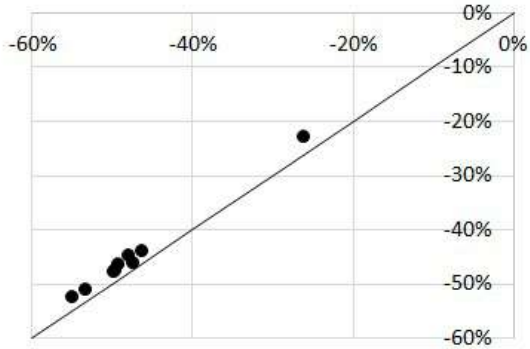
(b) Interaction term ($\delta = 0.04$)



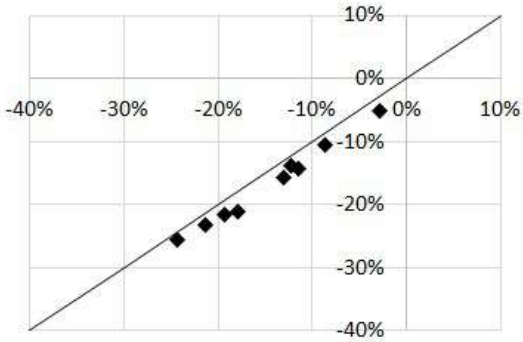
(c) Sum of isolated effects ($\eta = 0$)



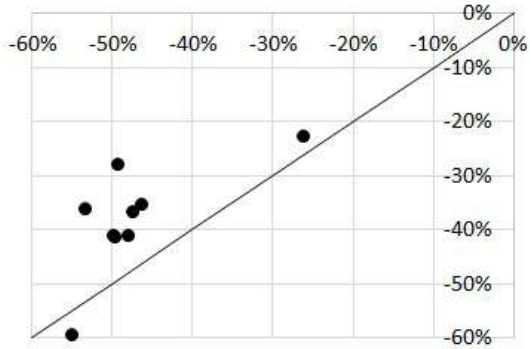
(d) Interaction term ($\eta = 0$)



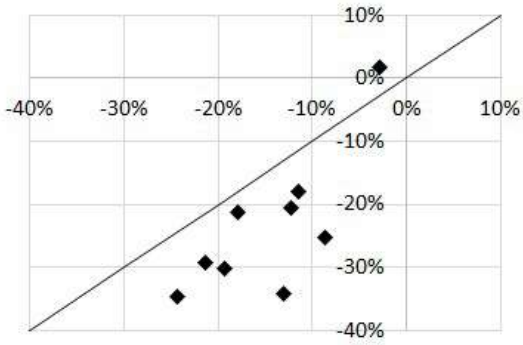
(e) Sum of isolated effects ($\sigma = 3.0$)



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



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



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

public infrastructure in isolation have little effects as they mostly impact productivity in the formal sector, and reduces the skill ratio and productivity in informality, where many unskilled workers are trapped.

Our paper sheds light on what are 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 term 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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