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Abstract

Extractive and agricultural resources do not have the same impact on poverty reduction and can compete with each other. We examine how extractive resource windfalls affect agricultural productivity, measured as the amount of output per worker in the agricultural sector. This is important since agricultural productivity is a key element of structural transformation and poverty reduction. To do this, we exploit a panel dataset of 38 countries over 1991-2016 and construct a country-specific commodity price index that captures resource-related gains and losses in aggregate disposable income. We find that an increase in the commodity price index leads to a drop in agricultural productivity in Sub-Saharan economies. Among the possible mechanisms to explain this result, our findings highlight the lack of spillovers across sectors and the low level of agricultural investment in autocratic regimes, both related to the exploitation of extractive resources. We also find that higher agricultural productivity is positively associated with the release of workers towards manufacturing and services, confirming its importance for structural transformation.

Keywords: Agricultural productivity ; Structural transformation ; Natural resource curse
JEL codes: O13; Q32

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1 Introduction

The long-standing literature on the *resource curse* has largely focused on the effect of natural resources on the manufacturing sector, institutions and long-term growth. As a consequence, little is known on how the presence of extractive resources may affect the agricultural sector in emerging countries, including in Sub-Saharan Africa (Dercon and Gollin, 2014). The goal of this paper is to fill this gap. This is important since agriculture employs most of the labor force in developing countries, and plays a critical role in structural transformation and economic development (Gollin et al., 2002, 2014b; Herrendorf et al., 2014).

To study how the exploitation of extractive resources may affect agriculture, we focus on Sub-Saharan Africa (SSA). Extractive resources play a crucial role in this region, and the level of agricultural output per worker is dramatically low. For instance, according to the *World Development Indicators* (WDI), in 2016, the level of output per worker in the agricultural sector was 25 times smaller than that of Europe. Though, agricultural productivity, as measured by the amount of output per unit of labor, is central to development. Its growth is often viewed as allowing a country to meet its food subsistence level and release workers towards more productive sectors, under certain conditions relative to trade openness (Gollin, 2010). This is also why we focus on this indicator.

Our goal is to analyze how resource windfalls may affect agricultural output per worker in SSA using a panel dataset of 38 countries over 1991-2016. Our results show that gains from resource extraction lower the level of agricultural productivity in a given country. To reach this conclusion, we exploit the exogeneity in the prices of six international commodities linked to extraction[1] and construct a country-specific index that captures gains and losses from resource exploitation.

We then investigate which macroeconomic channels could explain this negative link between natural resource windfalls and agricultural productivity. A key feature of agriculture in SSA is its low use of modern inputs and mechanization. For this reason, we explore three hypotheses possibly linking the exploitation of extractive resources to agricultural modernization.

[1]Namely oil, coal, gas, aluminum, copper, and gold.

First, we look at the lack of spillovers across sectors. Among others, Yang and Zhu (2013) show how a larger manufacturing sector may favor agricultural modernization through the provision of modern inputs, which become relatively cheaper as the sector expands. Following the literature on the so-called Dutch Disease, we examine whether the exploitation of natural resources hinder the development of manufacturing activities.[2] Indeed, we find evidence that positive variations in our commodity price index are associated with a decline in the size of the manufacturing sector. The expansion of the resource sector, at the expense of manufacturing, could therefore hinder the provision of modern inputs and thus affect agricultural productivity negatively.

Our second hypothesis concerns aggregate investment in agriculture. On the one hand, by increasing global income, resource windfalls may contribute to an increase in agricultural investment and, thus, potentially to modernization. On the other hand, resource-rich countries may be more corrupted than others.[3] If this the case, it is then likely that income windfalls are not reinvested in key sectors like agriculture. Our findings support the latter hypothesis. Indeed, we find that an increase in the commodity price index is negatively associated with the level of investment in agriculture in SSA. However, this negative effect becomes non-significant for less corrupted countries whose political regime is democratic. Globally this is consistent with the literature showing that the use of resource revenues for agriculture depends on the political agenda (Omgba, 2011; Levy, 2007; Bategeka and Matovu, 2011).

Our third hypothesis to understand why agricultural productivity and resource windfalls may be negatively correlated focuses on the role of trade. This channel, instead of explaining the negative effect of resources on agriculture, could actually help understanding how this effect could be attenuated. As commodity prices increase, the terms of trade rise, making it relatively cheaper to import modern inputs. As most countries in SSA rely on imports for modern inputs, resource gains could favor input adoption over the short term. However, the effect might be just temporary and not significant enough to have a strong impact on agricultural modernization. We test this hypothesis with fertilizer imports as a proxy for modern input imports and find no evidence that resource windfalls are positively correlated

[2]The Dutch Disease highlights the relationship between a boom in the resource sector and a decline of the tradable sectors due to a loss of competitiveness. This mechanism is further detailed in Section 2.

[3]See, among others: Arezki and Brückner (2012); Auty (2001); Caselli and Tesei (2016); Mehlum et al. (2006); Sala-i Martin and Subramanian (2013).

to fertilizer imports in our sample. This result suggests that potentially positive effects of resource gains on agricultural productivity, such as favorable terms of trade to import modern inputs, do not compensate for the adverse effects discussed above.

Eventually, in the last part of our analysis, we consider the implications of our results for structural transformation. For this purpose, we test the hypothesis according to which reaching high levels of agricultural labor productivity allows a country to release workers towards more growth-enhancing sectors. Indeed, in our sample, we find that the share of employment in the manufacturing and services sectors is positively correlated to improvements in the level of output per worker in agriculture the previous year. This result reinforces the set of evidence linking agricultural productivity and structural transformation.

This paper is related to several strands of literature that we extensively discuss in Section 2. Our contribution to the literature on the agricultural productivity gap and structural transformation is to provide evidence of the potential indirect role of extractive resources in this process. We also contribute to the literature on the natural resource curse by focusing on the agricultural sector, and by explaining the possible channels through which the resource sector may affect agricultural modernization.

The paper is organized as follows. Section 2 presents the related literature in details. Our analytical framework is presented in Section 3, while Section 4 describes our data and empirical strategy. Section 5 displays the results and Section 6 concludes.

2 Related literature

In this section, we detail how our work is related to two strands of literature and emphasize our contribution. We begin with the literature on the role of agriculture in development, then turn to the natural resource curse and finally review the existing research linking both.

2.1 The importance of agriculture for development

While the potential of agriculture for development has long been neglected (Byerlee et al., 2009), there has been a renewed interest in the role of agriculture in poverty reduction (Diao et al., 2007; Haggblade et al., 2007; Byerlee et al., 2009; Ligon and Sadoulet, 2018)[4]. Christi-

[4]For a review of the role of agriculture in development strategies for SSA, see Dercon and Gollin (2014).

aensen et al. (2011) highlight four elements that determine to what extent the development of a sector can affect poverty reduction: i) the extent to which poor people participate in the sector, ii) the relative importance of that sector in the economy, considering the value-added share, iii) growth of the sector itself and iv) its indirect impact on growth in other sectors. Using cross-country estimations over 1960-2005 for 100 countries, their main finding is that the development of agriculture may be on average more poverty-reducing than any other sector, especially at the early stages of development. This finding particularly holds for Sub-Saharan Africa and is mostly driven by the fact that the bulk of the population is still employed in the agricultural sector. Importantly as well, they find that in extractive economies, growth from the resource sector has a limited role in poverty alleviation, compared to agriculture. This highlights not only the importance of agriculture in growth strategies at the early stages of development but also suggests the need for policy intervention in the agricultural sector in resource-rich economies in particular. Dorosh and Thurlow (2018), using a CGE model for five African countries, also support this conclusion. They investigate the role of several sub-sectors in the economy on poverty reduction. When considering the same growth rate in agriculture and mining (among others), the effect of the latter remains limited while agriculture is significantly poverty-reducing.

The growth of agricultural productivity, as measured by the amount of output per unit of labor, is key for development and structural transformation. A similar pattern for many developed countries has been observed: as GDP per capita grows, the share of agriculture in total employment and in GDP declines, in favor of the manufacturing and services sectors (Herrendorf et al., 2014). Timmer (1988) emphasizes the importance of agricultural transformation[5] in this pattern, while Gollin et al. (2002) show that growth in agricultural productivity may be a key starting point for development. As labor productivity increases, the amount of food produced per worker increases, prices decline, pulls up real wages, reduces absolute poverty, and releases agricultural workers toward more productive sectors, thus increasing aggregate productivity. Moreover, agricultural growth is also important for development because of the linkages between the agriculture and non-agriculture sector (Hazell and Haggblade, 1993).

[5]Agricultural transformation refers here to the transition from a traditional subsistence-based agricultural economy to a commercial agriculture relying on the agro-business sector

As explained above, an increase in output per worker in the agricultural sector is key for structural transformation. Yet, agricultural productivity in developing countries tends to be significantly lower relative to the non-agricultural sectors. This fact is known as the agricultural productivity gap (Gollin et al., 2014b). A quite large literature investigates the determinants of this gap, as well as its role in cross-country income differences (Caselli, 2005; Gollin et al., 2014a; Lagakos and Waugh, 2013; Adamopoulos and Restuccia, 2014). Implications for development are huge as reducing the gap may increase aggregate productivity and be growth-enhancing. Different explanations for such a low agricultural productivity in developing countries have been investigated.[6] Here we focus on one that strongly characterizes agriculture in Sub-Saharan Africa: the low level of agricultural modernization.

Many research articles support that the use of modern inputs is important for agricultural growth and structural transformation (e.g., Restuccia et al., 2008; Yang and Zhu, 2013; Bustos et al., 2016; McArthur and McCord, 2017). For example, Restuccia et al. (2008) show that high agricultural labor productivity is positively associated with the adoption of intermediate input use. For the 5% richest countries, the average expenditure on intermediate inputs is 38% of final output value, whereas it is only 12% in the poorest 5% of the countries. McArthur and McCord (2017), considering a set of 75 developing countries over the period 1961-2001, show evidence of a causal link between agricultural productivity and structural transformation by instrumenting agricultural productivity by the use of fertilizers. In this paper, we look at how resource windfalls may impede agricultural modernization and thus generate a "curse". Hence, in the next section, we discuss how our work is related to the natural resource curse literature.

2.2 The natural resource curse

Contrary to what we would expect, resource windfalls do not always translate to better outcomes regarding economic growth or poverty reduction. This seems to be the case for most resource-exporting countries in Sub-Saharan Africa, such as Nigeria, Angola, or Gabon (Elbadawi et al., 2008). This is preoccupying, given that most African countries had in

[6] E.g., geography (Adamopoulos and Restuccia, 2018), high transports costs (Adamopoulos, 2011; Gollin and Rogerson, 2014), frictions related to transportation costs in international trade (Tombe, 2015), presence of a selection bias (Lagakos and Waugh, 2013).

their exports during the period 1965-2010 at least one extractive resource (Elbadawi and Mohammed, 2015). Furthermore, according to the WDI, in 2003, the average resource rents from oil, gas, coal, and minerals in Sub-Saharan Africa represented 5% of total GDP. A few years later, in 2011, it almost tripled to reach 14.7%. It shows a strong response to increases in the prices of extractive commodities in the structure of Sub-Saharan economies. It is, in fact, acknowledged that Sub-Saharan Africa benefited from a favorable external environment that stimulated growth during the 2000s (Rodrik, 2016a), and that one of the major positive elements was the rising commodity price (Lipton, 2012). This may be an issue for long-term growth as extractive resources are exhaustible, and commodity prices strongly volatile.

The possible adverse effect of a resource boom on economic wealth and poverty indicators has long been studied in the resource curse literature, notably starting with Gelb (1988) and Auty (1994).[7] Their work originated from the observation that most newly developing and exporting countries in the 1970s were not better-off after experiencing a resource windfall, as expected. An extensive literature investigates the existence of an overall effect on growth or on the determinants of growth. Sachs and Warner (1995) provide the first empirical evidence for a negative link between natural resources exploitation and income growth using cross-country regressions. The literature has then further investigated this link as well as related channels. For example, Gylfason (2001) focus on how resource windfalls can crowd out public and private investments in education, which is key to growth.

Several potential channels of transmission of the resource curse have been widely investigated. Regarding the economic channels, two widely studied mechanisms are the Dutch Disease effect and commodity price volatility, which both depend on international commodity prices. The Dutch Disease effect corresponds to the shrink of the industrial sector due to a loss of competitiveness following an appreciation of the real exchange rate (Corden and Neary, 1982; Van Wijnbergen, 1984; Neary and Van Wijnbergen, 1986). The adverse effect on growth operates because the manufacturing sector is often the most productive sector and is considered as essential for long-term growth as it concentrates 'learning-by-doing' effects and other benefits (Rodrik, 2016b). Empirical evidence for the Dutch Disease effect can be found in Ismail (2010). When considering a group of exporting countries, he shows that a 10% oil windfall is on average associated with a 3.4% fall in manufacturing value-added.

[7] See Torvik (2009); Frankel (2010); Van der Ploeg (2011); Badeeb et al. (2017) for detailed reviews.

Harding and Venables (2010) also find empirical evidence for the Dutch Disease. Focusing on 135 countries from 1975 to 2007, they find that resource windfalls decrease by 35-80% while non-resource imports increased by 0-35%. Limited growth in resource-rich countries can also be explained by commodity price volatility. For example, Van der Ploeg and Poelhekke (2009) find a causal effect of price volatility and GDP growth. Their results show that countries that are the most dependent on their resource exports have the highest volatility in GDP per capita growth. Collier and Goderis (2012) show that a resource windfall can have a positive impact on the short-term but a detrimental one in the long term.

Regarding the political channels of the resource curse, a rich literature notably establishes that the political regime, the quality of institutions, conflicts, and rent-seeking behavior all have impacts or are impacted by resource windfalls. In an autocratic regime, resource windfalls may exacerbate the autocratic nature of the political system (Caselli and Tesei, 2016). In general, the quality of institutions is key in how revenues are managed and, therefore, on how it impacts growth (Mehlum et al., 2006; Sala-i Martin and Subramanian, 2013). Resource-rich countries are also prone to more conflicts (Berman et al., 2017; Dube and Vargas, 2013), and rent-seeking behavior implies that politicians having access to the resource revenues use them to benefit their interest rather than public welfare (Auty, 2001; Torvik, 2002). These political effects might lead to unproductive investments and hinders sustainable development. Overall this suggests that the effect of resource windfalls may be conditional on governance. We now conclude this literature review with works linking resource extraction and agriculture.

2.3 The effect of extractive resources on agriculture

As previously exposed, the resource curse literature mainly focuses on the effects on growth, poverty, or related channels. Only little research investigates how the presence of extractive resources may impact the agricultural sector. It is important to clarify that the resource curse literature does not always distinguish agricultural commodities and extractive resources. From an economic perspective, the main insight is that cash crops such as cacao or palm crops can have a similar detrimental effect on growth by providing little diversification. A key point of this paper is actually to make this distinction between agriculture and extractive resources so we can investigate the potential interactions between them. They could either compete or be complementary. Do extractive resources support or harm the agricultural sector? This is an important question to address, as extractive resources are exhaustible and potentially have an adverse effect on growth, whereas agriculture has been shown to be important for development and poverty reduction (Christiaensen et al., 2011).

From a macroeconomic perspective, existing studies on the topic have documented that a resource boom generally leads to a shrink in agriculture. Scherr (1989) investigates the decline of this sector after the 1970s' oil price booms in newly exporting countries such as Nigeria, Indonesia, or Mexico. Sala-i Martin and Subramanian (2013) investigate the resource curse considering the case of Nigeria and note that "it is clear that the agricultural sector declined in favor of services, especially government services". Brückner (2012) finds that an increase in the price of natural resource commodities leads to a decline in the agricultural value-added share. Other studies find evidence of similar links between natural resources and agriculture: for example Olusi and Olagunju (2005) for Nigeria, Apergis et al. (2014) for MENA countries or Abdlaziz et al. (2018) for 25 developing oil-exporting countries.[8]

Weng et al. (2013) hypothesize that the mineral industries and the associated construction of infrastructure could benefit agricultural development in Africa. The underlying mechanism is the creation of "growth corridors", where new infrastructures for mineral industries may improve market access for rural areas. This could create incentives to cultivate high-value crops for the new accessible markets, and also facilitate access to modern inputs. The authors also argue that it could stimulate foreign investments in agriculture. If their view is globally optimistic, Weng et al. (2013) also clearly acknowledge the possibility for adverse effects on the environment or possible natural resource curse effects, mainly through corruption and bad governance.

To conclude, little is known about the interaction between extractive resources and agriculture. Most studies assessing this interaction focus on case studies or solely on oil-exporting countries. Here we study 38 countries of Sub-Saharan Africa and consider six extractive commodities. Most importantly, we focus on the effect on agricultural labor productivity, which

[8]There is also a growing literature on the polluting effects of extractive resources, which could directly affect agriculture, e.g.: Aragón and Rud (2015) for the polluting effect of mining on agricultural productivity in Ghana; Akpokodje and Salau (2015) and Ojimba (2012) for the polluting effect of oil on crop production and agricultural productivity in Nigeria.

is crucial for structural transformation, allowing us to gain insights on economic growth. The first contribution of this paper is to determine the direction of the relationship between resource windfalls and agricultural labor productivity using cross-country estimations covering the period 1991-2016. The second contribution is to investigate the possible transmission channels at the macroeconomic level of an “agricultural curse”, and we do so by focusing on agricultural modernization. Our last contribution is to add evidence on the positive link between high output per worker in agriculture and labor reallocation toward manufacturing and services, which are often viewed as growth-enhancing sectors. In the following section, we present our analytical framework.

3 Analytical framework

We seek to investigate the effect of a resource boom on agricultural productivity. Several measures are used to assess the latter. Agricultural productivity can be measured either as a Partial Factor Productivity (PFP) (labor or land productivity) or as the Total Factor Productivity (TFP). TFP has the advantage of providing the contribution to agricultural growth of each input (labor, land, modern inputs) and to take into account technological change. One drawback is that its calculation is subject to debates, and results can greatly vary regarding the methodology used (Benin, 2016). PFP has the advantage of being straightforward to calculate, as it is defined as the ratio of output to total labor (labor productivity) or output to the total harvested area (land productivity). This measure focuses on a given input, and labor productivity is directly related to labor incomes, which are of first interest for policymakers seeking to reduce poverty (Fuglie et al., 2020).[9] As the aim of this paper is to study interactions between extractive resources, agriculture, and structural transformation, we chose to focus on labor productivity in agriculture.

3.1 Natural resources and labor productivity in agriculture

We define our variable of interest, agricultural output per worker, as follows:

[9] A detailed review of the pros and cons of these variables can be found in Benin (2016) and in Fuglie et al. (2020).

$$\frac{p_a Y_a}{L_a} = \frac{p_a F(\mathbf{X})}{L_a}, \tag{1}$$

where $p_a Y_a$ is the agricultural value-added, Y_a stands for agricultural output, p_a for the price of agricultural commodities and L_a for employment in agriculture. $\mathbf{X}$ is a vector of inputs including labor (L_a), land (Z_a) and modern inputs (X_a). Hereafter, we review the possible effects of resource windfalls on agricultural labor productivity by focusing on agricultural modernization. Then we investigate some potential channels of transmission.

A resource boom could affect agricultural labor productivity in diverse ways through its effect on agricultural value-added and agricultural employment. The Dutch Disease literature investigates how a resource boom can lead to a decline of the productive (and tradable) sector of the economy, often manufacturing. Considering a standard framework *à la* Corden and Neary (1982), let us assume there are two tradable sectors in the economy. One of them is the traditional export sector, and it can be either the manufacturing sector or the agricultural sector, depending on the country's specialization. The other tradable sector is the resource sector. In both sectors, prices are set internationally. This is an important characteristic, as changes in relative prices that will drive labor reallocation depends on this. The last sector is the services sector, and the production is sold solely on the domestic market. This simple framework allows us to draw upon potential expected effects on the two elements composing our dependent variable of interest (output per worker in the agricultural sector): employment and value-added in agriculture.

First, through a *spending effect*, Corden and Neary (1982) consider the effects of changes in the income distribution. Resource windfalls in the economy lead to an increase in domestic demand resulting in more consumption of both imports and domestic goods. Unlike non-tradable goods (from the services sector), the prices of tradable ones (agriculture/manufacturing and resources) are defined on the world market because the small open economy is price taker. Therefore, the increase in the price of the non-tradable good and domestic wages results in an increase of domestic price relatively to tradable products, implying a real appreciation of the exchange rate. It impacts the competitiveness of tradable sectors as they become more expensive for foreign countries to buy. As a result, in their framework, the agricultural (p_aY_a) sector contracts as goods from this sector become less profitable.

Second, through a *resource movement effect*, it is possible to observe changes in sectoral labor allocation. After a resource discovery or an increase in its price, wages increase in the resource sector, which attracts more labor. If the resource sector is too capital-intensive, part of the labor force may be redirected toward services. This occurs because demand in urban areas is higher consecutively to the extra-income available at the national level (Gollin et al., 2016). Consequently, it is expected that employment in the resource sector and the services sector increase, at the expense of the share of employment in agriculture (L_a). Additionally, we can sometimes observe a selection effect where it is the most productive workers who leave agriculture (Lagakos and Waugh, 2013).

The Corden and Neary (1982) framework provides a good start for thinking about the potential consequences of resource windfalls on agricultural labor productivity. Considering this framework, both the value-added (p_aY_a) and the labor share (L_a) in the agricultural sector might be subject to a decline in the case of a resource boom. Yet, the global effect on agricultural labor productivity, as defined in equation (1) is not obvious and cannot be anticipated theoretically in this framework.

Overall, this means that the effect of resource windfalls on agricultural output per worker remains essentially an empirical question, which we assess in this paper. In the second part of our analysis, we turn to the channels possibly driving this effect.

3.2 Channels of transmission

We now investigate possible channels of transmission between resource revenues and labor productivity in the agricultural sector. One way to do this is to consider the inputs that contribute to the agricultural function and investigate how resource gains could impact their provision or use. Given (1), elements contributing to labor productivity are land (Z_a), labor (L_a), and modern inputs (X_a). Since agriculture in SSA is still mostly traditional, and agricultural modernization remains low, we focus here on the effect on modern inputs adoption. At the macroeconomic level, resource exploitation could either have a positive or an adverse effect on modern inputs (X_a) adoption. We identify three transmission channels that we detail hereafter.

i) Spillovers across sectors: The development of the manufacturing sector is important for agricultural modernization. Yet, evidence from theoretical and empirical work suggests that resource windfalls are rather associated with trends of deindustrialization. The agricultural sector may benefit from the manufacturing sector expansion in at least three ways. First, it can benefit to it directly through modern inputs provision. For example, the agrochemical industries can supply fertilizers and machinery, and transport industries can supply tractors. As the size of industries expands, the price of modern inputs decreases and allows farmers to switch from traditional agricultural technology to modern technology (Hansen and Prescott, 2002; Yang and Zhu, 2013). Second, the manufacturing sector concentrates 'learning by doing' effects and spillovers (Matsuyama, 1992), which could contribute to increasing technological progress and therefore benefit agricultural modernization. Third, it also creates backward linkages such as increasing demand for agricultural products, raising incentives for farmers to adopt modern inputs to increase their productivity.

ii) Agricultural investment: Another key element contributing to agricultural modernization is investment. We consider investments in terms of agricultural capital formation, and it can be either public, private, or foreign. Examples of investment in agriculture are the construction of infrastructures (e.g., wells, dams, irrigation, roads, storage) but also investments that improve the quality of land such as afforestation. These elements contribute to increasing agricultural labor productivity mainly through a better access to modern inputs, as transport costs decline and market access expands. Does the resource windfalls stimulate or hinder investment in the agricultural sector? A resource boom can indeed, in theory, benefit development as resource windfall can finance a higher level of investments and increase the public budget that could be used for financing public goods such as schools or transport infrastructures (Sachs, 2007). In addition, as export revenues rise, income per capita increases, and demand for food rises, especially in urban areas, and therefore this could increase incentives for farmers to produce. The government could also invest in agriculture to increase domestic production. In the meantime, resource exploitation tends to lead to rent-seeking behaviors (Auty, 2001; Torvik, 2002) and affects corruption (Robinson et al., 2006; Arezki and Gylfason, 2013; Sala-i Martin and Subramanian, 2013), especially in autocratic countries (Bhattacharyya and Hodler, 2010; Caselli and Tesei, 2016). The effect of resource windfalls on agricultural investment is thus ambiguous, and we expect it to be linked to the quality of institutions.

iii) International trade: the majority of SSA countries do not produce modern inputs domestically and rely on imports for their use. How do resource gains affect modern inputs imports? A rise in resource prices in a country is usually associated with increased terms of trade: prices of exports increase relative to the price of imports. It then becomes cheaper to import modern inputs from foreign countries. Changes induced by the resources in the macroeconomic trade conditions could, therefore, allow countries to import modern inputs that they might not produce domestically. This would, in turn, stimulate agricultural modernization. Through this mechanism, we expect variations in our resource gains or losses variable to increase modern inputs imports, for example, fertilizers.

4 Data and empirical strategy

This section describes our variables of interest, their sources, and how we built them when necessary. It also provides details about our empirical strategy.

4.1 Data description

Our study focuses on the period 1991-2016 for 38 countries of Sub-Saharan Africa countries.[10] We removed small countries with less than 1.5 million inhabitants and dropped Somalia, South Sudan, Eritrea, and Equatorial Guinea because of missing values.

Table 1 provides summary statistics of our sample, and the description and sources of each variable are available in figure 6 in the appendix. Most of the variables are constructed as three-year moving averages.[11] We adopt this approach to smooth fluctuations and focus on the general trend rather than year to year volatility. This way, we limit seasonality bias in the data that could lead to downward or upward biased estimates. We also use this as

[10]The list of the countries considered is available in table 5 in appendix

[11]Moving averages are calculated based on the period 1991-2016, so no data before 1991 or after 2016 are used to calculate those moving averages. Therefore, for the average for t=1 is the average of t=1991 and t=1992 and the average of the last year is the average of t=2016 and t=2015. For each other year, the value in t is the average between t-1, t and t+1 (e.g., values in 2000 measures means over 1999, 2000 and 2001).

we expect the effect of extractive resources exploitation to affect our different dependent variables over the medium-term, not the short-term. Eventually, it is important to notice that our results hold when removing three-year moving averaged variables.

Table 1: Summary statistics for all countries of the sample

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Agr. value-added per worker (2010 const. USD)	914.78	1241.01	79.07	9229.72	988
Agricultural land (ha per agr. worker)	14.23	33.45	0.26	219.34	962
Agricultural land (% of land area)	47.06	18.69	8.04	82.46	988
Agricultural investment (% GDP)	1.514	0.818	0.052	5.046	787
Exchange rate (national currency/USD)	518.53	899.62	0	8222.61	988
Fertilizer imports (kg per agr. worker)	18.83	75.74	0	896.45	875
Fertilizer use (kg per agr. worker)	23.67	93.13	0	733.85	872
FDI (% of GDP)	4.15	9.47	-22.11	142.60	988
Government expenditures (% of GDP)	14.61	5.99	3.71	43.04	899
Gross Capital Formation (% GDP)	20.06	8.43	1.06	55.68	925
Manufacturing value-added (%)	9.64	4.65	0.53	33.26	906
Manufacturing and services employment (%)	35.69	18.34	6.86	84.32	988
NCPI (index)	0.001	0.03	-0.29	0.2	774
Net barter terms of trade index (2000 = 100)	116.46	37.94	25.08	330.45	968
Precipitation anomalies (mm)	0	0.981	-3.043	3.464	988
Polity2 (index)	1.31	4.91	-9	9	969
Urban population (% total)	35.56	15.49	5.89	88.33	988

Note: This table includes data for 38 countries of Sub-Saharan Africa. All variables are three-year means except NCPI, precipitation anomalies, and Polity2. E.g., values in 2000 measures the mean over 1999, 2000 and 2001. Timespan goes from 1991 to 2016.

One of our main variable of interest is the agricultural value-added per worker (agricultural labor productivity). It is defined as the net output per worker from forestry, hunting, and fishing, cultivation of crops and livestock production. Data comes from the World Development Indicators (WDI). There is a great heterogeneity across countries regarding this variable. South Africa had the highest agricultural productivity in 2016, while Burundi had the lowest.

Fertilizer use (kg) is taken from the Food and Agriculture Organization (FAO) for the period 2002-2016, and we combine these data with archives data from FAO for the period 1991-2001. Types of fertilizers considered are chemical and mineral fertilizers, in tons of nutrients, for the three main plant nutrients, nitrogen (N), phosphorus (P), and potassium (K). We also use fertilizer *imports* (kg), also taken from FAO, that we will use as a proxy for modern inputs imports.

We take annual gridded precipitations from Matsuura and Willmott (2018), who provide terrestrial precipitation from 1900 to 2017 for each month across the globe. We average them by year and then by country using QGIS, so we obtain millimeters of precipitation for each country each year. In line with the climatic literature (e.g., Muñoz-Diaz and Rodrigo, 2004) and as in Marchiori et al. (2012), we use anomalies in precipitation rather than yearly precipitation averages. As described by Barrios et al. (2010), cited by Marchiori et al. (2012), the anomalies allow taking into account the variability compared to the normal weather condition of the country and avoiding possible scale effects as it is more likely that arid countries get a larger variability compared to the mean. Therefore, anomalies are computed as the deviations from the country's long-term mean, divided by its long-run standard deviation. In our sample, in contrast to our other variables, precipitation anomalies are not three-year averaged so that we can conserve all its variability.

Measures of structural transformation, such as the value-added or employment share of different sector of the economy (manufacturing and services), are taken from the WDI. Manufacturing employment data are completed with employment data of the International Labor Organization (ILO).

As an index for the political regime of a country, we use the *Polity2* variable from the Polity IV database (Marshall and Jaggers, 2005). This database covers most states in the world over the period 1800-2019. The variable allows us to assess the level of autocracy or democracy of a country and varies from -10 (extreme autocracy) to +10 (perfect democracy). In our sample, maximum and minimum are from -9 to +9.

As a proxy of agricultural investment, we use the agricultural gross fixed capital formation provided by the FAO. It is defined as "the fixed assets of the economy and net changes in the level of inventories". We also use additional variables from WDI such as the share of urban population, the share of government expenditures in total GDP, the share of gross capital formation in GDP (a proxy for investment), the share of agricultural land in total area, as well as Foreign Direct Investment (FDI) in share of total GDP. The variable of exchange rate is taken from the Penn World Table (Feenstra et al., 2015).

Net commodity price index

A key variable of our study is the country-specific net commodity price index (NCPI). We construct it to take into account gains and losses of aggregate disposable income due to a resource discovery or a variation in international prices. To do this, we use two sources of data. First, we take commodity prices from the *Pink Sheet* database, provided by the World Bank. This database is available at the world level over the period 1960-2018 in annual or monthly data. We include the international price of six extractive commodities: oil, coal, gas, aluminum, copper, and gold.[12]

Second, we collect the export and import shares of each commodity listed above for every country in our sample. Data come from the United Nations Comtrade 4-digit Revision 2 database. For some commodities, the exports and imports are reported in several sections. Therefore we matched each commodity to each item at the 4-digit corresponding level.[13]

Equipped with our data, we follow Gruss and Kebhaj (2019) and build our country-specific commodity price index as follows:

$$\Delta \ln(NCPI_{it}) = (\sum_{j=1}^{J} \Delta P_{jt} \Omega_{ijt}), \tag{2}$$

where $NCPI_{it}$ is the index value for country i in year t, Δ stands for first differences, P_{jt} is the logarithm of the real price of commodity[14]. j, and Ω_{ijt} refers to commodity- and country-specific time-varying weights.

These weights Ω are constructed as follows:

[12] We do not take into account other commodities such as diamond, uranium, or iron because of missing values. Yet, on average over the period, for 20 countries of our sample, the six commodities we use represent at least 70% of their total exports in extractive resources.

[13] For example, for aluminum, we take into account section 6840 (aluminum) and section 2873 (aluminum ores and concentrates). A list of the sections of revision 2 is available on the UN Comtrade website.

[14] The prices are deflated by the MUV (Manufactures Unit Value) index.

$$\Omega_{ijt} = \frac{X_{ijt} - M_{ijt}}{GDP_{it}}, \quad (3)$$

where X_{ijt} and M_{ijt} are exports and imports of commodity j (in nominal US dollars) for country i in year t, and GDP_{it} represents the gross domestic product of country i that year. Note that using time-varying weights allows us to capture changes in the export mix of a country (e.g., discovery, shift in production).

To deal with potential issues of endogeneity, we follow Gruss and Kebhaj (2019) and use a three-year lagged moving average of net exports shares. Our weights then becomes:

$$\Omega_{ijt} = \frac{1}{3}\sum_{s=1}^{3} \frac{X_{ijt-s} - M_{ijt-s}}{GDP_{it-s}}, \quad (4)$$

The mean of net exports over the three previous years ensures possible lags in the reaction of agents to commodity price variation. It ensures that changes in the price index reflect those price variations rather than an endogenous response in exports or imports traded volume. Additionally, the mean over three years reduces measurement errors in this explanatory variable.

The use of *net exports* rather than just exports ensures that the consumption of imports is taken into account. For example, a country that exports oil will benefit from the increasing commodity price only if the country is a net exporter. Then, if the country is a net exporter, a rise in the international commodity price will translate into a positive income shock, and it will be captured by the increase of NCPI.

To identify the effect of a resource boom on agricultural productivity, we exploit the exogeneity of international commodity price variation. A large number of studies relies on this strategy (Deaton et al., 1995; Dehn, 2000; Chen and Rogoff, 2003; Cashin et al., 2004; Collier and Goderis, 2012; Spatafora and Tytell, 2009; Aghion et al., 2010; Gruss and Kebhaj, 2019). The literature of commodity price investigating macroeconomics outcomes has relied on aggregate commodity price index (i.e. not country-specific) or on a single resource (e.g., studies focusing only on oil-exporting countries). Using an aggregate price index for all extractive resources could lead to biased results as each resource's commodity prices can move in opposite directions. We focus here on extractive resources. The construction of a country-specific commodity price index allows taking into account the price movement of each commodity separately.

To summarize, conditional on the validity of the identifying assumption, the index captures two types of resource windfalls. First, it considers the effect of resource windfalls resulting from an increase in international prices. This is given by the annual growth rate ΔP_{jt}. Second, the share of net exports in GDP as defined in (3) allows our index to take into account shifts in the export mix and resource discovery.[15]

The country-specific index can be interpreted as resource gains and losses due to an increase in the international price, taking into account the relative importance of each resource in the country's export-mix. More precisely, the index captures changes in the aggregate disposable income. Note that this is just a first-order approximation as we consider changes only due to international price variation and not due to endogenous response linked to exports or imports (Gruss and Kebhaj, 2019).

Figure 1 presents the evolution of the price of each of the six commodities considered.

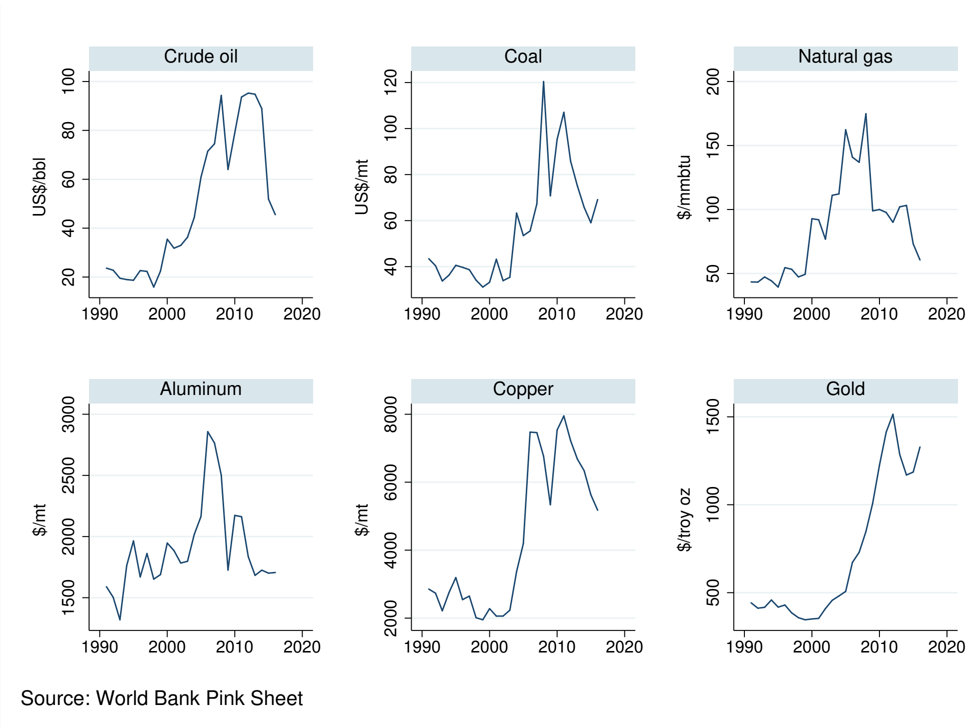


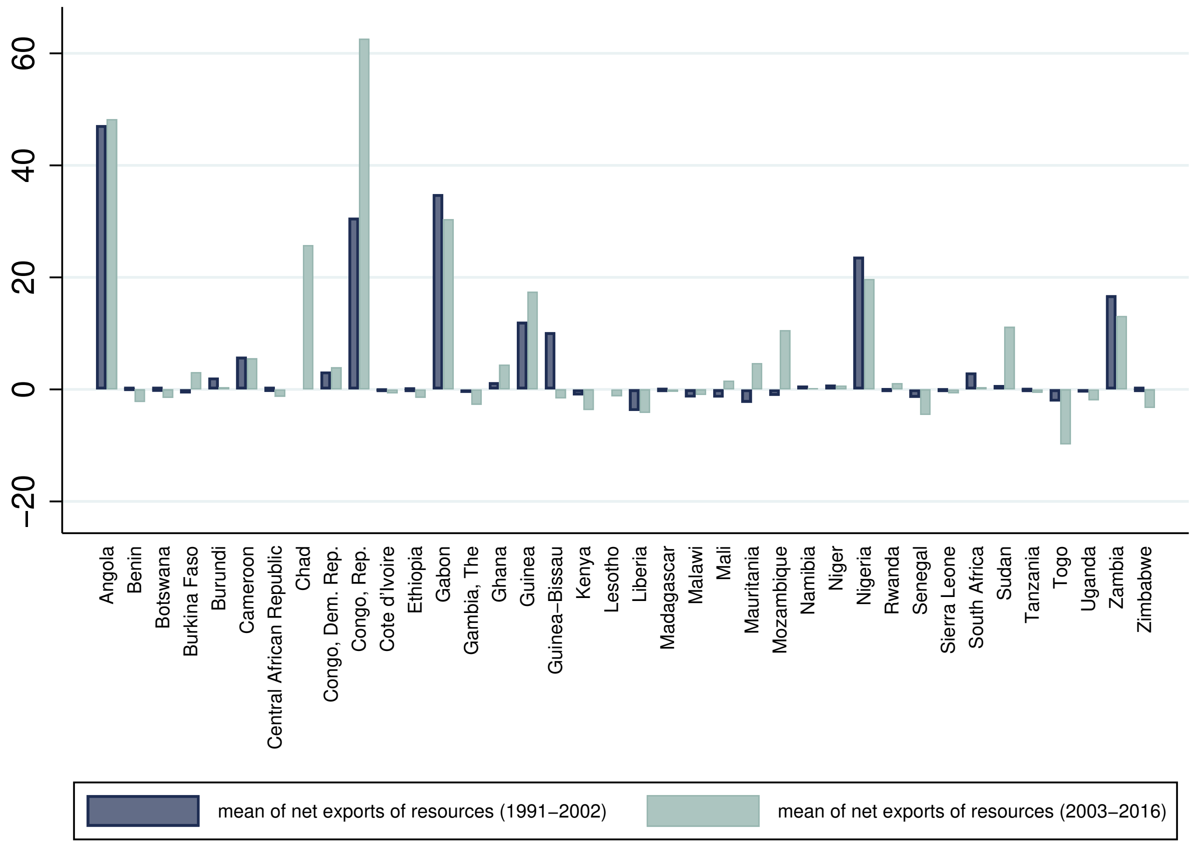
Figure 1: Annual commodity prices (real 2010 US dollars). Period: 1991-2016. Source: World Bank Pink Sheet

[15]In the sense of the effective start of exploitation. Some countries have discovered a resource yet started to exploited much later, such as Chad, who discovered oil in 1969 but started to exploit it only in 2004.

The prices experienced similar evolutions, all steadily increasing from 2003, peaking between 2008 and 2010 before experiencing a sharp decline. Exceptions are natural gas and aluminum whose prices were increasing since the mid-1990s. Gold and coal international price evolution differ because they experience an increase in price since 2014.

Figure 2 presents the mean of the weights Ω_{ijt} presented in equation (3) over the period 1991-2002 and the period 2003-2016 for each country of our sample. We observe that the net exports share increased for some countries such as the Republic of Congo, Sudan, or Guinea. Some countries became net exporters such as Mauritania, Mozambique, or Mali. Others remained net importers: e.g., Togo, Senegal, or Benin.

Figure 2: Net exports of extractive resources (% of GDP). Time-periods: 1991-2002 ; 2003-2016. Sources: UN Comtrade and WDI, authors' calculations.



This index assesses gains and losses from a resource boom in terms of aggregate disposable income, and our goal is to understand how it impacts agriculture.

4.2 Empirical strategy

In this part, we present our empirical strategy to assess the direction of the effect of a resource-boom induced variation in the aggregate disposable income of a country (captured by NCPI) on its agricultural labor productivity. We investigate possible channels of transmission and also expect a decline of the manufacturing sector (Dutch Disease effect), an effect on the agricultural investment depending on institutions, and an increase in fertilizer imports that could mitigate other negative effects. We also study the implications for structural transformation.

Agricultural productivity and channels of transmission

To assess the effect of resource gains on agricultural labor productivity and the different transmission channels, we use the following fixed-effect specification:

$$Y_{it} = \beta_0 + \beta_1 NCPI_{it} + \gamma C_{it} + \eta_i + \theta_t + u_{it}, \tag{5}$$

where Y_{it} is the outcome variable in country i for year t and $NCPI_{it}$ is the country-specific commodity price index. C_{it} is a vector of controls, η_i and θ_t are respectively country and time fixed effects and u_{it} is the error term.

We use panel fixed effect estimation for each regression. The country fixed effects (η_i) allow us to control for time-invariant country unobservables that could be correlated to NCPI and the dependent variable. The time fixed effects (θ_t) control for any period-specific changes in the dependent variable across the sample. To deal with heteroskedasticity and autocorrelation and obtain unbiased standard errors, we cluster the standard errors by country. We also lag the potentially endogenous variable stacked in C_i in order to avoid reverse causality issues in our regressions.

The outcome variable Y_{it} will successively be agricultural labor productivity, manufacturing value-added (as a share of GDP), agricultural investment (as a share of GDP), and fertilizer imports per worker. The dependent variables whose units are in proportions (the manufacturing value-added share and the agricultural investment share) were logit-transformed.

Structural transformation implications

To assess the effect of labor productivity in the agricultural sector on structural transformation, we use the following specification:

$$Z_{it} = \beta_0 + \beta_1 \text{AgrProd}_{it-1} + \gamma C_{it} + \eta_i + \theta_t + u_{it}, \quad (6)$$

where Z_{it} is the logit-transformation of employment in manufacturing and services (as a share of total employment) in country i for year t.[16] The variable AgrProd_{it-1} is the log of agricultural labor productivity. There might be a concern of reverse causality: the development of the non-agricultural sectors may have positive feedback effects on agriculture. To minimize this issue, we lagged the variable of agricultural productivity.

C_{it} is a vector of controls, which are lagged whenever there is a potential issue of inverse causality. These controls are i) government consumption (% of GDP), ii) gross fixed capital formation (% of GDP) as a proxy for investment and iii) FDI (% of GDP). η_i and θ_t are respectively country- and year- fixed effects and u_{it} is the error term.

5 Results

This section presents the estimation results regarding the link between resource-gains and agricultural labor productivity, as well as possible underlying channels. We also present estimation results on structural transformation implications.

5.1 Extractive resources and agricultural productivity

We start by investigating the link between resource windfalls, as measured by variations in NCPI, and agricultural productivity. Table 2 displays the panel fixed-effect estimation results of the model specified by equation (5).

Column (1) presents the result of the average effect of a variation in the commodity price index (NCPI) on the log of labor productivity in agriculture. We find that an increase in NCPI is associated with a declining agricultural labor productivity. The value of the

[16] We logit transform the share of employment as this dependent variable is a proportion.

Table 2: Estimation results: Agricultural productivity and resource windfalls

Dependent variable: Log of agricultural value-added per worker				
	(1)	(2)	(3)	(4)
NCPI	-0.351**	-0.463***	-0.438***	-0.436***
	(0.137)	(0.143)	(0.120)	(0.121)
ln(Agr. land per worker [ha])		1.008***	0.925***	0.926***
		(0.207)	(0.191)	(0.190)
ln(Fertilizer per worker [kg])			0.079*	0.079*
			(0.042)	(0.042)
Precipitations anomalies [mm]				0.004
				(0.012)
Constant	6.364***	4.893***	4.942***	4.944***
	(0.078)	(0.302)	(0.269)	(0.270)
Observations	774	749	678	678
R-squared	0.099	0.366	0.399	0.400
Adj. R-squared	0.069	0.343	0.374	0.374
Number of countries	38	37	34	34

*, ** and ***: significant at 10%, 5% and 1%, respectively.

Note: Panel fixed-effect estimations. Country and year fixed-effects are included in each regression. Robust standard errors clustered at the country level are in parentheses. All variables are 3 year means except NCPI and precipitation anomalies (e.g., values in 2000 measures means over 1999, 2000 and 2001). Time-period: 1991-2016.

coefficient is -0.351 and is statistically significant at the 5% level. This suggests that resource gains are harmful, on average, for agricultural labor productivity in SSA.

In columns (2) to (4), we successively add controls that could explain the sample variation of our dependent variable. We control for agricultural land per worker in column (2), and the coefficient is positive as expected and statistically significant at the 1% level. We control for fertilizer per worker in column (3) and find a positive coefficient as expected (significant at the 10% level). Eventually, in column (4), we add precipitation anomalies in order to control for climate shocks and we expect a negative sign. This is particularly important for Sub-Saharan Africa, given that most agriculture is rainfed. We obtain a coefficient of 0.004, which is not statistically different from zero. Hence, precipitation anomalies seem to not explain agricultural labor productivity in our sample. Note that overall, the model explains the variation in the log of agricultural output per worker relatively well, with an adjusted R-squared of 38%.

To summarize, the negative impact of an increase of NCPI on labor productivity in agriculture also holds when controlling for a set of inputs often used in the literature. The coefficient of NCPI stands at -0.436 (column (4)), and is significant at the 1% level.[17] This implies that a 10% increase in the commodity price index is associated with a decline of agricultural labor productivity of 4.36%. To provide a sense of magnitude, average agricultural labor productivity over the period was US$914.78, and a 10% increase in NCPI thus implies a decline of about US$40 per agricultural worker.[18]

These results suggest that resource gains resulting from a rise in international commodity prices or an intensification of resource exploitation are associated with a decline of agricultural productivity. We now turn to the possible transmission channels.

5.2 Possible transmission channels

This section investigates three possible mechanisms through which gains from the extractive resources exploitation can affect agricultural modernization and, therefore, labor productivity in the agricultural sector.

5.2.1 Spillovers across sectors

Manufacturing can be necessary for agricultural modernization by providing modern inputs and 'learning by doing' spillovers as described in the theoretical framework. Here, we study how resource windfalls impact the manufacturing value-added share in a country.

Column (1) and (2) in Table 3 present the estimation results of equation (5) when the dependent variable is the logit-transformed manufacturing value-added (% of total GDP).

[17] When we use NCPI constructed with two additional commodities, iron and silver, the number of observations drops significantly at 433. Yet, we find similar results when considering them. Results hold too when considering another independent variable of extractive resources such as extractive rents as a share of GDP.

[18] All estimations from this subsection also hold when using the agricultural productivity gap, that is, the agricultural labor productivity relative to labor productivity in the non-agricultural sector. That is, an increase in resource windfalls is associated with an increase in the agricultural productivity gap, suggesting greater labor misallocation.

Table 3: Estimation results: Transmission channels

	Dependent variable								
	Manufacturing value-added		Agricultural investment					Fertilizer imports per worker	
Independent variables	All SSA		All SSA	Autocratic countries		Democratic countries		All SSA	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NCPI	-0.636***	-0.600***	-0.392*	-0.519**	-0.491***	1.695	1.673	-0.262	-0.449
	(0.148)	(0.176)	(0.204)	(0.182)	(0.150)	(1.015)	(1.056)	(0.547)	(0.597)
Exchange rate [t-1]		0.000							
		(0.000)							
Government expenditures [t-1]		0.047							
		(0.071)							
FDI [t-1]		-0.004*			0.006		-0.003**		
		(0.002)			(0.005)		(0.001)		
Urban population (in %) [t-1]					0.025		0.002		0.035
					(0.023)		(0.026)		(0.045)
Agricultural land (% of land area) [t-1]									0.050
									(0.037)
Terms of trade [t-1]									-0.000
									(0.003)
Constant	-2.175***	-2.376***	-4.120***	-4.100***	-4.902***	-4.154***	-4.202***	1.317***	-2.001
	(0.095)	(0.176)	(0.057)	(0.069)	(0.756)	(0.098)	(0.796)	(0.152)	(2.079)
Observations	707	657	660	340	340	320	320	705	694
R-squared	0.053	0.087	0.212	0.309	0.354	0.177	0.188	0.125	0.155
Adj. R-squared	0.019	0.046	0.184	0.259	0.303	0.113	0.119	0.093	0.119
Number of country	37	36	35	18	18	17	17	35	35

*, ** and ***: significant at 10%, 5% and 1%, respectively.

Note: Estimation method used is fixed-effect panel data. Country and year fixed-effects are included in each column. Robust standard errors clustered at the country level in parentheses. The time span goes from 1991 to 2016. The dependent variable is logit transformed from column (1) to (7). All variables are three rolling averages.

Column (1) displays the unconditional result, for which there is a strong negative effect of aggregate disposable income induced by a resource boom. The coefficient of NCPI is -0.636 and statistically significant at the 1% level. The results hold when controlling for exchange rate, FDI or government expenditures in column (2).

The effect of the FDI is negative and statistically significant at the 5% level. We could expect the opposite, more FDI leading to greater development of the manufacturing sector. However, as pointed out by the literature, FDI may be mostly resource-related rather than manufacturing-related in countries with important resource endowments (UNCTAD, 2005; Dunning and Lundan, 2008; AfDB et al., 2013). This may explain why in our sample countries where FDI represents a large share of total GDP tend to industrialize less than others, all things being equal.

The coefficient of exchange rate is positive, which is not the expected sign. We expect a higher exchange rate to be associated with a smaller share of manufacturing, as an appreciation of domestic currency makes domestic products more expensive for international buyers, implying a loss of competitiveness. The positive sign could actually be explained by the fact that when a country experiences an appreciation, it reduces the cost of imported capital and other imported inputs, and it actually stimulates the manufacturing sector. Yet, the coefficient is not statistically significant.

The value of the coefficient of the manufacturing value-added decreases slightly when adding controls and stands at -0.6. It is still statistically significant. An increase of 1% in NCPI is associated with a decline of 0.6% in the logit value-added share of manufacturing.

The average positive or adverse effect of resource exploitation on the manufacturing sector depends on whether the country experiences resource gains or losses, that is to say, an increase or a decline of the NCPI over the period.

For example, Benin was a net importer of extractive resources on average over the period 1991-2016. Its average growth of NCPI over the period was -0.07%, meaning that the country mostly experienced resource losses when commodity prices rose. This implies that the absence of resource windfalls was positively associated with the expansion of the manufacturing sector.

In contrast, Nigeria, the biggest oil producer in Sub-Saharan Africa, was a net extractive resource exporter over all our period of study. The country has experienced gains from the resources: the mean annual growth of the NCPI is 0.43%. Therefore, our model predicts that resource windfalls were positively associated with a reduction in the size of the manufacturing sector for this country.

5.2.2 Agricultural investment

Investment in agriculture is a key element for agricultural modernization. For instance, in 2003, the Comprehensive African Agricultural Development Program (CAADP), part of the New Partnership for Africa's Development (NEPAD) was launched and highlighted the need for investment in agriculture. Specifically, two important goals were set: countries should reach an average annual growth rate in the agricultural sector of 6% and spend at least 10% of their national budget on agriculture.

To investigate how resource windfalls may impact investment in agriculture, we use the gross capital formation in the agricultural sector (% GDP) as a proxy. Resource windfalls may provide additional income that can be re-invested to modernize agriculture. This is the first mechanism we test. Column (3) of Table 3 displays the result.

We find a negative link between resource gains, as measured by an increase in NCPI, and agricultural investment. The coefficient is -0.392 and is statistically significant at the 10% level. This is the unconditional effect of an increase in NCPI for the 38 countries of our sample, and it suggests that income from extractive resources may be "misused" by governments, in the sense that it is not redirected towards a sector like agriculture, which often employs more than half of the total labor force. On the contrary, more resource rents seem to lead to a drop in key variables for productivity, here investment.

This result is not necessarily surprising since, as we point out in Section 2, it is likely that resource windfalls have adverse effects on the quality of institutions in general. Hence, we now try to disentangle the average effect found in column (3) by investigating whether the negative sign varies according to institutional contexts.

A simple way to do this is to control for variables such as the level of corruption or the rule of law in each country. However, this approach raises two issues. First, it is possible that resource windfalls explain a substantial part of the sample variation in corruption, that is, corruption could be endogenous (e.g., Hall and Jones, 1999; Acemoglu et al., 2001; Sala-i Martin and Subramanian, 2013). If this is the case, introducing a corruption index among the independent variables could create a multicollinearity problem. Second, as shown by Arezki and Brückner (2012) or Caselli and Tesei (2016), resource windfalls may have a differential effect on political systems depending on whether they occur in democracies or autocracies. In the latter, more income from resource windfalls may accentuate rent-seeking behaviors and further increase corruption.

As a consequence, to avoid multicollinearity and control for those differential effects, we group countries according to their different political regimes. For this purpose, we use the *Polity2* variable from the Polity IV database (Marshall and Jaggers, 2005), which is a continuous variable that varies from -10 (extreme autocracy) to +10 (perfect democracy).[19] We split our sample between two groups of 19 countries each, based on their average value of *Polity2* over the period 1991-2016. *Polity2* score for our first group equals -2.25 on average. These countries represent the autocratic regimes. In the second group, the average value is 4.65. The closer to 10 *Polity2* is, the more democratic the regime is. This second group of 19 countries thus represents democratic regimes in our sample.

Column (4) and (5) display the results of our estimation for the autocratic countries respectively with and without controls, and column (6) and (7) displays the same estimations for the democratic countries.

The results indicate that an increase in our net commodity price index leads to less investment in agriculture only in autocratic regimes. The intuition is that in these countries, more income from extractive resources further deteriorates the quality of institutions (e.g., increase in corruption), which encourages rent-seeking behaviors at the expense of productive investments. Existing evidence validating this intuition includes Bhattacharyya and Hodler (2010) who find that resource rents lead to an increase in corruption only if the quality of the democratic institutions is relatively poor. Arezki and Gylfason (2013) reach very similar conclusions when studying 29 countries from SSA over 1985-2007.

We do not find evidence supporting the adverse effect of a resource-induced variation in the aggregate disposable income for the democratic group of countries in our sample (see columns (6) and (7)). This suggests that the negative effect identified in column (3)

[19] Polity2 is a variable largely used in the political-science literature. For example, it has been used by Acemoglu et al. (2008), Persson and Tabellini (2009), Besley and Kudamatsu (2006) or Brückner and Ciccone (2011). The variable allows to assess the level of autocracy or democracy of a country and aggregates several categories of information such as civil liberties, political participation or constraints on the executive.

is strongly related to a country's political regime. In a democracy, resource windfalls do not alter the amount of investment dedicated to agriculture since it is likely that in those countries it does not increase corruption as much as in an autocracy.[20]

Overall, our results highlight that the quality of institutions and their political agenda are crucial for agricultural investment. This is consistent with the literature showing that the use of resource revenues for agriculture depends on resource windfalls management, as it has been the case for Cameroon (Omgba, 2011), for Chad (Levy, 2007) or Uganda (Bategeka and Matovu, 2011). This also echoes Pinto (1987), who compares the effect of the oil boom in the 1970s in Nigeria and Indonesia. Most cash crop production in Nigeria (cocoa, rubber, cotton, and groundnuts) heavily decreased and rural agricultural labor moved to urban areas. The country also became more dependent on food imports and prices increased (Sala-i Martin and Subramanian, 2013). As Pinto (1987) points it, Nigeria's government spending was biased toward non-agricultural sectors such as services, transport or construction rather than agricultural investment. The opposite happened in Indonesia, where the composition of government spending was more balanced between all sectors. The agricultural policy was also more market-oriented than in Nigeria, which did not enable a favorable environment for agricultural development (e.g., lack of a proper credit system, low producer price incentives, poor infrastructures) (Pinto, 1987).

5.2.3 International trade

Following a resource boom, some changes in trade conditions could help partly compensating for the adverse effect described by the channels investigated so far. Indeed, international trade can provide a way to increase agricultural modernization through imports of modern inputs and technology transfer, as described in our analytical framework. In this section, we investigate whether gains from a resource boom induce more or fewer fertilizer imports per agricultural worker.

Table 3 presents the estimation results.

In column (8), we find a negative but not statistically significant effect of the commodity price index variation on fertilizer imports. When adding the control variables in column

[20] Note that these results hold when we use directly an index of control of corruption or of rule of law, both provided by the Worldwide Governance Indicators project.

(9), the coefficient of fertilizers is still negative and not significant. The coefficients of the control variables have each the expected positive sign; however, none of them is statistically significant.[21] We cannot conclude that resource windfalls in the economy lead to more imports of fertilizer. Therefore, we find no evidence that this channel could help compensate for the negative effect of resource gains on agriculture.

To sum up, we find a negative link between resource gains and agricultural labor productivity. We also investigate for three channels through which resources exploitation can affect agricultural modernization and find evidence that i) resource windfalls are positively associated with a declining manufacturing sector, ii) resource windfalls are negatively associated with agricultural investment when considering autocratic countries but not democratic ones, and that iii) resource gains seem not to be associated with more fertilizer imports.

It suggests that the lack of industrialization induced by resource gains and the quality of institutions in a country may explain, in part, the negative effect of resource gains on agricultural labor productivity, through a negative indirect effect on agricultural modernization.

5.3 Structural transformation implications

This section presents estimates of the econometric model detailed in equation (6) and discusses structural transformation implications. Our aim is not to assess the causality of the link between agricultural labor productivity and non-agricultural employment. Rather, it is to provide basic evidence that supports the importance of labor productivity for structural transformation.

An increase in agricultural output per worker may be a starting point of the structural transformation process (Timmer, 1988; Gollin et al., 2002). Matsuyama (1992) highlights how agricultural labor productivity contributes in at least three ways to the development of the industrial sector. First, the rising productivity in the traditional food sector makes it possible to generate a surplus and feed the growing population. With more food being produced using less labor, more labor can be reallocated towards the non-agricultural sectors. Second, more income in the agricultural sector constitutes a positive linkage as it increases

[21] This specification was also estimated using various alternatives for the dependent variable (fertilizer imports as a share of merchandise imports, the value of imports, fertilizer imports per hectare) and none yield different results.

the demand for non-agricultural products. Third, as food quantity increases, prices decline and real wage increases, which increases the supply of domestic savings and can contribute to fund industrialization and urbanization.

Results of the estimation of equation (6) are presented in Table 4.

Table 4: Estimation results: Agricultural productivity and structural transformation

Dependent variable: Share of manufacturing and services employment		
	(1)	(2)
ln(Agricultural value-added per worker [t-1])	0.261**	0.281**
	(0.102)	(0.111)
Government consumption (% of GDP) [t-1]		0.059
		(0.052)
Investment (% of GDP) [t-1]		0.013
		(0.042)
FDI (% of GDP) [t-1]		0.001
		(0.002)
Constant	-1.011	-1.314*
	(0.674)	(0.752)
Observations	950	862
R-squared	0.188	0.187
Adj. R-squared	0.166	0.160
Number of countries	38	37

*, ** and ***: significant at 10%, 5% and 1%, respectively.

Note: Panel fixed-effect estimations. Country and year fixed-effects are included in each regression. Robust standard errors clustered at the country level are in parentheses. All variables are 3 year means except NCPI and precipitation anomalies (e.g., values in 2000 measures means over 1999, 2000 and 2001). The dependent variable is logit transformed. Time-period: 1991-2016.

In column (1), the coefficient of the lagged agricultural productivity is positive and statistically significant at the 5% level. It explains approximately 16% of the variation in the share of manufacturing and services employment in our sample.

In column (2), we control for government consumption, investment, and foreign direct investment. All these variables are also one-year lagged in order to avoid reverse causality. The coefficient of agricultural productivity in $t-1$ remains statistically significant at the 5% level.

These results suggest that reaching a high level of output per worker in the agricultural sector is important in order to release part of the labor force towards more growth-enhancing sectors (i.e., manufacturing and services). This simple correlation exercise is thus consistent with some traditional views of structural transformation. Earlier in this paper, we have shown that resource windfalls may be detrimental to labor productivity in agriculture. Precisely, we found that an increase in NCPI decreases the value produced per worker in the primary sector. Therefore, resource exploitation could be detrimental to long-term development if governments do not account for the potential interactions between the resource and agricultural sectors.

6 Conclusion

An extensive literature focuses on how the presence of natural resources impacts economic growth and development. Within this field, only little research has assessed the impact of extractive resources on agriculture; though it has important implications for poverty alleviation, food security, or structural transformation. This paper contributes to fill this gap by assessing the links between resource-gains in extractive commodities and agricultural labor productivity in Sub-Saharan Africa.

To do this, we have built a country-specific commodity price index that captures gains and losses from variations of international commodity prices or resource discovery. Our index also allowed us to consider the extent to which extractive resources were important for each country's economy.

Our first result was that resource windfalls (or increase in our country-specific commodity price index) decrease the level of agricultural output per worker in the 38 Sub-Saharan countries of our sample and over our period of study. To explain this result, we have then investigated three possible channels linking activities of resource extraction to agricultural modernization in a country.

First, we found evidence of a "Dutch Disease": when resource-gains increase the size of the manufacturing sector decreases. This could be problematic since having a large manufacturing sector can, under some conditions, benefit agriculture through the provision of cheap modern inputs (Yang and Zhu, 2013). In this case, sectoral spillovers would help modernizing agriculture. This is the first potential channel of transmission of a "curse" that we identified. Second, we found that the quality of institutions and, by extension, the political agenda of a country are key determinants of whether resource-gains are used for the development of the agricultural sector. Indeed, our results showed that in autocracies, resource windfalls lower investment in agriculture, while it has no effect in democracies. This is the second potential channel of transmission we shed light on. As a third one, we attempted to study whether resource-gains could lower the "curse" by favoring fertilizer imports thanks to changes in terms of trade. However, we did not find evidence of such a mechanism in our sample.

To close our analysis, we examined the potential implications of low labor productivity in agriculture for structural transformation. We found that a higher level of agricultural labor productivity is positively correlated with the employment in manufacturing and services, which are often viewed as the most productive sectors of an economy. This highlights the potential importance of reaching a high level of output per agricultural worker, including in resource-rich countries.

To conclude, this work has focused on the resource curse for the agricultural sector and has investigated its possible underlying mechanisms. Considering the agricultural sector is crucial, given its role in poverty alleviation and development strategies. Over the short run, it raises critical issues such as variations in food security level as international commodity prices vary. In the long run, the persisting low productivity in agriculture can undermine development by blocking labor in agriculture. In all, to implement efficient public policies, it suggests that in some countries the question of agricultural productivity needs to be thought in the context of resource dependency.

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7 Appendix

7.1 Additional tables and figures

Table 5: Sample composition

Sub-Saharan Africa (38 countries)
Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Dem. rep., Congo, Rep., Cote d'Ivoire, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe

Table 6: Variable description and sources

Variable	Description	Source
Agricultural investment	Share of Gross Fixed Capital Formation (GFCF) in agriculture, forestry and fishing in GDP.	GFCF: FAO STAT (2019), GDP: World Bank (2019)
Agricultural land	Agricultural land (% of land area) is the arable land under permanent crops and under permanent pastures	World Bank (2019)
Agricultural land per worker	Hectare of agricultural land per worker from the agricultural sector. Agricultural land is the area that is arable, under permanent crops or under permanent pastures.	World Bank (2019)
Agricultural productivity	Value added per worker (2010 constant USD). Includes forestry, hunting, fishing, cultivation of crops and livestock production	World Bank (2019), completed with UN STATS (2019)
Commodity exports	Commodity exports, current USD. Values for each commodity was extracted separately from the database using the SITC revision 2 classification. For some commodities, the exports and imports are reported in several sections. Therefore we matched each commodity to each item at the 4-digit corresponding level. For example, for aluminum, we take into account section 6840 (aluminum) and section 2873 (aluminum ores and concentrates)	UN Comtrade 4-digit Revision 2 database
Commodity international price	Commodity international price, real 2010 USD.	World Bank, Pink Sheet (2019)
Exchange rate	Exchange rate, national currency/USD	Penn World Table version 9.0. Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015)
Fertilizer imports	Fertilizer (kg per agricultural worker). Types of fertilizers considered are chemical and mineral fertilizers, in tones of nutrient, for the three main plant nutrients, nitrogen (N), phosphorus (expressed as P2O5) and potassium (expressed as K2O).	Fertilizer: FAO STAT Archives (2019) and FAO STAT (2019) Agricultural workers: World Bank (2019)
Fertilizer use per worker	Fertilizer use (kg per agricultural worker). Types of fertilizers considered are chemical and mineral fertilizers, in tones of nutrient, for the three main plant nutrients, nitrogen (N), phosphorus (P) and potassium (K).	Fertilizer: FAO STAT Archives (2019) and FAO STAT (2019) Agricultural workers: World Bank (2019)
FDI	Foreign Direct Investment, net inflows (% of GDP).	World Bank (2019)
Government consumption	General government consumption expenditures (% of GDP). Includes all government current expenditures for purchases of goods and services.	World Bank (2019)
Investment	Gross capital formation (% of GDP). Consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Includes for example land improvement, machinery or construction of roads or schools.	World Bank (2019)
Manufacturing value added	Manufacturing value added (% of GDP)	World Bank (2019)
Manufacturing and services employment	Manufacturing and services employment (% of total)	ILO (2019) and World Bank (2019)
Net barter terms of trade index	Net barter terms of trade index (2000=100). The percentage ratio of the export unit value indexes to the import unit value indexes, measures relative to the base year 2000.	World Bank (2019)
Precipitation anomalies	Calculated from the variable precipitation (mm per year), using Matsuura and Willmott (2018). Computed as the deviations from the country's long-term mean, divided by its long-run standard deviation as in Marchiori et al. (2012).	Matsuura and Willmott (2018)
Polity2	The variable allows assessing the level of autocracy or democracy of a country and aggregates several categories of information such as civil liberties, political participation or constraints on the executive. The variable varies from -10 (extreme autocracy) to +10 (perfect democracy)	Marshall, M. and Jaggers, K. (2005).
Urban population	Urban population (% total)	World Bank (2019).