# Reverse Dutch Disease with Trade Costs: Prospects for Agriculture in Africa's Oil-Rich Economies

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**Abstract**

Persistently low world oil prices are stimulating tradable sectors in oil-exporting countries. I use a three-location open economy model to investigate the prospects for reverse Dutch disease in African countries with a comparative advantage in agriculture but large internal and external trade costs. While falling resource revenues lead factors of production to shift into agriculture, remote farmers can lose when trade costs make agricultural goods behave like non-tradables. Household survey data from Nigeria shows a significant agricultural supply response that is correlated with exposure to international markets. Lowering trade costs and boosting agricultural productivity can help offset the lost income from oil.

# 1 Introduction

After over a decade of increasing and high values interrupted only briefly by the 2008 financial crisis, world crude oil prices fell by over 70% from June 2014 to January 2016 and have remained relatively low since then (figure 1). The initial fall in price was primarily due to supply-side factors, including the rapid expansion of US shale oil production using hydraulic fracturing and horizontal drilling (Stocker et al. 2018). In the longer term, environmental policies and improvements in energy efficiency are expected to lead to a peak in global demand for oil by the mid-2030s (Brandt et al. 2013; Dale and Fattouh 2018). The combination of increasing supply from new sources and decreasing global demand means that oil prices are likely to remain low and that historical oil exporters are likely to have less income from oil for the foreseeable future (Venables 2016).

A long literature in economics has documented the ways in which revenues from natural resources can affect economic outcomes, with an ongoing debate about whether resource

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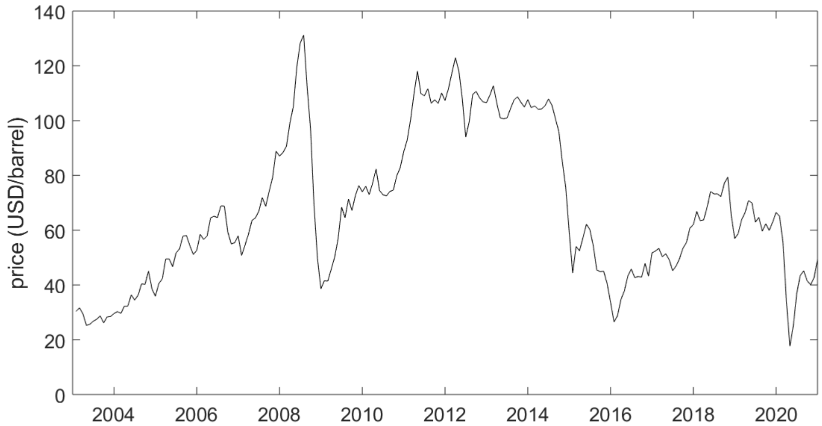


Figure 1: World Crude Oil Price, 2003–2020

*Notes:* Prices are nominal monthly OPEC basket prices in current USD/barrel from January 2003 through December 2020.

revenues can in some circumstances be considered a "curse" (Sachs and Warner 2001; Alexeev and Conrad 2009). An important strand of this literature has highlighted how resource revenues can cause tradable sectors to contract as the appreciation of the real exchange rate draws factors of production into non-tradable sectors, an effect commonly known as Dutch disease (Corden 1984). When productivity growth in tradable sectors like manufacturing is enhanced by learning-by-doing and spillovers, this reorientation of the economy towards non-tradables can have a negative effect on income in the long run (van Wijnbergen 1984). Conversely, a decrease in resource revenues like that experienced by oil-rich economies since 2014 should lead to "reverse Dutch disease," with factors of production flowing back into tradable sectors.

This paper seeks to assess the prospects for reverse Dutch disease in the oil-rich economies of sub-Saharan Africa. I focus primarily on Nigeria and Angola — the region's largest oil producers — but also include data from five Central African members of the CEMAC customs and monetary union (Republic of the Congo, Equatorial Guinea, Gabon, Chad, and Cameroon). Generally speaking, these countries have historically had a comparative advantage in agriculture rather than manufacturing, and they were major agricultural exporters prior to their surge in oil revenues. It is the agricultural sector, therefore, rather than the manufacturing sector, that has been most affected by Dutch disease (Benjamin, Devarajan, and Weiner 1989). I document that Nigeria, Angola, and the CEMAC have become major agricultural importers since they started exporting oil, and their agricultural imports are largest during periods of high oil revenues. Their agricultural sectors, meanwhile, have become increasingly oriented towards non-tradable goods.

An important feature of the agricultural sector in sub-Saharan Africa is the presence of trade costs several times larger than elsewhere in the world — both internal, overland trade costs within countries and external, oversea trade costs to and from the world market (Porteous 2019). Trade costs due to poor infrastructure, information costs, and policy barriers can prevent price signals from reaching isolated local markets. While trade costs may have helped cushion the effects of Dutch disease on the agricultural sector as resource revenues in Africa's oil exporters grew, they may also limit the stimulating effects of reverse Dutch disease as resource revenues fall.

To help understand the potential effects of changes in resource revenues in a context with high trade costs, I build a simple model of costly trade between three locations — an Interior region home to the agricultural sector, a Coast region home to the manufacturing sector, and the World. Both the Interior and the Coast region receive resource revenues, which lead to a shift of factors of production into the local non-tradable sectors. As resource revenues rise, the country passes through five distinct trade regimes as it transitions from an agricultural exporter to an agricultural importer. Simulations with a calibrated version of the model show that the effects of a change in resource revenues on farmers depend crucially on the trade regime. In the two regimes in which the agricultural sector is isolated from the world market, farmers are better off with higher resource revenues because the agricultural good behaves like a non-tradable good.

Empirical evidence from four waves of panel data from Nigeria's LSMS-ISA household surveys (2010, 2012, 2015, and 2018) suggests that declining resource revenues are already leading to reverse Dutch disease. Since the fall in oil prices, households have shifted both labor and land into agriculture. The number of farmers cultivating tradable crops has increased, while the number cultivating non-tradable crops has declined. Heterogeneity in the production response is broadly consistent with the predictions of the theoretical model. Acreage increases among existing farmers are correlated with their proximity to an international border, while new farming households are concentrated in areas that have experienced larger reductions in resource revenues.

In a series of counterfactual experiments, I use my calibrated model to explore the effects of different policy approaches to the decline in oil revenues. Increasing external trade costs — a policy that has been pursued by Nigeria through import restrictions — can hasten the transition to a trade regime where farmers expand production and gain from decreasing resource revenues. However, this policy ultimately leads to worse outcomes by hindering the transition to exporting. In contrast, a sequential lowering of internal trade costs followed by external trade costs leads to steadily increasing gains for farmers as resource revenues fall and the country transitions between trade regimes. When coupled with sufficient increases in agricultural productivity, the gains from this policy approach can completely offset the losses due to the decline in resource revenues.

This paper contributes to the large literature on the effects of natural resource revenues more generally and Dutch disease more specifically by connecting it to a more recent literature highlighting the importance of trade costs in developing countries, particularly in the agriculture sector and in Africa. The theory of Dutch disease was developed by Corden and Neary (1982) and Corden (1984), who contrast a booming resource sector with a lagging manufacturing sector, which suffers from a resource movement effect due to the increased demand for factors of production in the booming sector and a spending effect due to the increase in the relative price of non-tradables. In a study of Dutch disease in Cameroon, Benjamin, Devarajan, and Weiner (1989) note that the resource sector in developing countries is typically an enclave sector using few local factors of production, that the lagging tradable sector is typically agriculture rather than manufacturing, and that the imperfect substitutability of some locally-produced goods in tradable sectors can lead them to behave more like non-tradable goods, all of which are features that I incorporate in my model. In the subsequent literature, Dutch disease effects have been presented as one among a number of challenges faced by resource-rich developing countries in translating their resource revenues into rapid economic growth (see Venables 2016 for a review). The case of Nigeria, Africa's largest country and largest oil exporter, has drawn particular attention, with several studies highlighting the role of institutional quality and the volatility of public expenditure (Sala-i-Martin and Subramanian 2013; Budina, Pang, and van Wijnbergen 2007). In terms of Dutch disease-driven sectoral shifts, Nyatepe-Coo (1994) documents the dramatic contraction of export-oriented agriculture and surge in demand for agricultural imports in Nigeria during the oil price spikes of the 1970s and early 1980s, Nkang (2018) uses a computable general equilibrium model of Nigeria's economy to predict that the drop in world oil prices in 2014–2015 will lead to a significant increase in agricultural production, decrease in agricultural imports, and increase in agricultural exports due to the depreciation of the real exchange rate, and Abalo (2020) uses a Roy model calibrated with Nigeria's 2015 LSMS-ISA household survey data to explore the heterogeneous effects of reverse Dutch disease following the oil price drop on different groups of workers.

This paper goes beyond the existing literature by introducing internal and external trade costs into a model of Dutch disease. The recent trade literature has emphasized the role of major infrastructure projects historically in lowering trade costs for agricultural goods, thereby enabling the realization of substantial gains from trade (Donaldson and Hornbeck 2016; Donaldson 2018). Several recent papers using spatial price data have found that trade costs in African countries are several times higher than elsewhere in the world, suggesting that a significant portion of these potential gains have yet to be realized (Atkin and Donaldson 2015; Porteous 2019). High trade costs in the spatially-dispersed agricultural sector have been shown to prevent specialization in crops of comparative advantage, adoption of productivity-enhancing inputs like fertilizer, and expansion of production in the most productive regions (Sotelo 2020; Porteous 2020). The three-location open economy model used in this paper is closest to that of Gollin and Rogerson (2014), who use a three-location closed economy model calibrated with data from Uganda to show that high internal trade costs can help explain the large share of the workforce engaged in subsistence agriculture. Like these authors, I use my calibrated model to run counterfactual policy simulations in which I lower trade costs and increase agricultural productivity. However, my interest here is not on the direct impact of these policy interventions, but rather on how they can potentially alter the effects of an exogenous decline in resource revenues.

## 2 Historical Context

In this section, I present background information on the top seven oil exporters of sub-Saharan Africa, which are clustered around the Atlantic coast stretching south from the Gulf of Guinea. While my subsequent model, calibration, and empirical analysis are primarily focused on Nigeria (the 4th largest exporter of oil globally since the year 2000) and Angola (the 11th), the data I present here also include the smaller countries of Republic of the Congo (Congo-Brazzaville), Equatorial Guinea, Gabon, Chad, and Cameroon. These latter five countries belong — along with Central African Republic — to the CEMAC customs and monetary union, which uses the central African CFA franc as a common currency and for which I frequently use aggregate data.

As shown in table 1, the seven oil exporters have collectively exported \$1.95 trillion USD worth of crude oil since the year 2000. The share of oil revenues in GDP in these countries varied from less than 10% in Cameroon to over 70% in Congo during the oil boom years leading up to the 2014 price crash. Since 2015, low oil prices have led this share to fall by 56% in Nigeria, 49% in Angola, and 45% in the CEMAC. In 2016, the share of oil revenues in GDP was at its lowest level since 1973 in Nigeria, 1986 in Angola, and 1993 in the CEMAC. With the exception of Cameroon, all of these countries have experienced concurrent economic contractions or severe growth slowdowns. While GDP growth averaged 7.2% in Nigeria, 7.6% in Angola, and 4.8% in Congo (the median CEMAC country) from 2000 to 2014, it averaged 0.9% in Nigeria, –0.9% in Angola, and –0.1% in Congo from 2015 to 2018. Whereas the CEMAC has maintained the peg of the CFA franc to the euro, Nigeria and Angola have both experienced large currency depreciations, with the naira and the kwanza losing 55%

and 68% of their value against the US dollar from June 2014 through December 2018.

Table 1: Top Oil Exporters of Sub-Saharan Africa, 2000–2018

| | Population (2020, millions) | Crude Oil Exports (2000-18, bill. USD) | Share of GDP (2000-14) | Share of GDP (2015-18) |
|---|---|---|---|---|
| Nigeria | 206.1 | 945.0 | 0.207 | 0.092 |
| Angola | 32.9 | 646.1 | 0.571 | 0.294 |
| CEMAC (total) | 56.8 | 354.1 | 0.332 | 0.184 |
| Congo | 5.5 | 110.4 | 0.737 | 0.495 |
| Eq. Guinea | 1.4 | 99.9 | 0.688 | 0.307 |
| Gabon | 2.2 | 83.5 | 0.415 | 0.245 |
| Chad | 16.4 | 30.3 | 0.191 | 0.145 |
| Cameroon | 26.5 | 30.0 | 0.086 | 0.045 |
| *Cent. Afr. Rep.* | *4.8* | *0.0* | *0.0* | *0.0* |

*Notes:* Data are from the UN Population Division for population, CEPII BACI (Gaulier and Zignago (2010)) for oil exports, and the World Bank for GDP.

The left panel of figure 2 shows the evolution of the real value of net exports of crude oil in Nigeria, Angola, and the CEMAC countries over the last 60 years. Nigeria has been a major oil exporter throughout this entire period, with the value of its oil exports closely tracking world oil prices. In contrast, while Angola and several of the CEMAC countries have been exporting oil since the 1960s, production and revenues only began to expand dramatically around the year 2000 with the discovery of major deep offshore oil fields at a time when new technology was making deep-water drilling more cost-effective (Germain and Armengol 1999). While high oil prices supported rapid increases in deep offshore oil production through 2014, the low prices that have prevailed since then have limited investment in the development of new projects due to the high fixed costs of this extraction method.

The real value of net agricultural exports is shown in the right panel of figure 2. As oil exports grew, Nigeria, Angola, and the CEMAC countries switched from being major net agricultural exporters in the 1960s to being major net agricultural importers. This shift from exporting to importing agricultural goods occurred for Nigeria and Angola following the spikes in world oil prices in 1973 and 1979 respectively[1] and for the CEMAC in 2000, as world oil prices and revenues from new deep-water oil production began increasing. Agricultural imports peaked in 2014 in Nigeria and the CEMAC and in 2015 in Angola before falling by over 30% in Nigeria and the CEMAC and over 50% in Angola as oil prices slid.

Table 2 shows how this transition from net agricultural importer to net agricultural exporter has manifested itself in terms of net exports by weight for the 12 crops that these countries have historically traded most. Of these crops, cocoa, coffee, cotton, and rubber are

[1] The shift in Angola was likely also associated with decreases in agricultural production following its independence from Portugal and the outbreak of civil war in 1975.

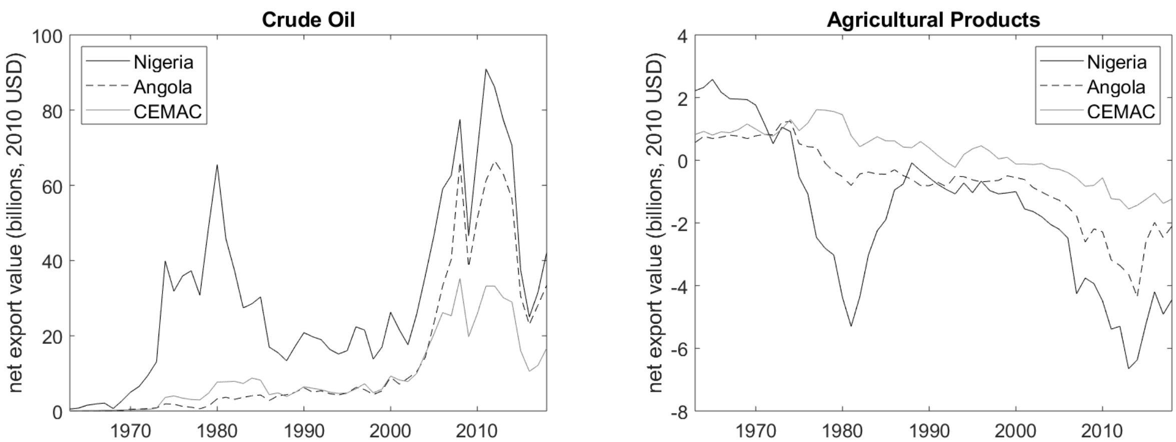


Figure 2: Real Net Exports of Crude Oil and Agricultural Products, 1963–2018

*Notes:* Data for the annual value of net exports (exports minus imports) are from the UN Comtrade Database for crude oil (using values reported by the trading partners of the countries of interest) and from FAOSTAT for agricultural products. Nominal values are deflated by the US CPI-U using 2010 as the base year. Values for the CEMAC countries include all six member states.

primarily produced for export, wheat consumption comes almost entirely from imports, and the other seven crops are produced and consumed in significant quantities domestically in addition to being traded internationally. Nigeria, Angola, and the CEMAC have all become major importers of maize, palm oil, rice, sugar, and wheat. The transition is starkest in Angola, which has had the highest share of oil revenues in GDP (table 1) and which no longer exports any of the 12 crops. In Nigeria, exports of groundnuts and palm oil have completely collapsed, exports of cotton and rubber have fallen, and exports of cocoa have remained stagnant, while exports of sesame have increased. In the CEMAC countries, exports of a number of crops have grown despite the surge in imports. This is due largely to the relative weight of Cameroon, the largest country and agricultural producer in the CEMAC, which has a relatively low share of oil revenues in GDP and is responsible for all of the increase in exports of bananas, cocoa, and cotton, as well as most of the increase in exports of rubber.

Despite the large swings in trade, the total volume of agricultural products traded has always been a relatively small share of the total volume produced, which is shown for the universe of all crops at the bottom of table 2. Although imports have increased dramatically, most consumption continues to come from local production, most production has always been for local consumption, and the total production of all crops has more than tripled since the 1960s, keeping pace with population, which has also more than tripled. This is partly due to the presence of high external and internal trade costs, which increase the price of imported agricultural goods (making local production more competitive) and decrease the price of exported agricultural goods (decreasing the likelihood that local production will be

Table 2: Average Net Exports of Individual Crops by Weight, 1961–1970 and 2005–2014

| | Nigeria | | Angola | | CEMAC | |
|---|---|---|---|---|---|---|
| | 1961–1970 | 2005–2014 | 1961–1970 | 2005–2014 | 1961–1970 | 2005–2014 |
| Bananas | 0 | 0 | 10 | 0 | 90 | 252 |
| Cocoa | 209 | 212 | 0 | 0 | 106 | 179 |
| Coffee | 2 | 0 | 162 | 0 | 73 | 44 |
| Cotton | 29 | 24 | 9 | 0 | 64 | 102 |
| Groundnuts | 533 | –7 | 1 | –1 | 11 | 0 |
| Maize | –1 | –25 | 131 | –217 | –1 | –69 |
| Palm Oil | 89 | –790 | 14 | –103 | -12 | –77 |
| Rice | –1 | –1,584 | 0 | –309 | –11 | –645 |
| Rubber | 61 | 39 | 0 | 0 | 9 | 46 |
| Sesame | 17 | 110 | 1 | 0 | 1 | 1 |
| Sugar | –66 | –1,427 | 25 | –320 | 16 | –150 |
| Wheat | –122 | –3,789 | –52 | –564 | –75 | –787 |
| Total Production | 41,014 | 155,565 | 3,883 | 18,373 | 9,012 | 31,290 |
| Population (millions) | 49.7 | 156.9 | 5.7 | 23.0 | 12.9 | 43.0 |

*Notes:* Data are from FAOSTAT in thousand metric tons, with population data from the UN Population Division. Averages are of annual data over the relevant ten-year period. Total production includes the universe of all crops. Livestock and animal products are not included.

exported), especially in remote locations. This is also due to the local importance of many crops that are generally not traded internationally due either to their low substitutability with crops traded on the world market (e.g. millet and cowpeas) or to their perishability or low value-to-weight ratios, which increase the costs of trade (e.g. yams, cassava, and fresh fruits and vegetables).

The graphs in figure 3 show that the share of non-tradable categories of agricultural goods (here defined as root crops, fruits, and vegetables) in total production has increased substantially in both Nigeria and Angola, while the share of tradable categories of agricultural goods (here defined as cereals, pulses, oilcrops, and other cash crops) has declined. The fluctuations in these shares are clearly coorelated with the fluctuations in the value of oil exports (figure 2)[2]. While the share of tradables in Nigeria has remained below 30% since 2009, in Angola it rebounded from below 12% from 2007 through 2013 (the years of highest oil revenues) to above 20% in 2017.

In the next section, I develop a model that can reproduce the important features evident in these country-level data.

[2]In the CEMAC (not shown here), the aggregate shares stayed close to 57.5% for non-tradables and 42.5% for tradables throughout the 60-year period, a reflection of the fact that most agricultural production is in countries like Cameroon that have a smaller share of oil revenues in GDP.

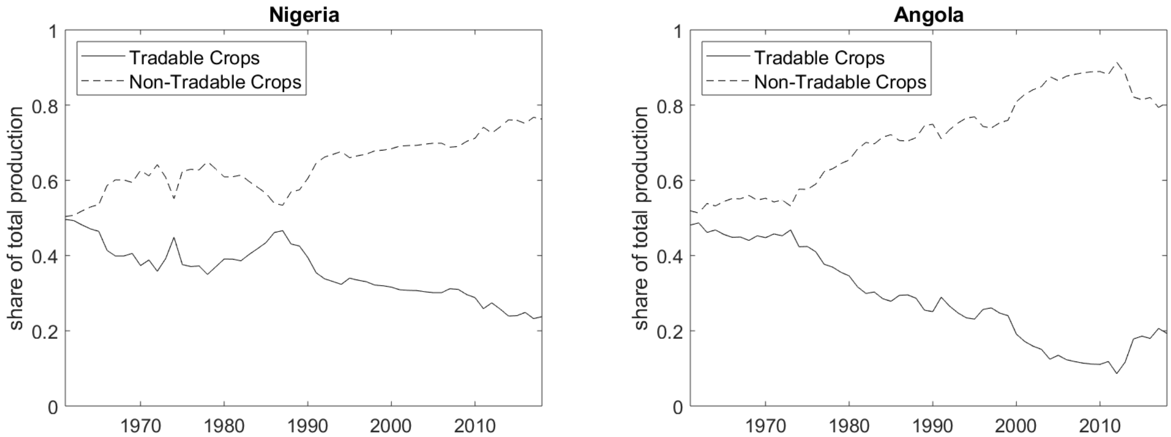


Figure 3: Production of Tradable vs. Non-Tradable Crops in Nigeria and Angola, 1961–2018

*Notes:* Production data are from FAOSTAT, with shares based on weight. Tradable crops include cereals, pulses, oilcrops, and other cash crops. Non-tradable crops include root crops, fruits, and vegetables.

# 3 Model

In this section, I build and calibrate a model of Dutch disease under costly trade and use it to simulate the effects of a decline in resource revenues. The model is designed to be consistent with both the previous literature and the data presented in the previous section. Resource revenues are exogenous, and the resource sector is an enclave sector that does not use local factors of production. The country in the model has a comparative advantage in agriculture and is an exporter of the tradable agricultural good in the absence of resource revenues. Trade is subject to both internal trade costs (between the two regions within the country) and external trade costs (between the country and the world market). In an extension, I add a second agricultural good that is not traded internationally.

## 3.1 Baseline Model of Costly Trade with Resource Revenues

Consider an economy with two regions: an urban Coast (c) and a rural Interior (i). The two regions can trade directly with each other subject to symmetric iceberg trade costs $\tau_i$: in order for a unit of a good to arrive, $\tau_i > 1$ units must be shipped. Similarly, the urban Coast can trade directly with the World subject to symmetric iceberg trade costs $\tau_w$.

There are three goods in the model economy: a tradable agricultural good ($a$), a tradable manufactured good ($m$), and local non-tradables ($n$). The Coast can produce the manufactured good but not the agricultural good (perhaps due to a lack of suitable land), while the Interior can produce the agricultural good but not the manufactured good (perhaps due to a lack of technology). Both regions produce non-tradables, which represent a basket of goods like housing and services that can only be consumed locally. Since these are not traded between the two regions, the basket they represent is not necessarily the same in the two regions, and the prices of the baskets are determined independently by local demand conditions.

For simplicity, suppose that there is a single mobile factor of production called labor (L) used for the production of the three goods. Production of the agricultural good in the Interior and production of the manufactured good on the Coast are both concave in labor, reflecting the diminishing returns to labor on a fixed amount of land for agriculture or with a fixed amount of capital for manufacturing:

$$Q_t = B_t L_t^{\beta} \tag{1}$$

where $0 < \beta < 1$ and the subscript $t$ refers to the relevant tradable sector (agriculture or manufacturing). Production of non-tradables is linear in labor:

$$Q_n = B_n L_n \tag{2}$$

Choose units of local non-tradables such that $B_n = 1 \Rightarrow Q_n = L_n$ in each region.

Labor is mobile across sectors but not across regions[3]. The wage $W$ must therefore be equal across sectors within a region but is not necessarily equal across regions. All sectors are always operating given that demand for non-tradables can only be satisfied by local production and that the production function for tradables is concave. Assuming full employment, the number of workers in the tradable and non-tradable sectors in each region must add up to the total local labor force ($\bar{L}$). Suppose that labor markets are competitive, so workers are paid the value of their marginal product. Then the price of local non-tradables is equal to the wage in equilibrium, and the following condition holds in both regions:

$$W = P_n = \beta B_t L_t^{\beta-1} P_t \tag{3}$$

Combining this last equation with the production function for tradables (equation 1) gives

[3]This differs from previous papers like Gollin and Rogerson (2014) and Gollin, Jedwab, and Vollrath (2016), which allow labor mobility across regions, since the relative long-run distribution of population across regions is a variable of primary interest for them. Here the primary interest is the distribution of labor across sectors in the medium-run as resource revenues change. Even with immobility across regions, movement between agriculture and non-tradables in the Interior, for instance, may still involve movement between rural areas and interior cities like Kano and Kaduna in Nigeria or Lubango and Huambo in Angola.

the following supply function for the tradable good in each region:

$$Q_t = \beta^{\frac{\beta}{1-\beta}} B_t^{\frac{1}{1-\beta}} \left(\frac{P_t}{P_n}\right)^{\frac{\beta}{1-\beta}} \tag{4}$$

Output of the locally-produced tradable good is thus an increasing function of its relative price in terms of local non-tradables (the real exchange rate). An appreciation of the local real exchange rate (i.e. a decrease of this relative price) will lead to a decrease in the output of the tradable good.

Suppose that consumers in each region choose consumption of the three goods given local prices and income to maximize the same Cobb-Douglas utility function:

$$U(C_a, C_m, C_n) = C_a^{\alpha_a} C_m^{\alpha_m} C_n^{\alpha_n} \tag{5}$$

where $\alpha_a + \alpha_m + \alpha_n = 1$. Given Cobb-Douglas preferences, consumers in each region spend a constant fraction $\alpha$ of total regional income $Y$ on each good, so consumption of each good in each region is given by:

$$C = \frac{\alpha Y}{P} \tag{6}$$

Income $Y$ comes from total revenues from sales of local production in addition to resource revenues. As in Benjamin, Devarajan, and Weiner (1989) and Gollin, Jedwab, and Vollrath (2016), natural resources are considered to be an exogenous source of revenues generated by an enclave sector that does not use local factors of production. Let $R$ denote total resource revenues for the country as a whole, and $r$ the share of the revenues allocated to consumers in a particular region. Then total income in each region is given by:

$$Y = P_t Q_t + P_n Q_n + rR \tag{7}$$

For welfare analysis, it is helpful to distinguish between three different groups of consumers in each region, each of which has the same preferences but differs in income. The first group, workers, individually earn $W = P_n$. Since $L_n = Q_n$, workers in non-tradables receive all revenues from this sector ($WL_n = P_n Q_n$). In contrast, since $\beta < 1$, workers in the tradable sector receive only a fraction $\beta$ of total sector revenues:

$$WL_t = (\beta B_t L_t^{\beta-1} P_t) L_t = \beta P_t Q_t \tag{8}$$

We can think of the remaining fraction of local tradable sector revenues ($(1-\beta)P_t Q_t$) as accruing to a second group consisting of specific factors in the tradable sector (land-owners or "farmers" for agriculture in the Interior, "capital-owners" for manufacturing on the Coast). Finally, a third group — "rentiers" — receives income exclusively from resource revenues ($rR$). Realistically, individual consumers might belong to one, two, or even all three of these groups depending on their sources of income.

In a competitive equilibrium, consumers consume their utility-maximizing bundles (equation 6), local production of tradable goods satisfies the supply function (equation 4) with all remaining labor in the non-tradable sector, local markets clear, and prices of each tradable good satisfy the following no-arbitrage condition:

$$\tau P_o - P_d \geq 0, \ = 0 \text{ if } X_{od} > 0 \tag{9}$$

where $X_{od}$ are exports from origin market $o$ to destination market $d$. This no-arbitrage condition holds for each tradable good for trade in either direction between the Interior and the Coast ($\tau = \tau_i$) and between the Coast and the World ($\tau = \tau_w$). World prices of both tradable goods are exogenous and unaffected by local imports and exports, as in Porteous (2019) and Sotelo (2020).

## 3.2 Resource Revenues and Trade Regimes

Having developed a model economy in the previous sub-section, I now turn my attention to how changes in resource revenues can affect the allocation of factors of production across sectors and the pattern of trade across regions. I begin with the following helpful proposition and corollary, which are proved in the appendix:

**Proposition 1.** *For either region, the labor allocation between the tradable and non-tradable sectors is given by:*

$$\frac{L_t}{L_n} = \beta \frac{(1-\alpha_n) - \frac{rR}{Y}}{\alpha_n} \tag{10}$$

**Corollary 1.** *For a given expenditure share for non-tradables ($\alpha_n$), supply parameters $\beta$ and $B_t$, and labor force ($\bar{L}$), the share of resource revenues in total income determines the production of all goods and the consumption of non-tradables. The production and consumption of non-tradables are increasing in the share of resource revenues in total income. The relative price of the tradable good in terms of non-tradables ($\frac{P_t}{P_n}$) and the production of the tradable good are decreasing in the share of resource revenues in total income.*

The results in the corollary show that resource revenues lead to Dutch disease — a decrease in the relative price and production of tradable goods and a shift of factors of production into non-tradables. In the Interior region, this means that the production of the agricultural good decreases as resource revenues increase, even as demand for the agricultural good increases with increased income. If resource revenues increase sufficiently, this will alter the equilibrium pattern of trade for the agricultural good. In table 3, I define five possible regimes for trade of the agricultural good based on the relationship between its price in the Interior ($P_{ai}$) and the world price ($P_{aw}$). Since the Interior must always import the manufactured good (as it does not produce it) and trade is balanced, it is only possible for the Interior not to export the agricultural good (regimes 4 and 5) when resource revenues are positive and can be used to purchase imports of the manufactured good.

Table 3: Five Trade Regimes

| Regime | $P_{ai}$ | Trade flows of agricultural good |
|---|---|---|
| 1: Exports to World | $P_{ai} = \frac{P_{aw}}{\tau_w \tau_i}$ | Interior to Coast and World |
| 2: Self-Sufficiency | $\frac{P_{aw}}{\tau_w \tau_i} < P_{ai} < \frac{\tau_w P_{aw}}{\tau_i}$ | Interior to Coast only |
| 3: Import Substitution | $P_{ai} = \frac{\tau_w P_{aw}}{\tau_i}$ | Interior to Coast and World to Coast |
| 4: Interior Isolation | $\frac{\tau_w P_{aw}}{\tau_i} < P_{ai} < \tau_i \tau_w P_{aw}$ | World to Coast only |
| 5: Interior Imports | $P_{ai} = \tau_i \tau_w P_{aw}$ | World to Coast and Interior |

Suppose that the economy as a whole has a comparative advantage in agriculture relative to the rest of the world by choosing values of the productivity parameters for the agricultural good ($B_a$) and the manufactured good ($B_m$) such that in the absence of resource revenues the country would be in regime 1, exporting the agricultural good from the Interior to the World. As resource revenues increase, trade flows move through each of the different regimes sequentially. With sufficiently large resource revenues, trade flows of the agricultural good can even be completely reversed (regime 5), with the Interior importing it from the World.

Aside from the productivity parameters and resource revenues, trade costs $\tau_w$ and $\tau_i$ are clearly important in determining the prevailing trade regime. The larger is $\tau_w$, the larger is the range of values of $P_{ai}$ that fall in regime 2, in which the Interior supplies the Coast with the agricultural good but there is no trade of the agricultural good with the World. Conversely, as $\tau_w$ falls to 1, regime 2 disappears as the values of $P_{ai}$ in regimes 1 and 3 converge. Likewise, the larger is $\tau_i$, the larger is the range of values of $P_{ai}$ in regime 4, in which the Interior does not export or import the agricultural good (even with the Coast). As $\tau_i$ falls to 1, regime 4 disappears as the values of $P_{ai}$ in regimes 3 and 5 converge.

For simplicity, I have treated the agricultural good as a single composite good with a single productivity parameter and subject to a single set of trade costs. In reality, a country produces and consumes a wide range of agricultural goods, which may have a wide range of local productivities. The goods with the highest productivity may be exported to the World (regime 1) even when resource revenues are high, while goods with lower productivities may fall in each of the subsequent regimes. Trade costs may also vary across goods (e.g. due to differences in perishability and value-to-weight ratios), and $\tau_i$ may vary across sub-regions within a country's interior, which may have easier or more difficult access to coastal ports. These heterogeneities in productivity and trade costs explain the heterogeneity in the trade pattern across crops at a given level of resource revenues seen in the columns in table 2. By aggregating crops into a single composite, the model focuses attention instead on how these trade patterns change when resource revenues change over time (as in the rows in table 2). In the next section, I use a calibrated version of the model to explore how these changes affect the relative size of different sectors and the welfare of different groups.

## 3.3 Calibration and Simulations of Changes in Resource Revenues

The values of the key parameters that I use for the calibrated version of the baseline model are summarized in table 4. My goal in calibrating the model is not to use it to make precise quantitative predictions, but rather to use it for numerical simulations to obtain qualitative results that cannot be proved mathematically. My calibrated parameters are therefore intended to be broadly representative of conditions in the countries of interest.

Table 4: Calibration of Model Parameters

| Parameter | Calibration |
|---|---|
| World prices | $P_{aw} = P_{mw} = 1$ |
| Trade costs | $\tau_i = \tau_w = 1.5$ |
| Expenditure shares | $\alpha_a = 0.4$, $\alpha_m = \alpha_n = 0.3$ |
| Labor force | $\bar{L}_i = 650$, $\bar{L}_c = 350$ |
| Labor share | $\beta = 0.44$ |
| Productivity | $B_a = 58.4$, $B_m = 14.4$ |
| Revenue shares | $r_i = 0.65$, $r_c = 0.35$ |
| Resource revenues | $R = 0$ to $2,000$ |

For simplicity, I let the world prices of the agricultural and manufactured goods both be 1 by choice of units, and I assume that these prices are constant over time. For trade costs, I base my calibration on estimates of additive trade costs for cereals for Nigeria for 2003–2013 from Porteous (2019). Average estimated external trade costs from two Nigerian ports to the least-cost world market are 0.477 USD/kg, average estimated internal trade costs along the least-cost path from a port to the largest city in each of the four interior geopolitical zones of Nigeria are 0.350 USD/kg, and the average domestic price for all cereals was 0.652 USD/kg during the study period, implying external and internal iceberg trade costs of 1.73 and 1.54 respectively. I let both trade cost parameters equal 1.5.

The share of household consumption expenditure spent on food was 0.57 in Nigeria in 2019, with expenditure on non-food items split between tradables (clothing, household goods...) and non-tradables (rent, services...) (NBS 2020). Household consumption expenditure averaged 70% of Gross National Expenditure in Nigeria from 1996 to 2015, so I calibrate the expenditure share for the agricultural good to $\alpha_a = 0.57(0.7) = 0.4$. Assuming that other expenditure (including government and investment expenditure) is split roughly equally between non-agricultural tradables and non-tradables, I let $\alpha_m$ and $\alpha_n$ both equal 0.3.

I let the total labor force equal 1,000 by choice of units, with 65% allocated to the Interior and 35% to the Coast. In Nigeria, 34.7% of the population in 2015 lived in the two coastal geopolitical zones (the South West and the South South), with 40.3% of the population of these two zones in urban areas with more than 300,000 residents, as compared to 20.7% in the four interior zones (NBS 2018, UN Population Division 2018). In Angola, 38.4% of the population in 2015 lived in Luanda, Benguela, or Cabinda provinces, three coastal provinces with ports where 83.6% of the population lived in urban areas with more than 300,000 residents, as compared to 12.7% in the rest of the country (INE 2016, UN Population Division 2018).

For the supply parameters, I calibrate $\beta$ to 0.44, the relative input cost share of labor to land estimated by Fuglie (2015) for sub-Saharan Africa from 1961 to 2008. I use the same value of $\beta$ for the manufactured good. Jayadev (2007) and Guerrero (2019) both report economy-wide labor shares for Nigeria under 0.2, but (as both papers note) these are underestimates due to low employment in the formal sector and large (uncaptured) employment (including self-employment) in the informal sector. I then set the relative values of $B_a$ and $B_m$ such that 10% of production of the agricultural good is exported to the World with zero resource revenues (a percentage close to that of Angola's in 1961–1970 based on the data in table 2). I set the absolute values of $B_a$ and $B_m$ such that the prices of the agricultural good and non-tradables in the Interior are equal with zero resource revenues.

I set the share of resource revenues accruing to each region to match the population shares ($r_i = 0.65$ and $r_c = 0.35$). It is likely that a larger share of revenues ends up in urban coastal areas (where oil extraction and political power are sometimes both concentrated), but using different shares does not affect the key results discussed below as long as the shares remain constant at different levels of resource revenues $R$. I proceed to run simulations for values of $R$ ranging from 0 to 2,000. In the simulation results, resource revenues reach 39.5% of total national income when $R$ is 2,000. This is in between the shares of crude oil exports in GDP of Nigeria (20.7%) and Angola (57.1%) during the oil boom of 2000–2014 (table 1).

The transition between trade regimes as resource revenues increase from 0 to 2,000 is clearly visible in the graphs in figure 4. As shown in the left panel, the economy starts as an exporter of the agricultural good (regime 1), transitions through self-sufficiency (regime 2), and then imports increasing amounts of the agricultural good as resource revenues increase and the Interior transitions from exporting to the Coast (regime 3), to neither importing nor exporting (regime 4), to importing (regime 5). As shown in the right panel, the real exchange rate in the Interior and the labor allocated to the agricultural good (and by extension its production) decrease as resource revenues increase, with the notable exception of regime 4, in which the agricultural good behaves like a non-tradable good, its price increases proportionally to the price of non-tradables, and the local real exchange rate, labor allocation, and production remain constant.

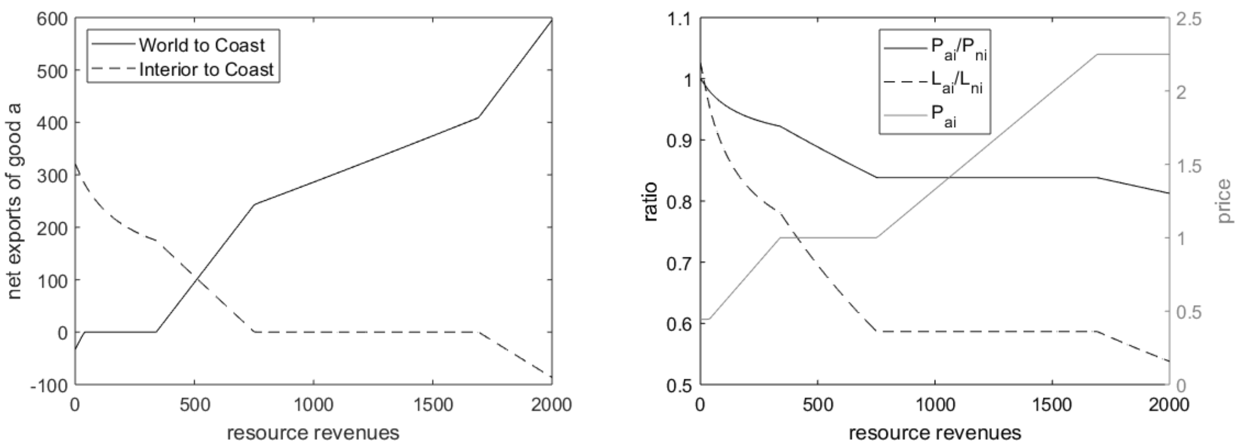


Figure 4: Effects of Changes in Resource Revenues on Trade, Prices, and Labor Allocation

*Notes:* Variable values are from model simulation results using parameters from table 4. Thresholds between trade regimes are located at inflection points.

The corresponding changes in real income for workers and specific factors in the Interior and on the Coast are shown in the left panel of figure 5. Increases in resource revenues are generally good for workers (with the exception of regime 2 on the Coast), as wages are pulled up by increasing demand for non-tradables. The decline in real income for capital-owners (specific factors in the manufacturing sector on the Coast), meanwhile, reflects a contraction due to standard Dutch disease. In contrast, farmers (specific factors in the agriculture sector in the Interior) experience alternating decreases and increases in real income as resource revenues increase. When local prices of the agricultural good are pinned down by the world price (regimes 1, 3, and 5), an increase in resource revenues causes farmers to lose real income. But when the agricultural good is either not traded with the World (regime 2) or with the Coast (regime 4), farmers gain real income, as the agricultural good increases in price like a non-tradable good would, while the price of the manufactured good remains constant.

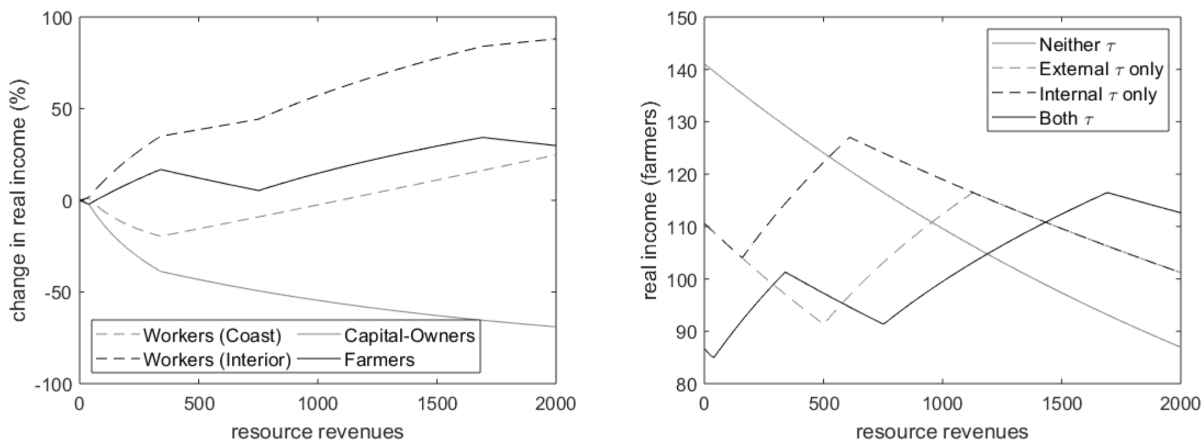


Figure 5: Effects of Changes in Resource Revenues on Welfare

*Notes:* Variable values are from model simulation results using parameters from table 4. Capital-owners and farmers are the specific factors in the Coast and Interior respectively. Real income is calculated by dividing nominal income $Y$ by the Cobb-Douglas price index $[(P_a/\alpha_a)^{\alpha_a}(P_m/\alpha_m)^{\alpha_m}(P_n/\alpha_n)^{\alpha_n}]$.

The importance of including trade costs to fully understand the effects of resource revenues on farmers in remote locations is underscored by the right panel of figure 5, which compares the trajectory of real income for farmers with no trade costs, external trade costs only, internal trade costs only, and both internal and external trade costs. In the absence of trade costs, farmers experience a monotonic decline in real income as resource revenues increase (standard Dutch disease). Including either external or internal trade costs introduces a single regime (2 or 4) in which farmers gain as resource revenues increase. In both of these cases, there is a level of resource revenues for which farmers are better off than they were with zero resource revenues, although further declines in real income in regime 5 lead to a small loss in overall income when resource revenues reach 2,000. Including both internal and external trade costs together means that there are two regimes in which farmers gain. Due to the gains in these two regimes, real income for farmers is actually 30% *higher* with resource revenues of 2,000 than with no resource revenues at all.

These initial simulation results have important implications, which are explored further in the counterfactual policy simulations later in this paper. As resource revenues increase, high trade costs can be beneficial to farmers (and specific factors in tradable sectors more generally) by insulating them from the effects of Dutch disease. Remote farmers facing high trade costs are likely to do better than exposed farmers facing low trade costs. In contrast, as resource revenues fall, high trade costs mean that remote farmers can miss out on the potential stimulating effects of reverse Dutch disease because of their isolation from the world market.

### 3.4 Extension: Non-Traded Agricultural Goods

In this sub-section, I extend the baseline model to account for the empirical fact that some major crops in the countries of interest are not traded internationally. Suppose that the agricultural sector in the Interior now produces two goods: a tradable agricultural good ($a$) as in the original model and a second good ($b$) that can be traded with the Coast but not with the World. For simplicity, suppose that the two goods are subject to the same trade costs $\tau_i$ for trade with the Coast. Good $b$, however, is subject to prohibitively high trade costs with the World.

Let good $b$ be produced by the same production function as good $a$ (equation 1), with $B_b = B_a$. The equilibrium wage condition (equation 3) must now hold for both goods $a$ and $b$ in the Interior. Suppose that consumers still spend the same fraction of their income on agricultural goods, but that half of this expenditure is on tradable good $a$ and the other half on non-traded good $b$ (in the calibrated model, this means that $\alpha_b = \alpha_a = 0.2$). Total income in the Interior is now given by:

$$Y = P_a Q_a + P_b Q_b + P_n Q_n + rR \tag{11}$$

Proposition 2, which is proved in the appendix, shows that the addition of the non-traded agricultural good ($b$) does not change the labor allocation between the agricultural sector and non-tradables ($n$) in the Interior, which is still determined by the share of resource revenues in total income:

**Proposition 2.** *In the extended model with the non-traded agricultural good $b$, the labor allocation between the combined agricultural sector ($L_t = L_a + L_b$) and the non-tradable sector ($L_n$) is still determined by equation 10. Within the agricultural sector, the relative production of each good is determined by their relative price in the Interior:*

$$\frac{Q_a}{Q_b} = \left(\frac{P_a}{P_b}\right)^{\beta/(1-\beta)} \tag{12}$$

As shown in proposition 2, the relative production of the two agricultural goods is determined by their relative local price. To see how relative prices and production change as resource revenues change, I re-run the model simulations in which I vary resource revenues from 0 to 2,000. Maintaining $B_m$ at the same value as in the baseline calibrated model, I adjust $B_a = B_b$ until 10% of the total production of agricultural goods $a$ and $b$ is once again exported to the World with zero resource revenues, which occurs when $B_a = B_b = 41.5$.

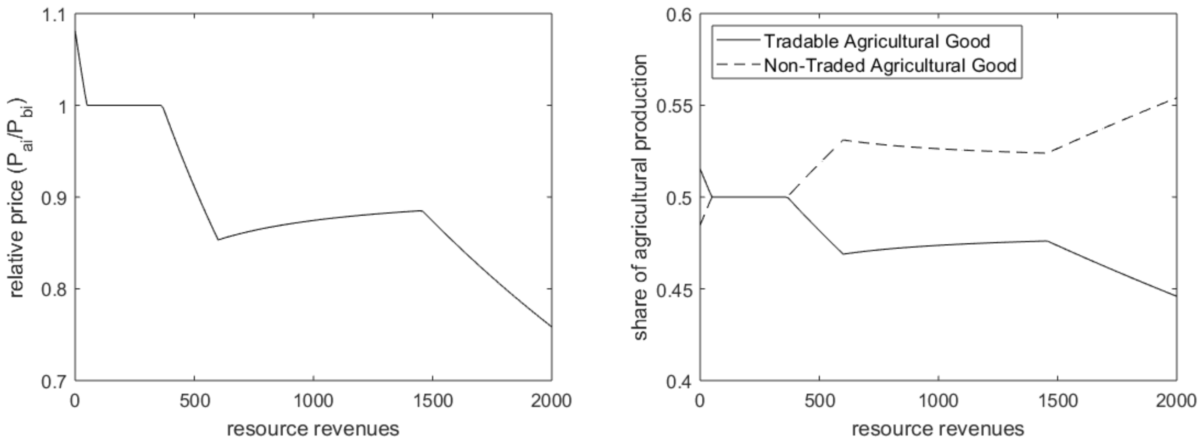


Figure 6: Relative Price and Production of Tradable and Non-Traded Agricultural Goods

*Notes:* Variable values are from simulation results from the model extension using parameters from table 4, with the exception of $\alpha_a = \alpha_b = 0.2$ and $B_a = B_b = 41.5$. Shares of agricultural production are based on total quantities produced, e.g. $Q_a/(Q_a + Q_b)$ for good $a$.

Simulation results in figure 6 show an overall decline in the share of the tradable agricultural good in total agricultural production as resource revenues increase that is similar to that seen in the historical data in figure 3. However, the decline in both the relative local price of the tradable good and its production share occurs exclusively in the three trade regimes in which its local price is pinned down by the world price (regimes 1, 3, and 5). In regime 2, both agricultural goods are traded with the Coast but not the World, so the relative price and production share are constant at 1 and 0.5, since the demand and supply parameters for the two agricultural goods in the calibrated model are identical. In regime 4, the non-traded agricultural good continues to be traded with the Coast (since it is only produced in the Interior), while the tradable agricultural good is not traded at all. Overall demand for the non-traded agricultural good increases more slowly than for the tradable good as resource revenues increase, since income on the Coast is rising less rapidly due to the constant price of the manufactured good. This leads the relative price and production share of the tradable agricultural good in the Interior to *increase* slightly as resource revenues increase in this regime.

# 4 Household-Level Evidence of Reverse Dutch Disease

Having explored theoretically how changes in resource revenues in a context with high trade costs can alter trade and production patterns and affect the welfare of different groups, in this section I present empirical evidence on the effects of the current slump in oil prices. Using data from a panel of four nationally-representative household surveys conducted since 2010 in Nigeria, Africa's largest oil exporter, I show that factors of production have already started to shift both across sectors and across crop categories within agriculture in ways consistent with the model simulations in the previous section. Heterogeneity in the response to the drop in oil revenues is correlated with heterogeneity in exposure to changes in oil revenues and heterogeneity in internal trade costs separating farmers from the world market.

The World Bank's LSMS-ISA project has collaborated with Nigeria's National Bureau of Statistics (NBS) since 2010 to incorporate an agriculture-focused panel component within the larger General Household Survey conducted regularly by NBS. The LSMS-ISA household surveys, which have now been conducted in 8 countries, were designed to be the gold standard in terms of household-level data on agriculture in sub-Saharan Africa. The information collected is highly detailed, including individual-level data on time use, plot-level data on input use, and GPS measurements of individual plot sizes (Christiaensen 2017). Nevertheless, the usefulness of the data has some limitations. Because the surveys are representative at the household level rather than the area level, they include few large farms (Jayne et al. 2016). The data collection exercise has also highlighted how difficult it is to accurately measure input use and output on small farms using household recall and non-standard units. The survey data are very noisy, and measurement error due to both misreporting and respondent misperceptions has been shown to explain much of the apparent productivity dispersion and misallocation of factors of production in African agriculture (Abay, Bevis, and Barrett 2020; Gollin and Udry 2021; Maue, Burke, and Emerick 2020).

In Nigeria, four waves of the LSMS-ISA panel survey have been completed to date (NBS 2011, 2013, 2016, 2019). In each wave, households were visited twice: once after planting (data collection in July through November) and once after harvest (data collection in January through April of the following year). The data presented in this section were all collected in the post-planting questionnaires, in July through November of 2010, 2012, 2015, and 2018. Nigeria's annual oil revenues were increasing in 2010 and near all-time highs in 2012 before plummeting in 2015 (figure 2), although the full effects of the oil price crash may not have been felt until after 2016, when the economy experienced a –1.6% contraction of GDP and the naira lost 37% of its value against the US dollar.

The initial panel sample for the 2010 LSMS-ISA survey consisted of 5,000 households — 10 in each of 500 enumeration areas — and was designed to produce representative data at both the national level and the level of Nigeria's six geopolitical zones. For the fourth wave in 2018, a partial refresh of the panel was conducted, with the households from 159 of the original enumeration areas retained from previous waves. I focus my analysis on the continuous panel of 1,386 households that were surveyed in all four waves. Of these households, 1,041 reported cultivating crops in at least one of the four waves.

Table 5 shows that factors of production have shifted into agriculture, starting in the 2015 survey wave and accelerating in the 2018 wave. The upper portion of the table shows that the percentage of all working individuals age 5 and over working outside the household has fallen by a third, while the percentage working on the household farm has increased from 62.8% during the peak in oil revenues in 2012 to 71.6% in 2018. A parallel shift is evident in the household-level data in the bottom portion of the table. The percentage of households planting field crops increased from 57.9% in 2012 to 69.1% in 2018, and the median area planted by these households increased 21% from 0.56 to 0.68 hectares.

Table 5: Shift of Factors of Production into Agriculture

| | 2010 | 2012 | 2015 | 2018 |
|---|---|---|---|---|
| Share of Labor Force Working Outside Household | 0.148 | 0.144 | 0.099 | 0.095 |
| Share of Labor Force Working on Household Farm | 0.645 | 0.628 | 0.671 | 0.716 |
| Share of Labor Force Working in Household Non-Farm Enterprise | 0.370 | 0.393 | 0.344 | 0.363 |
| Share of Households Planting Field Crops[a] | 0.574 | 0.579 | 0.617 | 0.691 |
| Houeshold Median Area Planted (Hectares) | 0.53 | 0.56 | 0.53 | 0.68 |

*Notes:* Data are from the post-planting questionnaires for the 1,386 households surveyed in all four waves. The median area planted excludes households not planting field crops in each wave. The labor force shares are based on data for all household members age 5 and over engaged in at least one of the three activities.
[a]Following the survey categorization, this includes all annual crops including vegetables but not tree/permanent crops like bananas, cocoa, and oil palm (for which the response time is likely much slower).

The shift of factors of production seen in table 5 is largest in the South South zone, the coastal region around the Niger Delta where Nigeria's oil production is concentrated. Nigeria's constitution entitles oil-producing states to 13% of the revenues generated from their own natural resources (Takon 2014). Data from Nigeria's Federation Account Allocation Committee (FAAC) shows that the six states in the South South zone received 31.9% of the 6.8 trillion naira (19 billion USD) of funds distributed to state governments in 2017–2019, despite accounting for only 14.9% of national population. Given this larger share of overall oil revenues, this zone should experience larger changes in the share of resource revenues in total income when revenues fall, resulting in larger shifts in factors of production across sectors (proposition 1). Consistent with this theoretical result, the share of individuals working on their household farm in the South South zone increased by 51% from 0.443 in 2012 to 0.671 in 2018, while the share of households planting field crops increased by 75% from 0.386 in 2012 to 0.674 in 2018, much larger increases than in the rest of the country (where the individual labor share increased from 0.667 to 0.724 and the household share from 0.615 to

0.694).

Within the agricultural sector, production has started to shift away from non-traded crops and towards tradable crops, as predicted by the extension of the model with non-traded agricultural goods. As seen in figure 7, although the share of farming households planting root crops has remained relatively constant, the shares producing non-traded cereals (millet, sorghum, and fonio), non-traded legumes (cowpeas/beans and pigeon peas), and vegetables all peaked in 2012 and have fallen sharply since then. In contrast, the shares of households producing traded cereals (maize and rice) and traded legumes (groundnuts, soybeans, and sesame) have increased.

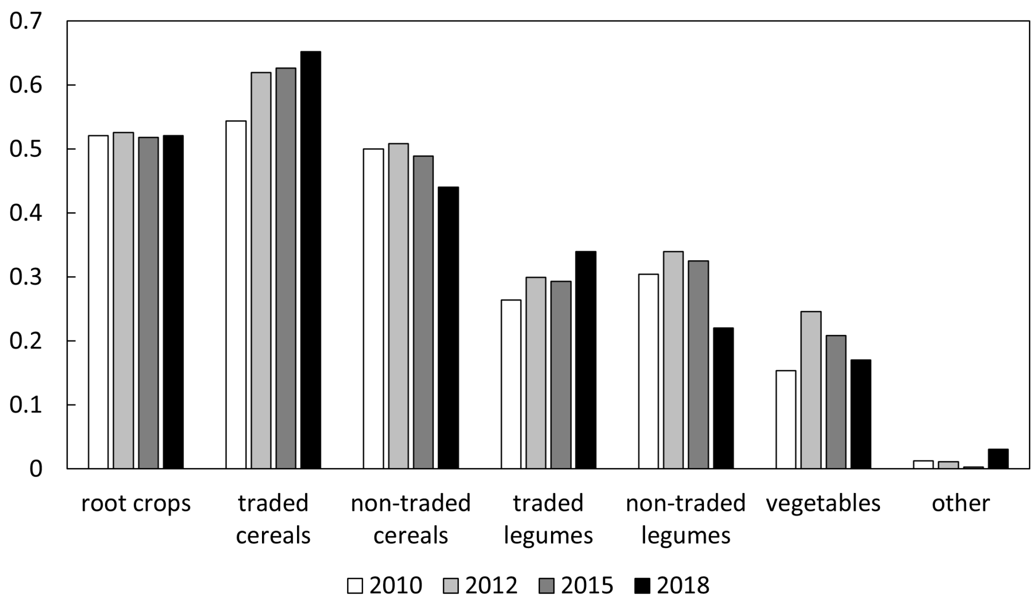


Figure 7: Share of Farming Households Planting Different Crop Types

*Notes:* For consistency, the sample is restricted to those households planting field crops in all four waves. Root crops include cassava, yams, cocoyam, sweet potato, and potato. Traded cereals include maize and rice. Non-traded cereals include sorghum, millet, and fonio. Traded legumes include groundnuts, soybeans, and sesame. Non-traded legumes include cowpeas/beans and pigeon peas.

A key prediction of the model is that the effects of changes in resource revenues depend on the prevailing trade regime. More isolated areas facing higher internal trade costs are more likely to be in regime 4, in which local agricultural production is unaffected by changes in resource revenues (figure 4) and farmers are worse off as resource revenues fall (figure 5). In table 6, I report results from OLS regressions of the change in the area of land cultivated at the household level from 2012 to 2018 on five distance variables reported in the LSMS-ISA data at the household level. I control for the average size of cultivated land in 2012 and 2018 in these regressions (since land size is positively correlated with remoteness) and include zonal fixed effects. I find a strong and statistically significant negative correlation between the change in the area of land cultivated and the distance to an international border, a proxy for internal trade costs $\tau_i$. A one standard deviation decrease in this distance is correlated with 0.40 hectares more of an increase in cultivated land from 2012 to 2018, more than two-thirds of the median area cultivated in 2012 (table 5). The other distance variables do not appear to be correlated with the acreage response, with the possible exception of the distance to the nearest hub market. The estimated coefficient on this variable is not statistically significant at conventional levels, but the magnitude suggests that a one standard deviation decrease is correlated with 0.09 hectares more of an increase in cultivated land. These results suggest that the production response to the fall in oil revenues is indeed stronger in areas more exposed to the world market, which are less likely to be in trade regime 4.

Table 6: Correlation of Acreage Response with Location

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Distance to Federal Road | –0.00664 | | | | |
| | (0.0155) | | | | |
| Distance to Town | | –0.000585 | | | |
| | | (0.00778) | | | |
| Distance to Own State Capital | | | 0.00154 | | |
| | | | (0.00227) | | |
| Distance to Hub Market | | | | –0.00207 | |
| | | | | (0.00171) | |
| Distance to Border Post | | | | | –0.00222*** |
| | | | | | (0.000791) |
| Land Size | –0.0959 | –0.102 | –0.108 | –0.0964 | –0.107 |
| | (0.251) | (0.248) | (0.242) | (0.242) | (0.238) |
| Fixed Effects | Zonal | Zonal | Zonal | Zonal | Zonal |
| Observations | 1,006 | 1,006 | 1,006 | 1,006 | 1,006 |
| Clusters | 131 | 131 | 131 | 131 | 131 |
| Mean of Distance Variable | 7.45 | 21.0 | 74.7 | 73.9 | 338.6 |
| S.D. of Distance Variable | 8.33 | 15.7 | 56.9 | 42.7 | 178.4 |

*Notes:* The dependent variable is the change in the area of land cultivated at the household level from 2012 to 2018 (median 0.11 Ha). The sample is restricted to households cultivating in at least one of these years. Land size is the average area cultivated in the two years (median 0.59 Ha). Standard errors in parentheses are clustered by enumeration area. *Significant at 10%, **Significant at 5%, ***Significant at 1%.

In table 7, I report results from probit regressions using the same five distance variables, in which the dependent variable is an indicator variable equal to one if the household did not cultivate land in 2012 but did in 2018. I find that households closer to federal roads, to towns (of more than 20,000 population in the 2006 census), and to their own state capital are more likely to have started farming between 2012 and 2018. A one standard deviation decrease in these three distances (from half a standard deviation above the mean to half a standard deviation below the mean) is correlated with an increase of 0.079, 0.073, and 0.057 respectively in the probability of starting farming, compared to a frequency in the full sample of 0.203. Unlike the acreage response, which is correlated with access to international markets, the likelihood of switching into the agricultural sector is correlated with proximity to urban, administrative centers. Since oil revenues in Nigeria are largely distributed to state and local governments located in towns and cities, proximate areas likely experience larger changes in the share of resource revenues in total income when resource revenues fall, leading to more reallocation of labor across sectors in these areas (proposition 1). At the regional level, the oil-producing South South zone (which accounts for 15.5% of the 1,386 households in the continuous panel) had only 10.0% of the total households cultivating land in both 2012 and 2018 but 34.3% of the total households starting farming between 2012 and 2018.

Table 7: Correlation of New 2018 Farming Households with Location

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Distance to Federal Road | –0.0346*** | | | | |
| | (0.0118) | | | | |
| Distance to Town | | –0.0169** | | | |
| | | (0.00682) | | | |
| Distance to Own State Capital | | | –0.00362** | | |
| | | | (0.00155) | | |
| Distance to Hub Market | | | | –0.00147 | |
| | | | | (0.00185) | |
| Distance to Border Post | | | | | –0.000357 |
| | | | | | (0.000460) |
| Constant | –0.608*** | –0.506*** | –0.579*** | –0.725*** | –0.954*** |
| | (0.108) | (0.148) | (0.130) | (0.161) | (0.178) |
| Observations | 1,006 | 1,006 | 1,006 | 1,006 | 1,006 |
| Clusters | 131 | 131 | 131 | 131 | 131 |

*Notes:* All columns are probit regressions. The dependent variable is an indicator variable equal to one if the household did not cultivate land in 2012 but did in 2018 (mean 0.203). The sample is restricted to households cultivating in at least one of these years. Standard errors in parentheses are clustered by enumeration area. *Significant at 10%, **Significant at 5%, ***Significant at 1%.

Table 8 shows how two proxies for welfare — the share of households reporting experiencing a food shortage in the previous 12 months and the value of monthly non-food expenditure on a set of 29 regularly-purchased goods and services — have changed as resource revenues have fallen. For comparison purposes, expenditure data for 2018 in naira are deflated to 2012 levels using Nigeria's Consumer Price Index. The data for all households show how difficult the decline in oil prices has been for many Nigerians, consistent with the effects of declining resource revenues on workers seen in the left panel of figure 5. The share of households experiencing a food shortage has increased by 72% from 0.248 to 0.427 (partly due to the increase in the prices of tradable agricultural goods), while median real non-food expenditure has fallen by 12%. Continuing farmers (those cultivating land in both 2012 and 2018) appear to be poorer on average than other households but have been less affected by the loss in revenues, with a smaller decrease in food security and a 7% increase in median real non-food expenditure. This reflects the possibility of gains for specific factors in agriculture due to reverse Dutch disease seen in figure 5, especially for those in less-isolated areas. New farmers, in contrast, appear to be better-off on average than other households (possibly due to their proximity to urban, administrative centers) but experience larger-than-average decreases in food security and a 6% drop in median real non-food expenditure. It is perhaps more appropriate to think of these new farmers as being pushed into agriculture by rising food prices and declining non-agricultural income opportunities than being attracted into agriculture by favorable market conditions.

Table 8: Changes in Food Security and Non-Food Expenditure

| | 2012 | 2018 |
|---|---|---|
| Share of All Households Experiencing Food Shortage | 0.248 | 0.427 |
| Share of Continuing Farmers Experiencing Food Shortage | 0.261 | 0.400 |
| Share of New 2018 Farmers Experiencing Food Shortage | 0.184 | 0.476 |
| Median Non-Food Expenditure for All Households | 3,000 | 2,642 |
| Median Non-Food Expenditure for Continuing Farmers | 1,800 | 1,917 |
| Median Non-Food Expenditure for New 2018 Farmers | 4,253 | 4,016 |

*Notes:* All households includes all households (farming or not) in the continuous panel. Continuing farmers are those cultivating land in both 2012 and 2018. New farmers are those cultivating land in 2018 but not in 2012. Expenditure data in Nigerian naira are for all 29 non-food items included in the survey's one-month recall. Values for 2018 are deflated to 2012 levels using Nigeria's Consumer Price Index.

Taken together, the household survey data from Nigeria presented in this section suggest that the loss of oil revenues has already had a significant impact on local economic activity, in ways which are broadly consistent with the predictions of my model. In the next section, I use the calibrated model to explore different policy options that have been used or are available to governments seeking to facilitate the potential positive effects of reverse Dutch disease on their agricultural sectors.

# 5 Policy Counterfactuals

The sharp decline in oil revenues since 2015 (figure 2) and the consequent negative effects on household welfare (table 8) have prompted governments in Africa's oil-rich economies to look for appropriate policy responses. Given their historical comparative advantage in agriculture, a number of countries have sought to actively stimulate their agricultural sectors as a way of diversifying their economies away from oil. Angola and Congo, for instance, have both embarked on commercial agriculture projects funded by the World Bank with budgets of $100 million USD or more that seek to improve both local agricultural productivity and internal market access. The Buhari administration in Nigeria, which took office in May 2015, has been particularly ambitious in prioritizing agriculture through a variety of initiatives, including the Central Bank of Nigeria's Anchor Borrowers' Programme. A key component of Nigeria's approach under Buhari has been to increase external trade costs for imported agricultural goods to stimulate domestic production. This has included restricting access to foreign exchange since June 2015 for imports of a number of important agricultural products including rice and palm oil, and closing Nigeria's land borders starting in August 2019 to prevent the smuggling of agricultural imports. These policies may be contributing to the shift of factors of production into agriculture observed in the household survey data from Nigeria presented in the previous section.

My initial model simulations (figures 4 and 5) showed that in the absence of trade costs, a decline in resource revenues should lead automatically to reverse Dutch disease, with both an increase in agricultural production and welfare gains for farmers. With trade costs, in contrast, the effects depend crucially on the trade regime. A common situation is for much of a country to find itself in regime 4 ("interior isolation"), either at the onset of the decline in resource revenues or after an initial decline has led to a transition from regime 5 to regime 4. In regime 4 (which, as in figures 4 and 5, can be quite wide), further declines in resource revenues lead to welfare losses for farmers and stagnant production. Accelerating the transition from regime 4 to regime 3 ("import substitution"), in which production expands and farmers benefit from reverse Dutch disease, may therefore be an important short-term policy goal.

In figure 8, I show how farmers' real income changes in the calibrated model as resource revenues decline from 1,200 (a level in which the model economy is in regime 4) to 0 under three different potential policy approaches. Changing external trade costs $\tau_w$ as Nigeria has done is perhaps the easiest way of affecting the prevailing trade regime, since it can be implemented through a change in trade policy. In order to shift from regime 4 to regime 3, agricultural products from the Interior have to be competitive on the Coast with imports from the World (table 3). One way to achieve this is by increasing external trade costs so as to increase the Coast price of imports from the World. I simulate this policy by increasing $\tau_w$ from 1.5 to 2.5 as resource revenues decline from 1,200 to 1,000, and then maintaining $\tau_w$ at 2.5 as revenues continue to decline to 0. A comparison of this "increase $\tau$" approach with a "laissez faire" approach in the left panel of figure 8 reveals several significant drawbacks. In the short run, farmers (and other consumers in the Interior) are hurt by the increase in price of the imported manufactured good[4]. More importantly, as resource revenues continue to decline in the longer run, the higher external trade costs lead the country to shift more quickly from regime 3 to regime 2 ("self-sufficiency"), in which farmers once again lose from further declines in resource revenues. While increasing external trade costs does lead to a faster transition from regime 4 to regime 3 than the "laissez faire" approach and a better outcome for farmers over an intermediate range of resource revenues, the welfare declines associated with regime 2 start sooner and last for longer, leading to worse outcomes for farmers at lower levels of resource revenues. Even when resource revenues fall to 0, the high external trade costs under the "increase $\tau$" approach mean that the country is still in regime 2, not yet exporting the agricultural good to the World.

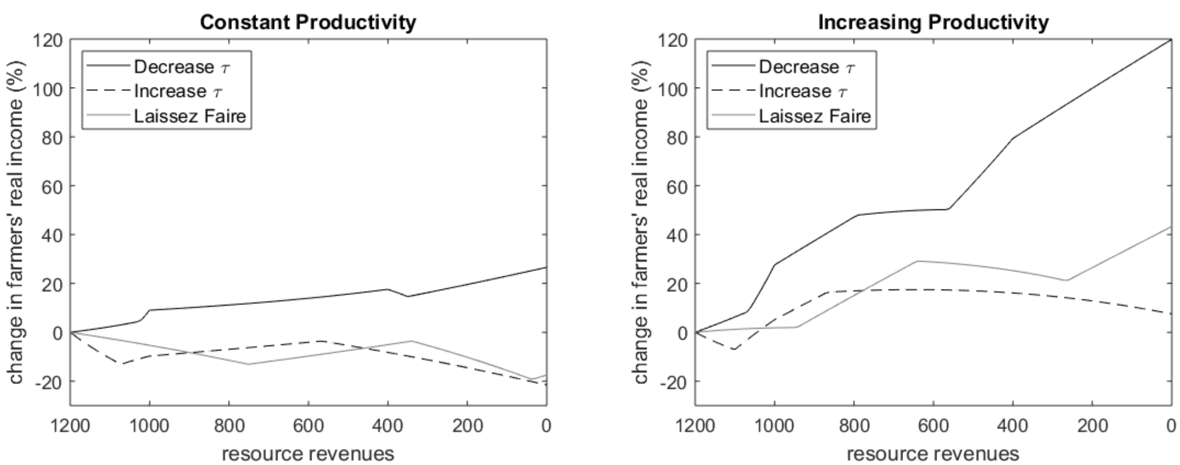


Figure 8: Welfare Effects on Farmers of Policy Approaches to Falling Resource Revenues

*Notes:* Variable values are from model simulation results using parameters from table 4 with changes in $\tau_w$, $\tau_i$, and $B_a$ at different levels of resource revenues as described in the text.

The left panel of figure 8 also includes a third policy approach, which takes into account the effects of declining resource revenues on farmers in the different trade regimes, the effects of changes in trade costs on farmers in the different trade regimes, and the effects of changes in trade costs on the thresholds between the regimes. To accelerate the transition from regime 4 to regime 3, this "decrease $\tau$" approach first lowers internal trade costs $\tau_i$ from 1.5 to 1.05 as resource revenues decline from 1,200 to 1,000[5]. This decreases the Coast price of

[4]In addition to hurting farmers in their capacity as consumers, the increased price of imported goods can lead to higher production costs if farmers rely on imported inputs like fertilizer.

[5]Iceberg internal and external trade costs of 1.05 are low but potentially achievable values that are in line with international benchmarks used by Porteous (2019) as counterfactual low trade costs for the African agricultural sector (1.03 for both internal and external trade costs when converted to iceberg form).

imports from the Interior to make them competitive with imports from the World (instead of increasing the Coast price of imports from the World as in the "increase $\tau$" approach). In addition to enabling a faster transition to regime 3, this approach has immediate benefits for farmers (and other consumers in the Interior) by lowering the price of the imported manufactured good. Once farmers in the Interior are competitive on the Coast with imports from the World (regime 3), this approach then begins to slowly lower external trade costs $\tau_w$ from 1.5 to 1.05 as resource revenues decline from 1,000 to 400 so as to both delay the transition to regime 2 and reduce its duration. The decrease in $\tau_w$ is gradual enough that (i) the economy does not revert back to regime 4, and (ii) the negative effect of the falling price of the agricultural good on farmers is more than offset by the positive effect of declining resource revenues on farmers in regime 3.

Once external trade costs have fallen to 1.05 in the "decrease $\tau$" approach, the transition through regime 2 is relatively painless, and the model economy quickly enters regime 1, in which it exports the agricultural good to the World. Further decreases in resource revenues lead to large welfare gains as farmers are able to take advantage of the elastic world market. As shown in the top half of table 9, farmers' real income is 26.6% higher when resource revenues reach 0 than it was initially with resource revenues of 1,200, whereas it is 21.5% lower under the "increase $\tau$" approach and 17.5% lower under the "laissez faire" approach. Although workers and capital-owners on the Coast are worse off under the "decrease $\tau$" approach because the manufacturing sector (the comparative disadvantage sector) is less protected from imports from the World, the better outcomes for farmers and workers in the Interior more than make up for this difference. Overall, the "decrease $\tau$" approach is able to offset 26% of the decline in the combined real income of all consumer groups in both the Interior and the Coast experienced due to the loss of resource revenues.

Aside from trade costs, the other key variable determining the prevailing trade regime that can be influenced by policy is agricultural productivity, represented in the model by $B_a$. All else equal, an increase in agricultural productivity puts downward pressure on the local price of the agricultural good in the Interior, increasing the threshold levels of resource revenues between each of the trade regimes (table 3). In the right panel of figure 8, I re-run the simulations of the three policy approaches from the left panel while also including increases in agricultural productivity equivalent to 10% of initial productivity for every 100-unit decline in resource revenues[6]. For simplicity, I treat these productivity increases as exogenous, although in reality they may occur due to both endogenous learning-by-doing as agricultural production increases as well as exogenous productivity-enhancing policy initiatives.

[6] I start with the calibrated level of $B_a = 58.4$ from table 4 at $R = 1200$, so this means that $B_a$ increases by 5.84 for every 100-unit decrease in $R$.

Table 9: Percentage Changes in Real Income Under Alternate Policy Approaches

| Consumer Group<br>Location | Farmers<br>Interior | Workers<br>Interior | Capital<br>Coast | Workers<br>Coast | All Factors<br>Both | All Groups<br>Both |
|---|---|---|---|---|---|---|
| *Constant productivity:* | | | | | | |
| Laissez faire | –17.5% | –39.8% | +139.2% | –2.8% | –18.7% | –48.7% |
| Increase $\tau$ | –21.5% | –42.7% | +155.8% | +3.9% | –19.1% | –49.0% |
| Decrease $\tau$ | +26.6% | –7.6% | +79.8% | –26.9% | +1.4% | –36.1% |
| *Increasing productivity:* | | | | | | |
| Laissez faire | +43.3% | +4.6% | +139.2% | –2.8% | +19.3% | –24.8% |
| Increase $\tau$ | +7.5% | –21.5% | +250.7% | +42.5% | +10.9% | –30.1% |
| Decrease $\tau$ | +119.9% | +60.5% | +79.8% | –26.9% | +59.6% | +0.6% |

*Notes:* Percentage changes are for a simulated decline in resource revenues from 1,200 to 0 under the policy approaches described in the text. Farmers and capital refer to the specific factors in the agricultural and manufacturing sectors respectively. All factors includes both specific factors and both sets of workers but not rentiers. All groups includes rentiers as well and is hence representative of the economy as a whole.

Broadly speaking, productivity increases lead to a greater divergence in farmers' real income under the three policy approaches. In particular, the lower are external trade costs $\tau_w$, the higher the threshold of resource revenues at which the model economy starts exporting the agricultural good to the World (regime 1), at which point further increases in productivity lead to increases in production of the agricultural good without a fall in price. As shown in the bottom half of table 9, the increase in farmers' real income under the "decrease $\tau$" approach is 2.8 times larger when resource revenues fall from 1,200 to 0 than under the "laissez faire" approach and 16 times larger than under the "increase $\tau$" approach[7]. For the economy as a whole, the gains in real income under the "decrease $\tau$" approach are now enough to completely offset the losses due to the decline in resource revenues. Whereas total combined real income for all groups of consumers in the Interior and the Coast decreases by 48.7% when resource revenues fall from 1,200 to 0 under the "laissez faire" approach without productivity increases, it increases by 0.6% under the "decrease $\tau$" approach with productivity increases.

Taken together, the simulation results presented in this section suggest that policies that change external trade costs, internal trade costs, or productivity can alter the effects of a decline in resource revenues on farmers, on other factors of production, and on the country as a whole. While increasing external trade costs can help isolated farmers compete with imported agricultural goods in the short run, this extra protection backfires as resource rev-

[7]Due to the high trade costs in the "increase $\tau$" approach, the model economy is still in regime 2 when resource revenues are 0. The price of the agricultural good is 71% lower in the Interior than in the "decrease $\tau$" approach and 58% lower on the Coast (the source of the extra gains in real income for consumer groups on the Coast seen in table 9).

enues continue to decline, domestic prices fall, and they are unable to access the elastic world market. In the longer run, investments in lowering trade costs and improving productivity are necessary for farmers to benefit from reverse Dutch disease and for these benefits to offset the negative effects of the decline in resource revenues on the country as a whole.

# 6 Conclusion

I have used a calibrated theoretical model and a panel of household survey data to explore how the agricultural sector of oil-rich African economies — a tradable sector of comparative advantage facing high trade costs — is likely to be affected by reverse Dutch disease due to the low world oil prices that have prevailed since the end of 2014. Using national-level trade data, I showed that since becoming major oil exporters, these countries have switched from being net agricultural exporters to net agricultural importers, and their domestic agricultural production has shifted towards non-tradable goods. I then developed and calibrated a three-location model with both internal and external trade costs and exogenous revenues from an enclave resource sector. Changes in the level of resource revenues in the model led to shifts of mobile factors of production between local tradable and non-tradable sectors and transitions between five distinct trade regimes. Importantly, trade costs create two regimes in which the agricultural good behaves like a non-tradable good, insulating farmers from Dutch disease effects. The model's predictions are broadly consistent with the empirical changes observed in waves of Nigerian household survey data from before and after the fall in oil prices. Nigerian households have shifted both land and labor into agriculture since 2014. The acreage response has been larger in areas more exposed to international markets, and new farmers are concentrated in areas experiencing greater declines in revenues. Counterfactual policy simulations using my calibrated model showed that while increasing external trade costs may help extend the stimulating effects of reverse Dutch disease to more isolated farmers in the short run, lowering trade costs and improving productivity are more promising long run solutions that can help offset resource revenue losses by enabling farmers to transition towards competitive exports to the elastic world market.

Looking ahead, as the global economy starts to shift away from oil, it will be increasingly important to understand the opportunities, challenges, and potential policy approaches associated with declining resource revenues. My results have shown how frictions like trade costs, which separate local producers and consumers from world markets and each other, can be crucial in determining the ultimate effects of revenue declines. They also highlight the importance of understanding how reverse Dutch disease will affect tradable sectors other than manufacturing, which has been the traditional focus of the Dutch disease literature. A key question going forward for oil-rich countries with a comparative advantage in agriculture like those considered here will be the extent to which the kind of endogenous productivity growth generated by learning-by-doing and spillovers in manufacturing is also possible in agriculture.

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# Appendix: Proofs of Propositions

**Proof of Proposition 1.** Dividing equation 1 by equation 3 gives:

$$\frac{Q_t}{P_n} = \frac{L_t}{\beta P_t} \Rightarrow \frac{\beta P_t Q_t}{L_t} = P_n \tag{13}$$

Multiplying the right-hand side of this last expression by $\frac{Q_n}{L_n} = 1$ and rearranging gives:

$$\frac{L_t}{L_n} = \beta \frac{P_t Q_t}{P_n Q_n} \tag{14}$$

Note that by equation 6 and market clearing, $P_n Q_n = P_n C_n = \alpha_n Y$. This also means that $(1-\alpha_n)Y = P_t Q_t + rR$ by equation 7, so the last expression becomes:

$$\frac{L_t}{L_n} = \beta \frac{(1-\alpha_n)Y - rR}{\alpha_n Y} = \beta \frac{(1-\alpha_n) - \frac{rR}{Y}}{\alpha_n} \tag{15}$$

**Proof of Corollary 1.** From equation 10, it is clear that the share of resource revenues in total income ($\frac{rR}{Y}$) determines $L_t$ and $L_n$ given $\alpha_n$, $\beta$, and $\bar{L}$. Since $\frac{L_t}{L_n}$ is decreasing in $\frac{rR}{Y}$, $L_t$ is decreasing in this share, and $L_n$ is increasing in this share. Since labor is the only (non-fixed) factor of production, $L_t$ determines $Q_t$, and $L_n$ determines $Q_n$ (given supply parameters $\beta$ and $B_t$). $Q_n$ equals $C_n$ by market clearing. Since $Q_t$ is increasing in $L_t$ and $Q_n$ is increasing in $L_n$, $Q_t$ is decreasing in the share of resource revenues in total income, and $Q_n = C_n$ is increasing in the share of resource revenues in total income. By equation 4, $Q_t$ determines $\frac{P_t}{P_n}$, which must therefore decrease as $L_t$ decreases (as the share of resource revenues in total income increases).

**Proof of Proposition 2.** Since equations 1 and 3 still hold for both agricultural goods ($a$ and $b$) individually, equation 14 does too. Summing the expressions for $a$ and $b$ gives:

$$\frac{L_a + L_b}{L_n} = \beta \frac{P_a Q_a + P_b Q_b}{P_n Q_n} = \beta \frac{(1-\alpha_n)Y - rR}{\alpha_n Y} = \beta \frac{(1-\alpha_n) - \frac{rR}{Y}}{\alpha_n} \tag{16}$$

where the second equality follows from equation 11. To obtain equation 12, divide the expression for $a$ by the expression for $b$ rather than summing them to get:

$$\frac{L_a}{L_b} = \frac{P_a Q_a}{P_b Q_b} \Rightarrow \frac{L_a Q_b}{L_b Q_a} = \frac{P_a}{P_b} \Rightarrow \left(\frac{Q_a}{Q_b}\right)^{(1-\beta)/\beta} = \frac{P_a}{P_b} \Rightarrow \frac{Q_a}{Q_b} = \left(\frac{P_a}{P_b}\right)^{\beta/(1-\beta)} \tag{17}$$

using the facts that $L_t = \left(\frac{Q_t}{B_t}\right)^{1/\beta}$ for both $a$ and $b$ (equation 1) and $B_a = B_b$.