Distributional and poverty effects of agricultural trade liberalization: The case of the Democratic Republic of the Congo

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* This study was prepared for the UNCTAD Virtual Institute project on trade and poverty. The views expressed are those of the author and do not necessarily reflect the views of the United Nations Secretariat. The author would like to thank Marion Jansen from the Economic Research and Statistics Division of the World Trade Organization, as well as the Virtual Institute team, for comments and suggestions on the direction and content of the study, and for their support during the drafting process. The author also thanks Charles Lusanda Matomina, National Coordinator of the Enhanced Integrated Framework at the Ministry of Economy of the Democratic Republic of the Congo, for his support in the development of the study, as well as anonymous peer reviewers for their comments on the work in progress.

Abstract

The study uses an analytical framework combining computable general equilibrium (CGE) and microsimulation models to assess the distributional and welfare effects of agricultural trade liberalization, as well as policies that aim to improve productivity and reduce transportation costs in agriculture, on the Democratic Republic of the Congo (DRC). The CGE model is linked to the microsimulation model by the top-down approach in which the CGE model delivers changes in the prices of factors and goods to the microsimulation model, which in turn simulates welfare effects based on household heterogeneity in terms of factor endowments and consumption patterns. The study finds that agricultural trade liberalization generates limited welfare gains due to high transaction costs and low initial tariff rates. The findings further indicate that reducing agricultural transportation costs creates important welfare gains, as it leads to an increase in producer prices and boosts agricultural exports. However, small-scale subsistence farmers gain less than better-off farmers in rural areas because they have a smaller share of marketed production, and therefore cannot benefit from higher producer prices. Reduced transportation costs for agricultural products also benefit the construction and trade sectors, and therefore improve wages of low- and semi-skilled workers in urban areas. The results reveal that improved agricultural productivity generates significant effects on agricultural production, increases consumption and reduces the DRC’s dependence on food imports. It also leads to the growth of sectors such as processed food and textiles, which use agricultural products as intermediate inputs. With regard to distributional effects, the findings show that agricultural trade liberalization, reduced transportation costs, and improved productivity in agriculture have a pro-poor impact in urban areas but tend to favour richer households in rural areas. Finally, the findings suggest that the highest priority should be given to improving agricultural productivity and investing in the reduction of transportation costs for agricultural products.
1 Introduction

The Democratic Republic of the Congo is the second largest country in Africa. It occupies 2.34 million square kilometres, of which 800,000 are arable non-forest lands. Located in the centre of Africa, the DRC lies on the equator and has the second largest rain forest in the world. It borders nine countries and is the fourth most populous country in Africa, with over 70 million inhabitants. However, its history is among the continent’s saddest and most tragic. The DRC has only recently emerged from long years of conflict and economic mismanagement that have had severe consequences for the country’s infrastructure and the welfare of its people.

According to recent data, the DRC ranks as the poorest country in the world, with a gross domestic product (GDP) per capita in purchasing power parity (PPP) terms estimated at $415. The already high proportion of poor households has been increasing, especially in rural areas. The poverty rate was 70.6 per cent in 2007; in rural areas, it rose from 75.8 to 82.4 per cent between 2005 and 2007. More than 5 million children under 5 years of age are malnourished, and the mortality rate for children under 5 is estimated at 168 deaths per 1,000 children. In addition to poverty and food insecurity, income and wage inequalities are high: the Gini coefficients for income and wage inequality are estimated at 0.46 and 0.65, respectively. The employment rate is 23.6 per cent, while 72.7 per cent of the active population are underemployed and 3.7 per cent are unemployed.1

Agriculture is a large sector in the DRC, employing 78.2 per cent of the active population, but it receives little attention from policymakers. The budget allocation to agriculture is very low (1.75 per cent of the total government budget in 2013), and all subsidies and price support measures to this sector were removed in 2002. In addition to receiving little support from the government, the agriculture sector faces high transaction costs,2 which represent 21 per cent of the total value of marketed agricultural production (Otchia, 2015a). Agriculture uses only 11 per cent of the total arable land, with a rudimentary technology mostly based on outdated production methods. The collapse of commercial agriculture has led to the emergence of subsistence farming; 51 per cent of agricultural production is home-consumed and does not enter the market.3 The DRC was the world’s second largest exporter of palm oil in 1960, but today it exports less than 500 metric tons of palm oil and imports more than 70,000 metric tons.

The Congolese National Development Strategy (based on the 2011 Growth and Poverty Reduction Strategy Paper and the Industrial Development Plan) discusses the impact of re-launching agricultural production on growth, employment, and poverty. It contends that trade and trade policy could yield significant benefits in terms of agricultural expansion, employment creation and poverty alleviation. However, no major empirical assessment has been undertaken to date in terms of the impact of agricultural reforms on growth, employment and poverty.

This study aims to fill this gap by assessing the poverty and distributional effects of agricultural trade liberalization in the DRC using a CGE model (first step of the analysis) linked to a microsimulation analysis at the household level (second step). The CGE model generates changes in the prices of factors and goods after a policy change. These changes are then transmitted to the microsimulation model, which takes into account household heterogeneity in terms of factor endowments and consumption patterns. The main policy change considered in this study is the reduction of import tariffs, which have represented the key trade policy instrument applied by the Congolese government since the removal of subsidies and price support measures. An empirical study of this kind allows for a more complete understanding of the channels through which agriculture affects poverty in the DRC, and may be useful for the review of the DRC’s Growth and Poverty Reduction Strategy Paper in line with the post-Millennium Development Goals.

Taking stock of the literature, many recent studies seem to indicate that agricultural trade liberalization alone would yield positive overall welfare gains, but that those gains would generally be small (Warr, 2010; Arndt and Thurlow, 2010). From a policy standpoint, one possible implication is that, in

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1 According to the ILO (1988), underemployment exists when a person’s employment is inadequate in relation to specified norms or alternative employment, taking into account the person’s occupational skill.

2 Transaction costs are defined here as margins between farm gate prices and retail prices. Transaction costs include trade (marketing) costs and transportation costs. Trade costs refer to the amount of trade services required to move goods from farm gates to market, and include commission, and information and local distribution costs. Transportation costs indicate the amount of transportation services to move goods to markets and include freight costs and time costs.

3 The high share of home-consumed production in the DRC is a consequence of high transaction costs.
order to attain and increase these gains, trade liberalization should be combined with complementa-
ty domestic policies. Among the areas for policy intervention suggested in the literature, productivi-
ty growth has been acknowledged as essential to generate widespread gains from trade reforms, as it
boosts value addition and promotes structural change (Avila and Evenson, 2010; Cheong et al., 2013;
Rutherford et al., 2006). Other complementary measures include investment in infrastructure to reduce
trade costs for farmers, job market information to increase worker mobility, and training to enhance
workers’ skills (Löfgren, 1999; Oktaviani and Vanzetti, 2013; Otchia, 2013b). However, the drawback of
these studies is that they do not simulate the additional effects of the complementary policies jointly
with trade liberalization.

This study differs from previous studies in that it tests the joint effect of agricultural trade liberaliza-
tion and other policies that are relevant to agriculture growth and likely to strengthen the relationship
between trade liberalization and poverty. Therefore, in addition to agricultural trade liberalization, this
study assesses the effects of the transmission of new technologies that are expected to increase pro-
ductivity in agriculture, and of investment in rural road infrastructure aimed at reducing transporta-
tion costs in agriculture.

The study is organized as follows: Section 2 provides an overview of the Congolese agricultural sec-
tor, Section 3 describes the data and the two steps of the empirical methodology, Section 4 reports the
findings, and Section 5 concludes.

2 Overview of the Congolese agricultural sector

The Congolese economy depends on the agricultural sector, which contributes more than 20 per cent
of the country’s GDP. However, it is important to note that the importance of agriculture is not a result
of improved agricultural production. Rather, it is due to the marked reduction of mining production,
which declined faster than agriculture. In recent years, agriculture became an urban phenomenon, es-
pecially for food security reasons and proximity to markets. Urban and peri-urban farming in the DRC
is not only a response to the rise in food insecurity; it also serves as an income-generating activity be-
cause of the increasing demand for vegetables in cities and soaring food prices. As a result, the agricul-
tural sector has become the second largest employer for urban workers after the trade sector.

2.1 Agricultural production and productivity trends

Table 1 shows the growth rates of production of the main agricultural products in the DRC between
1960 and 2010. The main food crops (cassava, plantains, and maize) accounted for 80 per cent of total
agricultural production, while cash crops represented less than 15 per cent.

Data in Table 1 reveal a widely varying pattern of production growth rates among the different agricul-
tural products over 1960–2010. This is the result of uncoordinated agricultural development strategies,
coupled with conflict and the progressive withdrawal of the government from supporting agricultural
activities. Cash crops were the backbone of DRC agriculture in the 1960s. In particular, palm oil gen-
erated half of total export earnings and made the DRC the second largest exporter of this crop in the
world. As a result of a succession of policy strategies and measures, however, the production of cash
crops (rubber, sugar, coffee, and cotton, in addition to palm oil) declined starting in the early 1970s.
For instance, the production of palm oil fell from 224,000 metric tons in 1961 to 187,000 metric tons
in 2011. This coincided with the implementation of the “Objectif 80”, a 10-year programme of indus-
trialization through domestic and external loans.4 The collapse of cash crop production was accelerat-
ed by “Zaïrianization” (1973–1974), a policy of expropriation of foreign-owned production units by the
government, which then handed them over to nationals. This policy led to the collapse of large-scale
commercial agriculture, favoured subsistence agriculture, distorted economic incentives against ag-
riculture (Otchia 2013a), and led to conflicts. Growth in palm oil production resumed in the 1990s as
a result of another agricultural and rural development plan, Le Plan Directeur,5 but could not be sus-

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4 Launched in 1970, this programme aimed at doubling copper production, constructing steel mills and deep-water ports,
and building dams to electrify the entire country.
5 This plan aimed to design regional and sectoral strategies to promote food security, and to define the role of the state and
the private sector.
Table 1  Agricultural growth rates and area harvested (per cent)

<table>
<thead>
<tr>
<th></th>
<th>Agriculture production</th>
<th>Growth rates of agriculture production</th>
<th>Growth rates of area harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>67.48 17.51 26.14 14.07 -18.72 1.20</td>
<td>-0.77 0.52 1.10 0.24 -1.90</td>
<td></td>
</tr>
<tr>
<td>Plantains</td>
<td>6.75 22.82 23.48 -4.75 -41.13 14.35</td>
<td>-35.47 -58.59 -4.96 14.77 3.27</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>5.83 21.18 35.81 51.97 4.37 7.29</td>
<td>3.70 13.54 21.70 19.64 4.58</td>
<td></td>
</tr>
<tr>
<td>Bananas</td>
<td>1.77 17.58 20.20 -6.53 -15.21 13.42</td>
<td>-0.70 -7.48 -22.62 3.18 10.7</td>
<td></td>
</tr>
<tr>
<td>Rice, paddy</td>
<td>1.55 53.24 51.56 21.85 -18.97 4.95</td>
<td>5.71 -5.07 -20.57 -18.60 11.66</td>
<td></td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td>1.15 11.12 19.65 2.20 -60.37 8.95</td>
<td>57.11 37.15 37.45 25.44 25.29</td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>0.09 48.52 53.54 45.64 8.89 25.62</td>
<td>42.87 7.54 10.05 0.03 1.95</td>
<td></td>
</tr>
<tr>
<td><strong>Cash crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm oil</td>
<td>0.81 -10.88 -17.74 8.81 -1.43 6.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>0.04 -6.55 39.67 49.62 -8.42 9.17</td>
<td>-8.59 -8.25 -12.56 -34.76 6.10</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s calculations, based on the FAOSTAT database of the Food and Agriculture Organization of the United Nations (FAO).

War and civil conflict in the 1990s negatively affected production of food crops as well. Table 1 indicates that sweet potatoes, plantains, rice, cassava, and bananas experienced a large drop during 1990–2000. In spite of this decline, the agricultural sector has continued to serve as the backbone of the Congolese economy. Growth of agricultural production, especially food crops, resumed during 2000–2010. Production of soybeans, which are grown extensively for their nutritional qualities, grew by 25.6 per cent, while that of plantains and bananas grew by 14.4 and 13.4 per cent, respectively. However, as long as production technology remains rudimentary and producers lack improved varieties and inputs, the growth of food crop production continues to depend on available quantities of the basic production factors of land and labour. For example, the harvested area of sweet potatoes and paddy rice grew by 23.3 and 11.7 per cent, respectively, from 2000 to 2010.
Data on factor supply and productivity show that land productivity, and especially labour productivity, decreased during 2000–2007. Panel (a) of Figure 1 displays agricultural land productivity and the per capita capital stock in land development, while panel (b) plots agricultural labour productivity and per capita capital stock in machinery and equipment. As can been seen, land productivity increased between 1980–1989 and 1990–1999, but dropped afterward due to the collapse of infrastructure and frequent displacement of farmers during the war period. Labour productivity, on the other hand, decreased continuously starting in 1980–1989, and then fell drastically between 1990–1999 and 2000–2007. This may be explained by war and displacement as well as the informal character of agriculture, lack of education, and the rudimentary nature of technology used in this sector.

2.2 Agricultural trade patterns

Exports from the DRC, after having more than doubled from 1961–1980, decreased sharply during 1980–2000, as shown in Table 2. The reason is that the development policies implemented during the latter period, such as Zaïrianization, undermined the viability of large-scale agricultural projects and disrupted the maintenance of rural infrastructure and support services, as discussed in the previous section. Exports of palm oil, rubber and cotton collapsed in the 1990s, and in later years DRC agricultural exports came to be dominated by bran of wheat and coffee, which amounted to 62.8 per cent of such exports in 2010.

### Table 2  Agricultural exports, selected years

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Total agricultural exports (thousand constant $)</td>
<td>107,340</td>
<td>112,196</td>
<td>234,839</td>
<td>159,080</td>
<td>39,308</td>
<td>75,120</td>
</tr>
<tr>
<td>Export share in total agricultural exports (per cent)</td>
<td>0.00</td>
<td>0.00</td>
<td>16.25</td>
<td>14.65</td>
<td>41.12</td>
<td>52.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bran of wheat</td>
<td>1.23</td>
<td>1.43</td>
<td>2.26</td>
<td>3.28</td>
<td>4.84</td>
<td>2.09</td>
</tr>
<tr>
<td>Coffee, green</td>
<td>8.27</td>
<td>16.74</td>
<td>40.16</td>
<td>65.54</td>
<td>50.02</td>
<td>10.75</td>
</tr>
<tr>
<td>Cotton lint</td>
<td>3.71</td>
<td>2.48</td>
<td>1.19</td>
<td>0.00</td>
<td>0.54</td>
<td>0.00</td>
</tr>
<tr>
<td>Palm oil</td>
<td>37.62</td>
<td>34.08</td>
<td>5.42</td>
<td>0.00</td>
<td>0.00</td>
<td>0.90</td>
</tr>
<tr>
<td>Rubber nat dry</td>
<td>9.18</td>
<td>9.86</td>
<td>10.55</td>
<td>4.25</td>
<td>0.27</td>
<td>1.03</td>
</tr>
<tr>
<td>Tea</td>
<td>1.23</td>
<td>1.75</td>
<td>0.79</td>
<td>1.59</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>Other</td>
<td>38.76</td>
<td>33.69</td>
<td>23.37</td>
<td>12.71</td>
<td>5.25</td>
<td>32.98</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Since the level of food production is low, the DRC’s dependency on imported food has increased. Table 3 indicates that food imports increased approximately 40-fold between 1960 and 2010, from $23 million in 1960 to $977 million in 2010. Major imports included flours of wheat and maize, sugar, palm oil, and meat. As can also be seen in the table, the DRC only started to import significant amounts of maize, sugar, and palm oil in 2000.

### Table 3  Food imports, selected years

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total food imports (thousand constant $)</td>
<td>22,792</td>
<td>61,887</td>
<td>156,900</td>
<td>241,595</td>
<td>214,424</td>
<td>977,295</td>
</tr>
<tr>
<td>Import share in total agricultural imports (per cent)</td>
<td>0.03</td>
<td>0.00</td>
<td>39.60</td>
<td>29.56</td>
<td>21.54</td>
<td>28.66</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.47</td>
<td>15.18</td>
</tr>
<tr>
<td>Flour of maize</td>
<td>32.47</td>
<td>27.82</td>
<td>1.76</td>
<td>11.37</td>
<td>18.03</td>
<td>13.18</td>
</tr>
</tbody>
</table>

6 Land productivity indicates the total output per hectare of agricultural land, whereas labour productivity is expressed as the value of agricultural production per agricultural worker.

7 We plot the DRC and its neighbouring countries for comparison purposes. Chad was excluded because its land and labour productivity are much higher than for the displayed countries.
2.3 Agriculture and poverty

Figure 2 plots the breakdown of the poverty headcount by sectors of activity, i.e. agriculture and other sectors, and compares it across urban and rural areas. This allows for evaluating the contribution of agriculture to poverty reduction. The figure clearly shows that the agricultural sector is home to the poor. In rural areas, where the poverty rate is extremely high, 83.4 per cent of poor households work in agriculture, while only 16.6 per cent of the rural poor work in other sectors. In urban areas, the agricultural sector accounts for 34.4 per cent of the poor population, which is still very high compared to the trade and transportation sectors. At the national level, the share of poor households that work in agriculture is 63.4 per cent. It can thus be concluded that high poverty rates and the recent rise in rural poverty are at least partly related to the fall in labour and land productivity in agriculture described in Section 2.1.

Turning to the structure of budget shares and their distribution across groups, Table 4 reports a product-disaggregated breakdown of consumption expenditure by deciles of the income distribution. Here the interest is in examining how the expenditure allocation across different consumption items evolves with the income level of the household. Several points are worth noting. Looking first at food expenditure, it is important to highlight the importance of food consumption in Congolese households’ expenditure. Table 4 shows that Congolese households allocate the highest share of their expenditure to food consumption, and that this share decreases for rich households, following Engel’s Law. Apart from food consumption, the category that includes housing, electricity, gas, and water represents the second largest expenditure item. The share of this category is almost homogeneous across all households, averaging 14 per cent of total expenditure. The expenditure breakdown implies that after households cover their needs in food and housing, they have little money left for other services such as education and medical care. This is especially true for poor households: as can be seen, the share of education in total expenditure for the three lowest deciles is close to 1 per cent.
The Enquête 1-2-3 – a mixed household-informal producer survey on employment, the informal sector, and consumption conducted in 2005 by the DRC’s National Statistics Institute (Institut National de Statistique) – collected data on two different types of consumption: consumption of market goods and home-produced consumption. Market goods consumption refers to goods that households procure from markets at market price, while home-produced consumption denotes households’ consumption from their own production valued at market price.

In this study, we apply kernel density instead of a regression of food expenditure on income per capita in urban and rural areas because our main focus is to analyse the distribution of food expenditure relative to the poverty line.

The food expenditure poverty lines were taken from the National Statistics Institute, which established the food expenditure poverty line at 123,070 Congolese francs for urban areas, and at 82,755 Congolese francs for rural areas. We thus represent the log of the urban food expenditure poverty line by the solid vertical line at the value of 11.72 and the log of the rural food expenditure poverty line by the dashed vertical line at 11.32.

Table 4 Distribution of consumption by expenditure group (per cent)

<table>
<thead>
<tr>
<th>Products</th>
<th>Expenditure group (decile)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Food consumption</td>
<td>72.1</td>
</tr>
<tr>
<td>Marketed</td>
<td>40.1</td>
</tr>
<tr>
<td>Home-produced consumption</td>
<td>32.0</td>
</tr>
<tr>
<td>Beverage and tobacco</td>
<td>2.7</td>
</tr>
<tr>
<td>Clothing &amp; footwear</td>
<td>3.5</td>
</tr>
<tr>
<td>Housing, electricity, gas, water</td>
<td>15.8</td>
</tr>
<tr>
<td>Medical care</td>
<td>2.8</td>
</tr>
<tr>
<td>Transportation &amp; communications</td>
<td>0.2</td>
</tr>
<tr>
<td>Education</td>
<td>0.8</td>
</tr>
<tr>
<td>Recreation &amp; culture</td>
<td>0.2</td>
</tr>
<tr>
<td>Restaurant &amp; hotels</td>
<td>0.9</td>
</tr>
<tr>
<td>Other services</td>
<td>1.1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Author’s calculations, based on the 2005 household and informal producer survey (Enquête 1-2-3).

In order to obtain more detailed information on food consumption patterns, Table 4 disaggregates food expenditure into market goods consumption and home-produced consumption. The food consumption pattern varies significantly using this disaggregation. Market food consumption represents 40 per cent of poor households’ expenditure, and this share increases with income. This means that rich households spend a larger share of their income on market goods than poor households. Looking at the home-produced consumption pattern also provides some important insights for policymakers. Home-produced consumption represents 32 per cent of total expenditure for the poorest decile, which is approximately half of their food consumption expenditure, but this share declines significantly with income. It is 26.3 per cent for the 5th income group decile, 10 per cent for the 9th decile, and 4 per cent for the richest decile.

Figure 3 extends the expenditure analysis by plotting the kernel density estimates of urban and rural households for food consumption. The figure plots the estimated density function of food consumption per adult equivalent for urban and rural households. It can be clearly seen that the distribution of the log of food consumption per adult equivalent for urban households is skewed to the left, while for rural households, the distribution is slightly skewed to the right. Two vertical lines represent the food expenditure poverty line for urban and rural areas. This enables us to assess the potential impact of growth on poverty reduction. The figure shows that the distance between the poverty line and the mode of urban per capita expenditure distribution is not large. From a poverty reduction policy perspective, this implies that it would require only a very small increase in per adult equivalent food consumption to move many households out of poverty in urban areas. In rural areas, however, the mode of the density function is quite far from the rural food poverty line. This indicates the need for poverty reduction policies capable of increasing incomes of the poor by more in the rural sector than in the urban sector in order to achieve similar reductions in poverty rates.

10 The Enquête 1-2-3 – a mixed household-informal producer survey on employment, the informal sector, and consumption conducted in 2005 by the DRC’s National Statistics Institute (Institut National de Statistique) – collected data on two different types of consumption: consumption of market goods and home-produced consumption. Market goods consumption refers to goods that households procure from markets at market price, while home-produced consumption denotes households’ consumption from their own production valued at market price.

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3 Modelling framework

The analysis is conducted by combining a CGE model and a microsimulation model. This allows us to study the impact of macroeconomic policies at the household level. Both models are integrated by the top-down approach, which consists of simulating policy change in a CGE model, and then transmitting those changes into a microsimulation model that models household behaviour. Section 3.1 describes both models in detail, while Section 3.2 presents the model database used for the analysis.

3.1 CGE-microsimulation model

To assess the distributional and poverty effects of agricultural trade liberalization in the DRC, we developed a CGE-microsimulation framework. A top-down approach is used to combine the CGE model (top module of the framework) and the microsimulation model (bottom module). The top module models all the interactions registered in the DRC’s Social Accounting Matrix (SAM) and delivers changes in factor and goods prices. Using those changes in prices, the bottom module takes into account household heterogeneity in terms of factor endowments and consumption patterns to simulate the welfare distribution across households. The general specification of the Congolese CGE model follows the basic structure of the single-country model as described by Dervis et al. (1982). However, we closely follow Arndt et al. (2000) and Löfgren et al. (2002) for the specification of the structural and empirical features of the Congolese economy. Among the main features, the model considers trade and transportation costs for marketed commodities separately, and allows for home-produced consumption. This section provides a brief description of the main characteristics of the CGE model, including its general structure, the specification of transaction costs and home consumption, and the core features of the microsimulation model.13

13 The equations of the CGE model can be found in the Annex.
There are 19 sectors in the Congolese CGE model, each of which produces a distinct commodity. Figure 4 presents the structure of production and allocation. It is assumed that all producers operate under constant returns to scale and a perfectly competitive market. Sectoral production is modelled as a Leontief function of intermediate inputs and value added. This assumption introduces some rigidity in the model as it implies zero substitutability between value added and intermediate inputs. Intermediate input is represented by a Leontief function of disaggregated intermediate inputs. To generate value added, producers combine labour and capital. This combination is specified by a constant elasticity of substitution (CES) aggregate function. Capital, which includes all types of assets (such as land and machinery) used in production activities, is assumed to be sector-specific.

The labour market is decomposed into high-skilled, semi-skilled, and low-skilled categories. In addition, each of these labour categories is segmented into urban and rural areas. It is assumed that labour is fully employed and mobile across sectors, but not across regions.

Equation (1) defines the composite value added. In this equation, \( QF_a \) denotes the factor (labour, capital) demand quantity, while \( \delta^{f_a}_{fa} \) and \( \theta^{f_a}_{fa} \) are the productivity of factor, and \( \rho \) the substitution parameter.

\[
QV_a = \alpha^p_a \sum_f (\delta^{f_a}_{fa} \cdot \theta^{f_a}_{fa} \cdot QF^{1/\rho^f_a})^{1/\rho^f_a}
\]

(1)

Each sector produces outputs with fixed-yield coefficients and allocates them to market sale or home consumption. The production and allocation process is shown in equation (2), where \( QXAC_{ac} \) denotes the marketed production, \( QHA_{ach} \) denotes home-produced consumption, \( QA_a \) denotes output, and \( \theta_{ac} \) denotes yields of output per unit of activity.

\[
QXAC_{ac} + \sum_h QHA_{ach} = \theta_{ac} \cdot QA_a
\]

(2)

With regard to marketed production, producers are assumed to optimally deliver output to the domestic and export markets, given the relative prices and the imperfect transformability between exports and domestic sales expressed by a constant elasticity of transformation (CET) function. The producer price of exported goods (called the export price) is the world price adjusted by the exchange rate, export taxes, and transaction costs. Similar to the export side, we adopt the Armington assumption of

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14 Capital is immobile because, in the short term, it is difficult to transform machinery for use in another sector.

15 Low-skilled labour includes workers who have at most finished primary school. Semi-skilled labour includes workers with secondary schooling, including those with technical training. High-skilled workers are those with college, university, and post-university education.

16 This is because the model is run in the short-term perspective and we do not model the decision to migrate.
imperfect substitutability between imported and locally produced goods on the consumer side. The consumer price of imports (called the import price) is the world price adjusted by the exchange rate and tariffs, plus the transaction costs per unit of import. Finally, as the DRC accounts for a very small share of world trade, the small-country assumption is adopted for both import and export markets. This implies that the DRC faces perfectly elastic world supply and demand at fixed world import and export prices.

In the model, domestic transaction costs are calculated as the difference between the domestic demand price (the price paid by consumers) and the domestic supply price (the price received by producers) for goods that are produced and sold domestically. These transaction costs are very high in the DRC, as they reflect poor infrastructure and high costs of capital. In the CGE model, transaction costs also apply to imported and exported goods, as shown in Figure 5. It is assumed that each unit of a given agricultural and manufactured good requires a fixed amount per unit of trade and transportation services in order to reach the market. The demand for trade and transportation services $QT_c$ is given by:

$$QT_c = \sum_c \left( cd_{c,c} \cdot QD_{c,c} + cm_{c,c} \cdot QM_{c,c} + ce_{c,c} \cdot QE_{c,c} \right)$$

where $cd_{c,c}$, $cm_{c,c}$, and $ce_{c,c}$ are, respectively, domestic production, import, and export transaction cost coefficients of commodity $c$.

A feature that distinguishes this model from other standard CGE models is that it is extended to separately account for the use of trade services and transportation services within transaction costs. This implies that two production activities provide transaction services associated with goods produced and sold domestically, imported, and exported.

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**Figure 5  The price system**

![Diagram of the price system](image)

Source: Author.

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17 The high cost of capital generally results in high costs of holding inventories and high risks associated with trading activities.

18 From a policy standpoint, policies affecting trade margins may differ from those affecting transportation margins.
The model also makes it possible to account for home consumption of own production. This property allows modelling the consumption by households of some of their own production instead of selling it at a low price or purchasing similar goods at a high price.\footnote{Home-produced consumption is represented in the SAM (see Section 3.2) by payments from households to activities. From the household’s income side, activities pay to production factors and production factors to households. For a detailed description of how home-produced consumption is treated in the model see Lofgren et al. (2002).} Final household demand follows a linear expenditure system (LES) derived from the maximization of the Stone-Geary utility function subject to a budget constraint. Optimization leads to demand functions for marketed commodities and for home-produced commodities. Demand for marketed commodities is represented by an LES function of total household consumption expenditure, a commodity’s composite market price,\footnote{The composite price is the domestic market price paid by consumers. The composite price differs from the domestic demand price in that the former includes locally produced and imported goods, while the latter only includes locally produced goods.} and other commodity prices. Demand for home-produced commodities is free of transaction costs and uses producer prices.\footnote{Producer prices differ from domestic supply prices in that the former consider both locally sold and exported goods, while the latter only includes locally produced goods.}

Turning our attention to the microsimulation model, all of the 12,098 households from the 2005 household and informal producer survey are included in the simulation. It is assumed that agricultural trade liberalization or any other policy change affects household welfare through the change in domestic market prices, producer prices, and factor income. This assumption in turn implies that the welfare effects depend on household consumption patterns and factor endowments. Changes in labour income \((dw/w)\), marketed commodities prices \((dp_g/p_g)\), and producer prices \((dp_hg/p_hg)\) from the CGE model are fed into the microsimulation model to determine welfare gains or losses of each of the 12,098 households. The first-order welfare change function \(dW/h \cdot y_h\) is given as:\footnote{This equation is a variant of Chen and Ravallion (2004). We neglect the second-order effects as the price and wage changes are small (see Section 4). In addition, this money-metric welfare function considers only the income share of wages and assumes that other sources of income (land, capital, transfer) are constant.}  

\[
dW/h \cdot y_h = \sum_g \theta_l (dw/w) \cdot p_g + \sum_g \theta_l (dp_g/p_g) - \sum_g \theta_l (dp_hg/p_hg) \tag{4}
\]

where \(\theta_l\) is the share of labour category \(l\) in labour income of household \(h\),\footnote{Factor income of households includes income from labour, land, and capital. Production income of households does not go to households directly, but through production factors.} \(\theta_lpg\) is the share of marketed good \(g\) in the total consumption expenditure of household \(h\), \(\theta_lphg\) is the share of home-produced good \(g\) in the total consumption expenditure of household \(h\), and \(y_h\) is household income.

### 3.2 Model database

Two data sources are used for this study: a social accounting matrix for the DRC compiled by the author for 2005\footnote{The 2005 DRC SAM is fully documented in Otchia (2013a).} and the 2005 household and informal producer survey\footnote{The Enquête 1-2-3 is carried out in three phases on the same sample. The first phase collects information about employment and households’ economic condition and activities. The data collected through the first phase are used to identify household unincorporated enterprises (households whose production unit is not incorporated as a legal entity separate from the owner), which serve as statistical units for the next phase. The goal of the second phase is to provide information on business conditions, economic performance, and production linkages of the household unincorporated enterprises. Finally, the third phase uses the typical household budget survey to collect information on household consumption.} conducted by the DRC’s National Statistics Institute. The SAM is used to calibrate the CGE, whereas the microsimulations are conducted using the Enquête 1-2-3.

The SAM contains a detailed production side of 19 activities, among which two are related to agriculture, seven to manufacturing, and 10 to services. The SAM was modified for the present study by disaggregating transaction costs into trade margins and transportation margins for imports, exports, and domestically marketed commodities. Based on the SAM data, Table 5 presents the key characteristics of the Congolese economy in 2005. As can be seen, the DRC’s tariff structure provides less protection for agricultural products than for textiles and other manufactured products. However, trade and transportation costs are significant in agriculture due to underdeveloped markets, infrastructure, and institutions. Given those features, especially the high transaction costs, it can be assumed that tariff pass-through is low and therefore one can expect agricultural trade liberalization to have only a small impact on the Congolese economy.
Table 5  Structure of the economy, 2005

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Production (per cent)</th>
<th>HP (per cent of Q)</th>
<th>Value added (per cent)</th>
<th>Imports (per cent)</th>
<th>Exports (per cent)</th>
<th>IPR</th>
<th>EI</th>
<th>Tariffs</th>
<th>TRMG (per cent of total supply)</th>
<th>TPMG (per cent of total supply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>25.24</td>
<td>19.22</td>
<td>20.74</td>
<td>2.56</td>
<td>1.01</td>
<td>0.02</td>
<td>0.61</td>
<td>0.05</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>Forestry</td>
<td>1.90</td>
<td>50.72</td>
<td>2.05</td>
<td>0.00</td>
<td>0.65</td>
<td>0.00</td>
<td>0.05</td>
<td>0.20</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>11.50</td>
<td>0.14</td>
<td>12.78</td>
<td>7.89</td>
<td>69.14</td>
<td>0.10</td>
<td>0.44</td>
<td>0.15</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Processed foods</td>
<td>11.55</td>
<td>39.83</td>
<td>11.23</td>
<td>19.60</td>
<td>0.87</td>
<td>0.22</td>
<td>0.01</td>
<td>0.09</td>
<td>0.24</td>
<td>0.11</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.57</td>
<td>0.44</td>
<td>1.56</td>
<td>1.93</td>
<td>0.10</td>
<td>0.20</td>
<td>0.01</td>
<td>0.52</td>
<td>0.20</td>
<td>0.07</td>
</tr>
<tr>
<td>Wood</td>
<td>0.59</td>
<td>0.22</td>
<td>0.54</td>
<td>0.14</td>
<td>1.59</td>
<td>0.06</td>
<td>0.65</td>
<td>0.19</td>
<td>0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Chemicals</td>
<td>3.59</td>
<td>1.08</td>
<td>5.26</td>
<td>22.78</td>
<td>2.88</td>
<td>0.51</td>
<td>0.12</td>
<td>0.10</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>Non-metals</td>
<td>0.56</td>
<td>0.07</td>
<td>0.44</td>
<td>2.54</td>
<td>0.60</td>
<td>0.45</td>
<td>0.16</td>
<td>0.09</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Other manufacture</td>
<td>1.11</td>
<td>0.95</td>
<td>1.10</td>
<td>22.48</td>
<td>9.57</td>
<td>0.77</td>
<td>0.80</td>
<td>0.21</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>Utilities</td>
<td>1.13</td>
<td>1.07</td>
<td>0.00</td>
<td>1.13</td>
<td>0.00</td>
<td>0.00</td>
<td>0.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>5.28</td>
<td>3.87</td>
<td>0.83</td>
<td>0.01</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade</td>
<td>10.95</td>
<td>15.49</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotels and catering</td>
<td>2.77</td>
<td>0.54</td>
<td>1.90</td>
<td>0.12</td>
<td>0.10</td>
<td>0.01</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>12.56</td>
<td>15.87</td>
<td>8.10</td>
<td>1.53</td>
<td>0.10</td>
<td>0.02</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education and health</td>
<td>1.20</td>
<td>3.04</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial intermediation</td>
<td>1.23</td>
<td>0.74</td>
<td>0.95</td>
<td>0.12</td>
<td>0.11</td>
<td>0.01</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other services</td>
<td>4.29</td>
<td>6.49</td>
<td>4.77</td>
<td>2.62</td>
<td>0.15</td>
<td>0.09</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal and other community services</td>
<td>3.73</td>
<td>5.29</td>
<td>5.12</td>
<td>8.10</td>
<td>0.12</td>
<td>0.03</td>
<td>0.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private households with employed persons</td>
<td>0.05</td>
<td>0.12</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>2.92</td>
<td>4.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author.
Note: HP stands for home consumption share of production; Q stands for production; IPR stands for import penetration ratios; EI stands for export intensity. TRMG stands for trade margins; TPMG stands for transportation margins.

Additional data, including household demand elasticities, trade elasticities, and production elasticities, are required to fully run the CGE model. Household demand elasticities include income elasticity and the Frisch parameter, and were estimated based on the Enquête 1-2-3 survey data. Trade elasticities include elasticities for the Armington and transformation functions. Armington elasticities represent the elasticity of substitution in demand between imported commodities and domestic goods, whereas transformation elasticities include substitution elasticities among primary inputs in the value-added production function. For the case of the DRC, no trade elasticity was found due to the lack of time series data. Therefore, trade elasticities used in this study are from the Global Trade and Analysis Project (GTAP) based on Dimaranan (2006). Finally, production elasticities, which are drawn from the empirical CGE literature for African economies, vary between 0.3 and 1.2 (Fagernas, 2004; Diao, 2012).

4 Simulations and results

This section conducts and analyses a set of experiments using the CGE-microsimulation model presented in the previous section. The main focus of this study is to analyse the impact of trade liberalization in agriculture, but we also test other policies that are relevant to agricultural growth, such as those meant to reduce transaction costs or improve productivity, as well as those that are likely to

26 We use the Linear Approximate Almost Ideal Demand System (Deaton and Muellbauer, 1980; Alston et al., 1994) to estimate income elasticities. This system is used instead of the LES demand system because it is able to treat zero and no consumption in the household data.
27 Production elasticities, which include factor substitution elasticities, take a lower value (0.3–0.8) for agriculture, forestry, and mining.
strengthen the relationship between trade liberalization and poverty. Section 4.1 describes the policies considered in the study, Section 4.2 presents the results of the CGE model for the main macroeconomic variables, and Sections 4.3 and 4.4 present the sectoral and distributional effects.

4.1 Design of policy experiments

In order to simulate the effects of trade liberalization on the DRC’s economy and household welfare, the first scenario cuts tariffs in agriculture by 100 per cent. Even though it is unlikely that the DRC will move that drastically in this direction in trade negotiations, this experiment aims to benchmark the potential effect of a full tariff cut. Tariff reduction is intended to play a major role in the country’s agricultural strategy to increase growth and reduce poverty, given that subsidies and price support measures were abolished in 2002.

In addition to the objective to assess the distributional impact of agricultural trade liberalization, this study also simulates the effects of reduced transportation costs and productivity growth in agriculture. Both simulations illustrate the effects of the DRC’s current agricultural investment programme (DRC, 2012), which aims to increase agricultural production through infrastructure development and productivity growth. The objective of infrastructure development is to promote market integration and increase farmers’ competitiveness by reducing transportation costs. Currently, transportation costs are very high in the DRC due to the precarious conditions of road and railway infrastructure, most of which was destroyed during the 1990s. For example, the DRC has 87,000 km of agricultural feeder roads, but less than 10 per cent of these rural roads are accessible.

The government programme also aims to increase agricultural productivity via mechanization and the use of improved inputs. Raising agricultural productivity is an important policy objective for the DRC in terms of growth and income, because as it stands agriculture uses outdated technology and, as a consequence, labour and land productivity are low and have been decreasing since 1989. Given the low productivity, increasing the amount of labour and land used is the only way to increase production. Since low productivity in agriculture also implies unstable and low-paid jobs, an overwhelming proportion of agricultural workers are poor. Four of every five people among the rural poor work in agriculture. In urban areas, agriculture accounts for one-third of the poor.

Our scenarios simulate a 5 per cent growth in agricultural productivity and a 20 per cent reduction in transportation costs of agricultural products.28 Agricultural productivity growth is implemented by increasing the efficiency parameter of the composite value added for the agricultural sector (parameter $\alpha_{agr}$ of equation (1)). Reduced transportation costs for agricultural goods are posited by simultaneously reducing domestic production, import, and export transportation cost coefficients ($c_{d,agr}$,$c_{m,agr}$, and $c_{e,agr}$ parameters of equation (3)).29 Table 6 summarizes the policies simulated under the five scenarios.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 per cent cut in import tariffs in agriculture</td>
</tr>
<tr>
<td>2</td>
<td>20 per cent reduction of agricultural transportation costs</td>
</tr>
<tr>
<td>3</td>
<td>5 per cent increase in agricultural productivity</td>
</tr>
<tr>
<td>4</td>
<td>Scenarios 1 and 2</td>
</tr>
<tr>
<td>5</td>
<td>Scenarios 1, 2, and 3</td>
</tr>
</tbody>
</table>

Source: Author.

In these scenarios, it is assumed that government current expenditure is fixed and that the fiscal deficit adjusts to ensure that government accounts balance. For the saving-investment account, the balance closure assumes that savings are investment-driven. In this closure, it is assumed that the marginal savings propensities of households and enterprises are fixed, and that investment adjusts to maintain

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28 The scale of the simulation seems reasonable given the existing evidence. For example, total factor productivity grew by 2.3 per cent in Central Africa between 1961 and 1991 (Wiebe et al., 2001).

29 Indices ag and tr denote agriculture and the transportation sector, respectively.
the balance between investment and savings. The foreign exchange balance is achieved by assuming that a flexible exchange rate maintains a fixed level of foreign savings, which is consistent with the floating exchange rate system adopted in the DRC. The producer price index of non-traded domestic output is the numeraire.

4.2 Macroeconomic effects

Table 7 presents the simulation results for selected macroeconomic variables. Looking at Scenario 1, it is evident that agricultural trade liberalization has almost no effect on the Congolese economy. These insignificant effects were expected, as the initial tariff rate, import penetration ratio, and export intensity of the agricultural sector are very low. As can be seen, the exchange rate depreciates by 0.15 per cent, and both agricultural imports and exports increase by 4.9 and 1.08 per cent, respectively. Investment decreases by 0.21 per cent, which can be explained by an increase in the government deficit because government income decreases and current expenditure remains fixed. Agricultural trade liberalization thus yields very small, albeit positive, effects on factor income.

Scenarios 2 and 3 include the two additional policies relevant to agricultural growth that can potentially increase the relatively small positive impact of agricultural trade liberalization. According to Table 7, reduced transportation costs (Scenario 2) boost agricultural exports and imports. This is because they reduce import prices, on the one hand, and increase export prices and hence exporters’ gains, on the other. Agricultural exports increase by more than 95 per cent and agricultural imports increase by 10.72 per cent. The substantial increase in export performance relative to imports leads to appreciation of the real exchange rate. GDP and total absorption rise marginally. In terms of factor income, it can be seen that the remuneration of all labour increases except for high-skilled urban workers, for whom it falls marginally. The most significant rise in wages occurs for low-skilled urban workers, mainly because of the expansion of the trade sector where their labour is used extensively (see Table 7). Nevertheless, we should mention that wage gains for semi- and high-skilled workers in rural areas are higher than for those with similar skills in urban areas. This is because most rural workers are producers of agricultural products and benefit from increased producer prices. The wages of high-skilled and semi-skilled rural labourers increase by 0.64 and 0.45 per cent, respectively, whereas those of high-skilled and semi-skilled urban labour change by –0.02 and 0.13 per cent, respectively. Capital returns rise by 0.38 per cent.

Turning our attention to agricultural productivity growth (Scenario 3), the simulation results indicate that GDP and private consumption increase by 0.99 and 1.16 per cent, respectively. Under this scenario, total exports decrease slightly more than imports (–0.23 per cent against –0.22 per cent) and the exchange rate depreciates by 0.88 per cent to ensure that the trade balance is in equilibrium. However, it is worth mentioning that agricultural productivity growth leads to a significant rise in agricultural exports, whereas imports contract. According to Table 7, agricultural exports increase by 21.84 per cent, while imports of agricultural products decrease by 15.10 per cent. Unlike the reduction of agricultural transportation costs, agricultural productivity growth increases the return of all the factors of production. Wage gains for urban workers are higher than for workers in rural areas. Nonetheless, workers with higher skills gain less than those with lower skills in both areas. In urban areas, for example, wages of high-skilled workers increase by 1 per cent, whereas wages of semi-skilled and low-skilled workers increase by 1.04 and 1.11 per cent, respectively.

<table>
<thead>
<tr>
<th>Table 7 Simulation results – Changes in macroeconomic variables (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Gross domestic product</td>
</tr>
<tr>
<td>Absorption</td>
</tr>
<tr>
<td>Private consumption</td>
</tr>
<tr>
<td>Investment</td>
</tr>
<tr>
<td>Exports</td>
</tr>
<tr>
<td>Agricultural exports</td>
</tr>
<tr>
<td>Imports</td>
</tr>
<tr>
<td>Agricultural imports</td>
</tr>
<tr>
<td>Exchange rate</td>
</tr>
</tbody>
</table>
Scenario 4 is a joint implementation of trade liberalization (Scenario 1) and a reduction of transportation costs in agriculture (Scenario 2), whereas Scenario 5 combines agricultural productivity growth with agricultural trade liberalization and reduced agricultural transportation costs. Scenarios 4 and 5 are motivated by our interest in assessing whether these two policies, which have already proven to be relevant to agricultural growth, can be complementary to agricultural trade liberalization. This study defines policies as being complementary when their impact on a given objective is higher when they are jointly implemented than when they are implemented separately. Table 7 shows that Scenario 4, which combines policies in Scenarios 1 and 2, would yield effects on macroeconomic outcomes that are almost similar to the sum of the results in Scenarios 1 and 2. From a policy perspective, this result indicates that lowering transaction costs in agriculture and agricultural trade liberalization are not complementary policies, according to our definition.\(^{30}\) This implies that policymakers can implement these policies at different times, as there is no substantial gain from carrying out both of them simultaneously. Scenario 5, which is a joint simulation of Scenarios 1, 2, and 3, is similar to an arithmetic addition of individual scenarios, except for agricultural exports and imports and to a lesser extent wage returns. Thus, synergetic effects occur in exports. This implies that productivity improvement generates competitive gains for agricultural exports and can therefore constitute a complementary policy to agricultural trade liberalization and/or reduced transportation costs of agricultural products.

### 4.3 Sectoral effects

At a disaggregated level, agricultural trade liberalization (Scenario 1) causes a reduction of producer prices, domestic supply prices, domestic demand prices, and market prices of agricultural products (Table 8). The price changes are more pronounced for the import prices of agricultural goods than for the domestic demand prices of these goods, which in turn reduce the competitiveness of domestic products.\(^{31}\) The demand for domestically produced agricultural products therefore decreases in favour of imports. As a result, agricultural producer prices fall by 0.36 per cent (see Table 8). The decrease in producer prices leads to a reduction, albeit very small, of agricultural value added (Table 9).

Lowering agricultural transportation costs (Scenario 2) reduces market prices of agricultural products and raises agricultural producer prices. Table 8 shows that the market price of agricultural products decreases by 0.85 per cent. This is mainly due to the decrease of import prices, because domestic demand prices only fall by 0.65 per cent. The producer price of agricultural products rises by 0.75 per cent. This is mainly due to the improvement in the export price, since the domestic supply price of agricultural goods increases only by 0.61 per cent.

With regard to value added, Table 9 shows that reduced transportation costs of agricultural products, simulated in Scenario 2, have a small positive effect on agricultural value added, which increases marginally by 0.02 per cent. This result indicates that agricultural productivity is very low and consequently it cannot react to improved rural transportation infrastructure. Nonetheless, it is interesting to note that lower agricultural transportation costs benefit other economic sectors (except for mining, wood, and chemicals). Trade and construction capture most of these benefits, as their value added rises by 0.58 and 0.21 per cent, respectively. Surprisingly, small changes occur in sectors for which agricultural products are used as intermediate inputs. As can be seen from Table 9, under Scenario 2, value added in textiles and processed food sectors rises by 0.14 and 0.06 per cent, respectively.

\(^{30}\) From a policy standpoint, this indicates that the government could prioritize lowering agricultural transaction costs, as net benefits seem to be higher. However, our results are not robust enough to support this policy implication because our research does not address explicitly the issue of costs.

\(^{31}\) Import prices are not reported here but we should keep in mind that the price of agricultural imports decreased by 1.49 per cent, while the price of domestically produced agricultural products decreased by 0.26 per cent.
Table 8  Simulation results – Changes in prices (per cent)

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PA</td>
<td>PS</td>
<td>PD</td>
<td>PQ</td>
<td>PA</td>
</tr>
<tr>
<td>Agriculture</td>
<td>-0.36</td>
<td>-0.26</td>
<td>-0.36</td>
<td>0.75</td>
<td>-0.61</td>
</tr>
<tr>
<td>Forestry</td>
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<td>0.08</td>
<td>0.08</td>
<td>0.15</td>
<td>0.21</td>
</tr>
<tr>
<td>Mining</td>
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<td>0.15</td>
<td>-0.23</td>
<td>-0.15</td>
<td>-0.07</td>
</tr>
<tr>
<td>Processed foods</td>
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<td>0.07</td>
<td>0.11</td>
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<td>0.29</td>
</tr>
<tr>
<td>Textiles</td>
<td>0.04</td>
<td>0.10</td>
<td>0.20</td>
<td>0.20</td>
<td>0.21</td>
</tr>
<tr>
<td>Wood</td>
<td>0.09</td>
<td>0.06</td>
<td>0.07</td>
<td>-0.14</td>
<td>-0.05</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.07</td>
<td>0.10</td>
<td>0.12</td>
<td>-0.19</td>
<td>-0.20</td>
</tr>
<tr>
<td>Non-metals</td>
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<td>0.05</td>
<td>0.10</td>
<td>-0.19</td>
<td>-0.19</td>
</tr>
<tr>
<td>Other manufacture</td>
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<td>0.06</td>
<td>0.12</td>
<td>-0.19</td>
<td>-0.18</td>
</tr>
<tr>
<td>Utilities</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Construction</td>
<td>-0.04</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.21</td>
<td>0.22</td>
</tr>
<tr>
<td>Trade</td>
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<td>0.28</td>
<td>0.28</td>
<td>2.38</td>
<td>2.44</td>
</tr>
<tr>
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<td>0.06</td>
<td>0.07</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Transportation</td>
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<td>0.04</td>
<td>0.05</td>
<td>-2.66</td>
<td>-2.77</td>
</tr>
<tr>
<td>Education and health</td>
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<td>0.04</td>
<td>0.04</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Financial intermediation</td>
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<td>0.06</td>
<td>0.07</td>
<td>-0.82</td>
<td>-0.85</td>
</tr>
<tr>
<td>Other services</td>
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<td>0.01</td>
<td>0.04</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Personal and other community services</td>
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<td>0.03</td>
<td>0.05</td>
<td>-0.20</td>
<td>-0.19</td>
</tr>
<tr>
<td>Private households with employed persons</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Source: Author’s calculations.
Note: PA stands for producer price; PS stands for domestic supply price without margins; PD stands for domestic demand price with margins; PQ stands for composite market price.
On the other hand, agricultural productivity growth (Scenario 3) raises agricultural value added by 4.91 per cent (Table 9). This result is not surprising because productivity improvement leads to efficiency gains that enable an industry to produce more of the same output with fewer inputs. The increase in the supply of agricultural products leads to a reduction of domestic demand prices and market prices. Table 8 above shows that these prices decrease by 4.18 and 3.85 per cent, respectively, whereas the producer prices fall by 5.22 per cent. In addition to improving the valued added of agriculture, agricultural productivity growth also increases the value added of processed food, textiles, and some services such as hotels and catering. These sectors are characterized by a high proportion of inputs from agriculture and a lower import penetration ratio. The 0.23 per cent increase in value added in processed food is caused mainly by the price change in inputs from agriculture, whereas the 0.17 per cent increase in valued added in hotels and catering is due to the increase in demand, as agricultural productivity growth increases the income of all types of labour. It is worth noting that agricultural productivity growth also increases the demand for chemicals, whose value added increases by 0.15 per cent.

The joint implementation of agricultural trade liberalization and reduced transaction costs (Scenario 4) leads to a decrease in prices in the domestic market. The domestic demand price and composite market price of agricultural commodities fall by 0.93 and 1.22 per cent, respectively (Table 8). However, there is no change in agricultural value added (Table 9), despite the small increase in the producer price of 0.37 per cent (Table 8). Finally, under the combined Scenario 5, value added in agriculture improves by 4.92 per cent and all agricultural prices decrease by about the same amount (between 4.61 and 4.96 per cent). This scenario also increases the value added of other agriculture-related sectors. In contrast to agricultural productivity growth (Scenario 3), which marginally reduces value added in the trade sector, this scenario increases value added in trade by 0.59 per cent.

### Table 9  Simulation results – Changes in value added (per cent)

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>QV</td>
<td>PV</td>
<td>QV</td>
<td>PV</td>
<td>QV</td>
</tr>
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<td>Agriculture</td>
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<td>0.02</td>
<td>0.04</td>
<td>0.48</td>
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</tr>
<tr>
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<td>0.16</td>
<td>-0.17</td>
<td>-0.20</td>
<td>-0.02</td>
</tr>
<tr>
<td>Processed foods</td>
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<td>0.19</td>
<td>0.06</td>
<td>1.25</td>
<td>0.23</td>
</tr>
<tr>
<td>Textiles</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.14</td>
<td>0.95</td>
<td>0.09</td>
</tr>
<tr>
<td>Wood</td>
<td>0.15</td>
<td>0.11</td>
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<td>0.20</td>
<td>-0.11</td>
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<tr>
<td>Chemicals</td>
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<td>0.15</td>
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</tr>
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</tr>
<tr>
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<td>0.56</td>
<td>0.06</td>
</tr>
<tr>
<td>Trade</td>
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<td>0.35</td>
<td>0.58</td>
<td>3.16</td>
<td>-0.05</td>
</tr>
<tr>
<td>Hotels and catering</td>
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<td>0.05</td>
<td>0.09</td>
<td>0.59</td>
<td>0.17</td>
</tr>
<tr>
<td>Transportation</td>
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<td>-0.69</td>
<td>-3.48</td>
<td>-0.01</td>
</tr>
<tr>
<td>Education and health</td>
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<td>0.36</td>
<td>-0.07</td>
</tr>
<tr>
<td>Financial intermediation</td>
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<td>0.05</td>
<td>0.27</td>
<td>0.15</td>
<td>-0.01</td>
</tr>
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<td>0.58</td>
<td>-0.01</td>
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<tr>
<td>Personal and other</td>
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<td>0.25</td>
<td>-0.07</td>
</tr>
<tr>
<td>community services</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Private households</td>
<td>-0.04</td>
<td>0.05</td>
<td>0.09</td>
<td>0.21</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

Source: Author’s calculation s obtained from the CGE model for the DRC.

Note: QV stands for composite value-added quantity; PV stands for composite value-added price.
4.4 Distributional effects

To assess the distributional effects of the policy scenarios, a non-parametric locally-weighted regression is applied to the welfare function shown previously (equation (4)). This method allows for plotting the distribution of average welfare changes along the entire income distribution. In this context, it can be concluded that a policy change improves welfare when the distribution curve of average welfare lies above the null horizontal line. In addition, if the slope of the distribution curve is downward, then the policy change is deemed to be pro-poor, as welfare gains are higher for those who are poorer. For each policy experiment, the distributional effects are estimated at the urban, rural, and national levels.

Figure 6 plots the total welfare effects of agricultural trade liberalization (Scenario 1), reduced domestic transportation costs (Scenario 2), and increased agricultural productivity (Scenario 3) across the entire income distribution. The figure reveals that all three policy experiments produce welfare gains for all households and for both urban and rural regions. Agricultural trade liberalization by itself produces a small welfare effect, which significantly differs along the income distribution and across regions. At the national level, the highest welfare gains appear to have accrued to households at the lower tail of the welfare distribution, as shown in panel (a) of Figure 6. It can also be seen that rural households’ gains are higher than those for urban households. In urban areas, trade liberalization is pro-poor, since poor households benefit more from it than rich households. The impact of agricultural trade liberalization on consumption contributed more to welfare gains of poor urban households than the impact on factor income. This is explained by the large share of agricultural goods in total food consumption of these households, the price change of agricultural products, and the change in factor income due to agricultural trade liberalization seen in the previous section. In rural areas, households in the middle of the income distribution benefited the most.

We use the kernel-weighted local polynomial smoothing (lpoly) available in STATA. For further details, see e.g. Porto (2006).

We use the expenditure per adult equivalent as the household income indicator.

It is also worth mentioning that national average welfare in many simulations is influenced by rural areas. The reason is because all the simulated policies were targeted at agriculture, which accounts for 60 per cent of households in the DRC, and 80 per cent of those households are in rural areas. From a policy perspective, this indicates the importance of increased investment to develop rural economies, and it has a significant influence on the whole economy.
Panel (b) of Figure 6 shows the distributional effects of reduced transportation costs in agriculture. It shows that urban households’ gains are higher than those for rural households in the lower part of the income distribution. This is because lowering transportation costs for agricultural products has significant effects on market prices, which fall by 0.85 per cent (Table 8), mainly benefiting lower-income urban consumers.

In rural areas, however, lowering agricultural transportation costs is not pro-poor because it does not benefit poor rural households as much as it does richer households. A possible explanation is that poor households’ share of marketed production is smaller compared to richer households, and therefore poor households do not benefit from higher producer prices as much as richer households do. Poor households that are likely to be affected include those of subsistence and small-scale farmers, who tend to be disconnected from markets and therefore have few possibilities to substitute the consumption of home-produced commodities with marketed commodities. Since reducing agricultural transportation costs has less of a benefit for households that sell a small share of their production, the government should complement rural infrastructure development with policies to increase non-farm income through marketing support, skill upgrading, labour mobility, and promotion of non-farm activities.

Finally, panel (c) of Figure 6 displays the total welfare gains from improved agricultural productivity. Welfare gains in this simulation are much larger than in the previous scenarios. Rural households capture higher benefits than urban households, as productivity improvement raises agricultural output and sales. However, agricultural productivity growth is not pro-poor in rural areas because much of the gains go to middle-income households. In urban areas, however, productivity growth is pro-poor. Households at the lower tail of the urban income distribution benefit more than those at the upper tail. At the national level, the distribution is almost flat up to the middle of the income distribution, and then drops. This indicates that productivity growth is distribution-neutral for most of the low-income households.

Figure 7 plots the distributional impact of the joint simulations. Panel (a) displays the combined distributional effects of agricultural trade liberalization and reduced transportation costs in agriculture (Scenario 4). Panel (b) portrays the combined implementation of agricultural trade liberalization, reduced agricultural transportation costs, and agricultural productivity growth (Scenario 5). These two simulations indicate that welfare gains are higher than when the individual policies are implemented alone. Starting with panel (a), the combined scenario of agricultural trade liberalization with a reduction of agricultural transaction costs is pro-poor in urban areas and not pro-poor in rural areas. In addition, poor households in urban areas benefit more than those in rural areas because the impact on market prices is higher than the changes in factor returns. At the national level, the gains are captured by the middle-income group.

The distributional effects of agricultural trade liberalization, combined with a simultaneous reduction of agricultural transaction costs and an improvement in agricultural productivity (Scenario 5), are presented in panel (b) of Figure 7. Once again, those who benefit most are rural households, although the welfare effects vary along the income distribution in favour of richer rural households. This contrasts with urban areas, where the higher welfare gains accrue to poor households. Furthermore, this distribution is very similar to the welfare distribution of Scenario 5 in Figure 6, panel (c). This is because the welfare effects of the increase in agricultural productivity are higher than the welfare effects of tariff reductions and transportation cost reductions, and therefore an improvement in agricultural productivity dominates the other two policies. Nevertheless, differences can also be seen in the magnitude of the welfare change, which is more pronounced in urban areas compared to rural areas, meaning that gains from trade and transport efficiency go mainly to urban households. These findings indicate that improving productivity and lowering transportation costs for agricultural products should be given the highest priority.
5 Conclusions and policy recommendations

5.1 Conclusions

This study used an analytical framework combining computable general equilibrium and microsimulation models to analyse the distributional and welfare effects of agricultural trade liberalization in the form of tariff cuts in the Democratic Republic of the Congo. The CGE model was linked to the microsimulation model through a top-down approach, where the CGE top model delivered changes in factor and goods prices to the microsimulation bottom model. Unlike many other studies on trade and poverty, this study went a step further by considering other policies that are relevant for agricultural growth and likely to be complementary to trade liberalization and increase its impact on welfare: a reduction in agricultural transportation costs and an increase in agricultural productivity.

When simulating the three policies separately, the analysis found that agricultural trade liberalization only has a small positive effect on welfare. The reason is that transaction costs are very high, whereas the initial tariff rate, import penetration ratio, and extent of exports are very low.

A reduction in transportation costs for agricultural products generates higher welfare gains than trade liberalization because lower transportation costs increase producers’ gains and boost agricultural exports. In addition, reduced transportation costs in agriculture benefit other economic sectors, such as construction and trade, and therefore increase wages of low- and semi-skilled workers in urban areas. However, low productivity in agriculture prevents farmers from taking full advantage of opportunities offered by reduced transportation costs.

Policies directed towards increasing agricultural productivity result in larger welfare gains than trade liberalization and reduced transportation costs. Moreover, the boost in agricultural production resulting from increased productivity reduces the DRC’s dependence on imports, lowers consumer prices, increases consumption, and stimulates the growth of sectors such as processed food and textiles, which use agricultural products as intermediate inputs.

The analysis also sought to identify if additional effects may result from the interaction of policies, and to understand the importance of sequencing and prioritizing reforms in agriculture. This was done by running simulations of jointly implemented policies. The results at this stage suggest that reduced transportation costs may not be necessarily complementary to agricultural trade liberalization,
meaning that these two policies combined do not produce additional gains. In the case where trade liberalization, reduced transportation costs, and productivity growth were jointly implemented, the analysis found that it is the productivity growth that drives the welfare gains. In terms of policy priorities, the results of the analysis suggest that improving agricultural productivity should be given the highest priority, followed by reducing transportation costs for agricultural products.

In terms of welfare distribution, the findings indicate that agricultural trade liberalization favoured poor households in urban areas, while in rural areas middle-income households benefitted the most. Lowering agricultural transportation costs generated higher welfare gains for poor urban households compared to their counterparts in rural areas, where pro-rich welfare effects were observed. These pro-rich effects may result from the fact that the share of marketed production is smaller for poor rural households compared to richer households, and therefore these poor households cannot benefit from higher producer prices. With regard to agricultural productivity growth, the study revealed that it leads to total welfare increases, especially in rural areas. The welfare impact of productivity growth is not pro-poor in rural areas, but it is in urban areas.

The CGE model used in this study has some limitations, given that its results depend on assumptions and functional forms, which is common to many CGE models. Therefore, future research should aim at conducting sensitivity analysis of the results under different model closures. This study also assumes productivity growth and reduced transportation costs to be exogenous, and the model does not consider the resources needed to implement policies in those areas. To compare the net benefit of these policies, an extension of this analysis should include estimates of the costs associated with each policy and its financing sources. Another caveat of this study refers to the microsimulation analysis, which only considers changes in labour income, assuming that income from other sources remains constant.

5.2 Policy recommendations

The DRC government should take concrete actions to increase investment in agriculture in rural areas. Such investment accounted for less than 2 per cent of the government budget in 2013, despite the government having pledged since 2004 to allocate at least 10 per cent of the budget to agriculture under the Comprehensive Africa Agriculture Development Plan and the National Programme of Medium-term Investment. Investment should prioritize improving productivity and transport infrastructure, especially for small-scale farmers, who are responsible for 80 per cent of the country’s agricultural output. In this regard, a necessary first step would be to establish an agricultural promotion agency to increase the government’s capacity to implement effective agricultural policies and strategies.

Three sets of recommendations flow from the findings of this study:

(a) Modernize the agricultural production methods of small-scale farmers

In the last five years, the Congolese government has invested $56 million and imported nearly 3,000 tractors to increase productivity and boost agricultural production. However, the use of such technology is limited because 69 per cent of farmers are subsistence smallholders with less than two hectares of mostly fragmented land. For these farmers, it may be more effective, at least in the short run, to introduce improved hand tools and machines that can be used manually or powered by animals. Mountainous regions in the eastern part of the country should be given priority, particularly in view of the outdated equipment they use as a consequence of war and displacement. The government may also need to establish supply chains to provide spare parts and back-up services to farmers, and to train them in the use of the new equipment. It should also facilitate access to modern harvesting, on-farm storage, and post-harvesting equipment to enable farmers to add value to their products and reduce post-harvest losses.

In order to ensure the sustainability of these measures, they should be accompanied by training for farmers in operating the equipment, promotion of local production of agricultural equipment, and credit and subsidy programmes for poor small-scale farmers to encourage them to invest in farm machinery.

(b) Strengthen agricultural extension services, research, and education

As land productivity in the DRC is low and has been decreasing since 2000, the government should help farmers strengthen their capacity to produce more output through rural extension services and
the transfer of appropriate innovation. One way to achieve this would be to transform the more top-down extension service created in 1988 into one that employs a more bottom-up participatory approach. This could be achieved by giving more autonomy to provinces to allocate extension services so as to respond to local needs. Another option would be to build the capacity of Ministry of Agriculture and Rural Development field staff – who number between 13,000 and 18,000 personnel and mainly work in farm inspection and the collection of data – so that they can provide rural extension services.

In addition, research, extension, and education should be linked to promoting on-farm agricultural extension work and to developing technologies that respond to farmers’ needs. The DRC has two agricultural and rural development education institutions – the High Institute of Agronomic Studies and the High Institute of Rural Development – as well as one agricultural research entity, the National Institute for Agricultural Studies and Research. These institutions – which fall under the Ministry of Higher Education and Scientific Research and have a field presence across almost the entire country – should join their efforts by promoting on-farm extension work for students, developing and adapting technologies to the needs of farmers, and providing farmers with training.

For the long-term sustainability of these actions, the government may need to strengthen coordination between ministries and their services, as well as the links between agricultural education and research institutions, farmer associations, non-governmental organizations, churches, and private extension services and advisors. It should also provide support to farmers’ organizations and strengthen the links between farmers, input suppliers, and credit providers.

(c) Build and maintain rural feeder roads and markets

The Congolese government has already embarked on an extensive road investment programme, mainly focusing on the construction and rehabilitation of inter-urban roads. Those efforts should be encouraged, with increased attention paid to the quality and sustainability of these upgraded roads. Moreover, to improve market access and the mobility of small-scale farmers, investments should also be directed towards on-farm and village-level transport. The capacity of communities to maintain local roads and organize village-level transportation of agricultural products should be strengthened. Providing utility trailers, in addition to tractors, is important for transporting agricultural products to markets. The government should also design tax systems that protect agricultural products from excessive tolls charged for the use of urban access roads.

Finally, other government policies aimed at helping small-scale farmers could focus on increasing the proportion of marketed agricultural products by supporting the establishment of cooperatives and by providing farmers with market information and research.
Annex: Democratic Republic of the Congo CGE model

Indices

\( a \) Activities
\( f \) Factors (labour and capital)
\( c \) Commodities
\( h \) Households

Exogenous parameters (Greek characters)

\[ \alpha^{ac} \] Domestic goods aggregation function shift parameter
\[ \alpha^{p} \] Production function efficiency parameter
\[ \alpha^{q} \] Import function shift parameter
\[ \alpha^{t} \] Export function shift parameter
\[ \beta^{h} \] Household marginal budget share for home products
\[ \beta^{m} \] Household marginal budget share for marketed goods
\[ \gamma^{h} \] Subsistence consumption for home commodity
\[ \gamma^{m} \] Subsistence consumption for marketed commodity
\[ \theta_{ac} \] Yield of output \( c \) per unit of activity \( a \)

Exogenous parameters (Latin characters)

\[ ca \] Intermediate input coefficients
\[ cd \] Domestic transaction cost coefficients
\[ ce \] Export transaction cost coefficients
\[ ci \] Capital price index weights
\[ cm \] Import transaction cost coefficients
\[ cpi \] Consumer price index
\[ cw \] Consumer price index weights
\[ fpr \] Productivity of factor in activity
\[ ga \] Government consumption adjustment factor
\[ gh \] Per capita transfer from government
\[ inta \] Quantity of aggregate intermediate input per activity unit
\[ iva \] Quantity of value added per activity unit
\[ qgov \] Base government consumption quantity
\[ qinv \] Base investment demand quantity
\[ sh \] Marginal propensity to save
\[ shiftd \] Factor income distribution shares
\[ ta \] Activity tax rate
\[ te \] Export tax
\[ tf \] Factor direct tax rate
\[ th \] Personal direct tax rate
\[ tm \] Import tariff rate
\[ tq \] Sales tax rate
\[ wh \] Net transfer from rest of world

Endogenous variables

\( FS \) Fiscal surplus (deficit)
\( PA \) Activity output price
\( PD \) Domestic supply price with margin
\( PE \) Export price
\( PM \) Import price
\( PN \) Aggregate intermediate input price
\( PQ \) Composite supply price
\( PS \) Domestic supply price without margin
\( PV \) Composite value-added price
\( QA \) Activity output quantity
\( QD \) Domestic supply quantity
\( QE \) Export quantity
\( QF \) Factor demand quantity
\( QG \) Government consumption quantity
\( QH \) Household consumption quantity
\( QI \) Investment demand quantity
\( QK \) New capital stock quantity
\( QM \) Import quantity
\( QN \) Aggregate intermediate input quantity
\( QQ \) Composite supply quantity
\( QT \) Transaction cost demand quantity
\( QV \) Composite value-added quantity
\( WF \) Economy-wide factor return
\( YF \) Total factor income
\( YG \) Total government revenues
\( YH \) Total household income
\( X \) Exchange rate

Exogenous variables

\( DPI \) Domestic producer price index
\( FSAV \) Foreign savings
\( GADJ \) Government consumption adjustment factor
\( IA \) Investment demand adjustment factor
\( QFS \) Total factor supply
\( WD \) Sector distortion in factor return
Production and price

\[ QINT_{ca} = ca_{ca} \cdot PN_a \]

\[ PN_a = \sum_c PQ_c \cdot ca_{ca} \]

\[ QV_a = \alpha^p \sum_c \left( \delta^p_{fa} \ast fpr_{fa} \ast QF_{fa}^\gamma_{fa} \right)^{-1/\rho_{fa}} \]

\[ WF_f \ast WD_{fa} = PV_a \ast QV_a \sum_f \left( \delta^p_{fa} \ast fpr_{fa} \ast QF_{fa}^\gamma_{fa} \right)^{-1} \ast \delta^p_{fa} \ast fpr_{fa} \ast QF_{fa}^\gamma_{fa} \ast QF_{fa}^{-\rho_{fa}^{-1}} \]

\[ QV_a = iv \ast QA_a \]

\[ QN_{ca} = inta \ast QA_a \]

\[ PA_a \ast (1 - ta_a) \ast QA_a = PV_a \ast QV_a + PN_a \ast QN_a \]

\[ QXAC_{ac} = \theta_{ac} \ast QA_a \]

\[ PA_a = \sum_c PXAC_{ac} \ast \theta_{ac} \]

\[ QXAC_{ac} = \sum_h QHA_{ah} = \theta_{ac} \ast QA_a \]

\[ QX_a = \alpha^p \left( \sum_a \delta^a_{ac} \ast QXAC_{ac}^{-\rho_{ac}^{-1}} \right)^{-1} \ast \delta^a_{ac} \ast QXAC_{ac}^{-\rho_{ac}^{-1}} \]

\[ PX_{ac} = PX_c \ast QX_c \left( \sum_a \delta^a_{ac} \ast QXAC_{ac}^{-\rho_{ac}^{-1}} \right)^{-1} \ast \delta^a_{ac} \ast QXAC_{ac}^{-\rho_{ac}^{-1}} \]

\[ QX_a = \alpha^t \left( \delta^t_{ac} \ast QE_{ec}^{-1} \ast (1 - \delta^t_{ac}) \ast QD_{e}^{\gamma_{ec}} \right)^{1/\rho_{ec}} \]

\[ PE_c = pw \ast (1 - te_c) \ast X - \sum_c PQ_c \ast ce_{ec} \]

\[ \frac{QE_{e}}{QD_{e}} = \left( \frac{PE_c}{PS_c} \ast \frac{1 - \delta^t_{ac}}{\delta^t_{ac}} \right)^{1/(\rho - 1)} \]

\[ PX_c \ast QX_c = PS_c \ast QD_{e} + PE_c \ast QE_{e} \]

\[ PD_c = PS_c \ast \sum_c PQ_c \ast cc_{ec} \]

\[ PM_{ec} = pwm \ast (1 + tm) \ast X + \sum_c PQ_c \ast cm_{ec} \]

\[ QQ_c = \alpha^p \left( \delta^p_{ec} \ast QM_{ec}^{-\rho_{ec}^{-1}} \ast (1 - \delta^p_{ec}) \ast QD_{e}^{\gamma_{ec}} \right)^{-1/\rho_{ec}} \]

\[ \frac{QM_c}{QD_{e}} = \left( \frac{PD_c}{PM_c} \ast \frac{1 - \delta^t_{ac}}{\delta^t_{ac}} \right)^{1/(1 + \rho_{ec})} \]

\[ PQ_{ec} \ast (1 - ta_c) \ast QQ_c = PD_c \ast QD_{e} + PM_{ec} \ast QM_{ec} \]

\[ QT_c = \sum_c (cd_{ec} \ast QD_{e} + cm_{ec} \ast QM_{ec} + ec_{ec} \ast QE_{e}) \]

\[ CPI = \sum_c cw_{c} \ast PQ_{c} \]

Incomes and domestic demand

\[ YF_f = \sum_c WF_f \ast WD_{fa} \ast QF_{fa} \]

\[ YH_h = \sum_f sh_{hf} \ast (1 - tf_f) \ast (1 - rf_f) \ast YF_f + gh_h \ast cpi + wh_h \ast X \]

\[ QH_{ch} = \gamma_{ch} \ast \frac{\beta^{m}_{h}}{\gamma_{ch} - \sum_a \sum_c PXAC_{ac} \ast \gamma_{ach}^{h} \ast \frac{PV_{ach}}{PXAC_{ach}}} \]

\[ QHA_{ach} \ast \gamma_{ich}^{h} \ast \frac{\beta^{h}_{ach}}{\gamma_{ach} - \sum_a \sum_c PXAC_{ac} \ast \gamma_{ach}^{h} \ast \frac{PV_{ach}}{PXAC_{ach}}} \]

\[ QI_c = IA \ast qirv \]
\[ QG_c = GA \times qgov_c \]

\[ YG = \sum_{h} th_h \times YH_h + \sum_{f} tf_f \times YF_f + \sum_{c} (ta_a \times QA_a \times PA_a) \]
\[ + \sum_{c} (tm_c \times pwm_c \times QM_c \times X + te_c \times PE_c \times QE_c + tq_c \times PQ_c \times QQ_c) + gh_h + gh_{row} \times X \]

**Equilibrium conditions**

\[ \sum_{a} QF_{fa} = QFS_f \]

\[ QQ_{cl} = \sum_{a} QINT_{ca} + \sum_{h} QH_{th} + QG_c + QI_c + QT_c \]

\[ \sum_{c} pwm_c \times QM_c = \sum_{c} pwe_c \times QE_c + \sum_{h} wh_h + FSAV \]

\[ YG = \sum_{c} PQ_c \times QG_c + gh \times cpi + FS \]

\[ \sum_{h} sh_h \times (1 - th_h) \times YH_h + FS + FSAV \times X = \sum_{c} PQ_c \times QI_c \]

\[ DPI = \sum_{c} dw_c \times PS_c \]
References


