Global Trade Analysis Project
https://www.gtap.agecon.purdue.edu/

This paper is from the
GTAP Annual Conference on Global Economic Analysis
https://www.gtap.agecon.purdue.edu/events/conferences/default.asp

The Plunge in Oil Prices: Sectoral and Employment Dynamics in Colombia

Ricardo Arguello
Universidad del Rosario, Colombia

This version: May, 2017

Paper presented at the 20th Annual Conference on Global Economic Analysis, West Lafayette, June, 2017

The Plunge in Oil Prices: Sectoral and Employment Dynamics in Colombia

Abstract

From the first half of the 2000s until 2012 the Colombian economy was under the influence of an oil and mining production and export boom that triggered the potential for Dutch disease effects and led the government to implement policies for facing them. Concurrently with the phasing in of the policy intervention, an abrupt fall in oil prices ensued and the economy faced an important balance of payments shock. As a consequence it is relevant to ask what the effects of the plunge in oil prices and of policy intervention could be on sectoral and employment dynamics, as the shock essentially reverses the process that the economy was following until 2012 in a typical boom and boost fashion. For this, we use a recursive dynamic computable general equilibrium model, calibrated to a 2011 Social Accounting Matrix of the Colombian economy, in which activities are differentiated in terms of their formal and informal components, and suitable details are included to account for the stream of income the government receives from the oil sector. The model has a rich representation of the labor market as it differentiates between the formal and informal segments, allowing for unemployment in the formal segment and limited migration of labor from the formal to the informal segment. We find that the oil price plunge decreases the economy's growth rate in a significant manner and lowers demand for labor in general with a bias against formal activities and skilled labor. Furthermore, we find that the policy intervention makes matters worse and suggest that the government should consider temporarily suspending operation of the policy or implementing alternative policies that help prevent the relative informalization of the labor market.

JEL: O19; F17; C68.

Keywords: Exports, Terms of Trade, Boom and Bust, CGE modeling, Colombia

Author

Ricardo Arguello
Professor, Universidad del Rosario
Bogota, Colombia
luis.arguello@urosario.edu.co

Contents

List of tables

List of figures

1 Introduction

1.1 Context of the study

By mid 1980s Colombia started producing crude oil to a scale of some importance with the discovery of a relatively sizeable deposit. The mining sector's production volume index in 1983 was 116, the lowest among all economic sectors -48 points below that of the construction sector, the fastest growing sector at the time. Two years later the index reached 195 surpassing the index values for the rest of the economy and by 2000 it was at 808, 451 points above the second most dynamic sector (social and personal services). As a consequence, the sector moved from a 2.5% share in total value added to 6.5% while the agricultural and manufacturing sectors declined from 18.2% to 9.6%, and from 17.4% to 14.5%, respectively, and the whole of the services sectors increased their share from 55.2% to 62.2%.

With the sharp increase in international oil prices between 2003 and 2008 and their partial recovery in 2010 and 2011, the Colombian economy experienced an oil export boom that triggered the potential for Dutch Disease effects. Between 2000 and 2015 the sectoral production volume index increased the fastest for construction, and transport and communication services, with agriculture slagging along the period and manufacturing losing steam from 2008 on, as shown in figure 1. The share of mining in total value added remained relatively stable at around 7.6%, that of agriculture showed a smooth decline (from 8.6% to 6.8%), the one corresponding to manufacturing showed little variation until 2007 and then declined (from 15.6% in 2007 to 12.3% in 2015), and the one for services as a whole increased from 68% to 71.3%.[1]

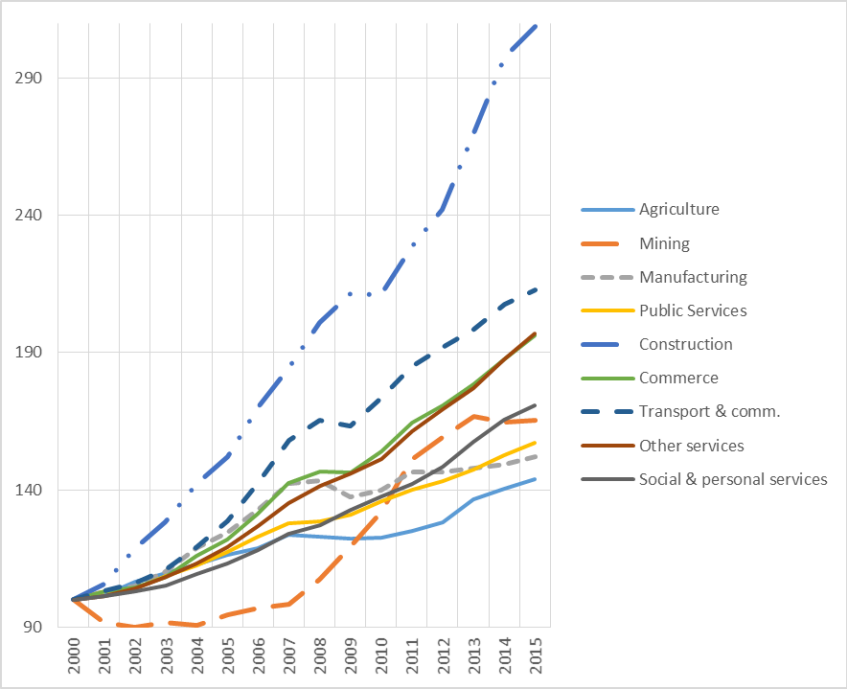
The increase in mining production goes hand in hand with the behavior of Foreign Direct Investment. Aside from a peak in 1997, inbound FDI was stagnant between 1994 at 2003, at around 2.5 US$ billion and changed regime in 2005 to locate for the next five years in the vicinity of 8.5 US$ billion, increasing up again in 2011, and until 2014, to a figure around 15.5 US$ billion, dropping to an average of 12.7 US$ billion for 2015 and 2016, as shown in the left panel of figure 2. Between 2003 and 2016, oil sector FDI represented 27.8% of total FDI in average, peaking up in 2010 to represent almost 48% of total FDI. When total FDI devoted to the extractive industries is considered, it amounted to an average of 48% of total FDI coming into the economy, reaching its peak in 2009 with a 70.3% share. Between 2003 and 2015, FDI has represented almost 4% of GDP in average.

The right hand side panel of figure 2 shows the evolution of Colombian exports (total and discriminated along broad sectoral categories). Between 2000 and 2015, Colombian exports increased almost fourfold, for an average annual compound growth rate of 9.1%. Agricultural and manufacturing exports grew at 6.4% and 7.9%, respectively, losing share as a consequence. The fastest growing export segment is extractive industries with a growth rate of 10.9%, followed by services with 9.6%. As illustrated in the graph, Colombian exports attained this accelerated pace from 2003 on, with the surge in oil prices in the international

[1] The differences in value added shares for 2000 with respect to those reported above are due to changes in the base year and the methodology of Colombian national accounts (the first set of shares has 1975 as base year and the second 2005).

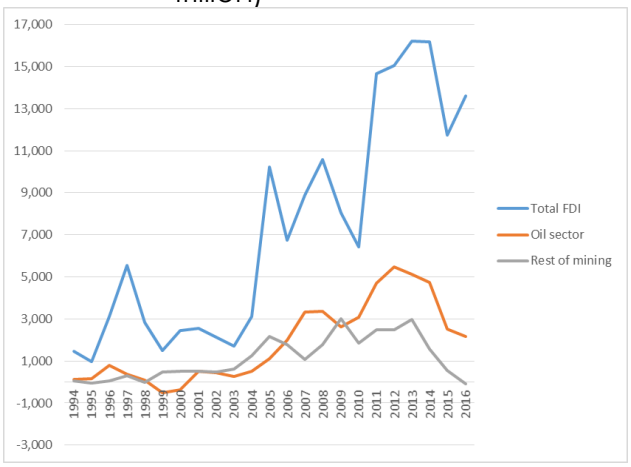
market. As evident from the graph, the behavior of total exports broadly trails the behavior of oil exports, the latter showing a constant share increase until 2014, raising from a 16.8% share in 2003 to 43.1% in 2014. In total, the share of the extractive industries in exports grows from 29.3% in 2003 to 54.9% in 2014.

Figure 1. Sectoral Production Volume Index for the Colombian Economy (2000 = 100)

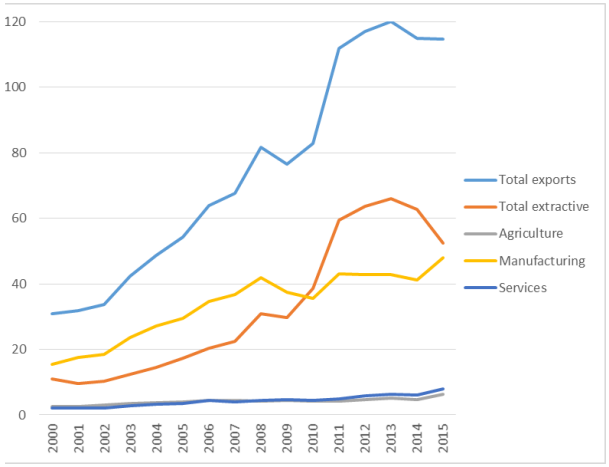


Source: Colombian National Statistical Office (DANE)

Figure 2. Inbound FDI (left panel US$ million) and Colombian Exports (right panel ($COP trillion)



Source: Colombian Central Bank

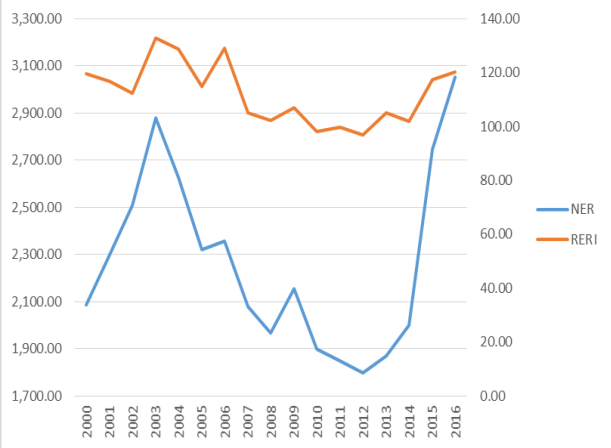


Source: National Statistical Office (DANE)

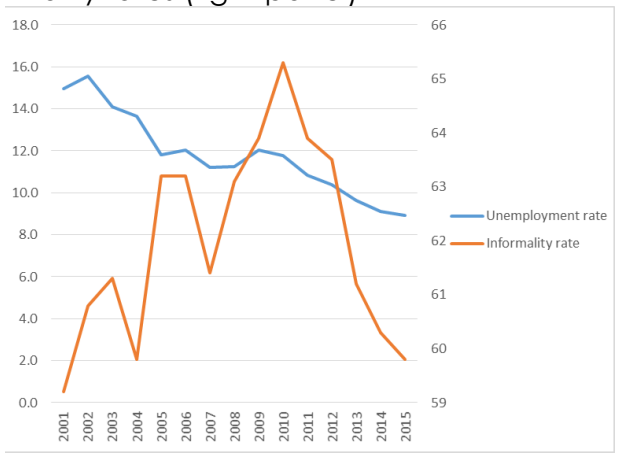
The inflow of foreign currency due to the increased value of mining exports and incoming FDI, along with other foreign currency sources such as portfolio investments and remittances, had an impact on the exchange rate (both nominal and real). Casual observation of the behavior of the nominal exchange rate (expressed as Pesos per US Dollar) shows that between 2003 and 2012, it continuously decreased at an annual compound rate of 5.1%,

appreciating the peso, to then increase between 2012 and 2016, at an annual compound rate of 14.2%, inducing a large depreciation of the peso.[2] As illustrated in the left hand side panel of figure 3, the real exchange rate index calculated by the Colombian Central Bank (based on the producer price index), showed an appreciation of the peso coming from a decrease in the index value from 132.8 in 2003 to 96.9 in 2012, followed by a peso appreciation that led the index to a value of 120.1 in 2016.

Figure 3. Nominal and real exchange rates in Colombia between 2000 and 2016 (left panel) and unemployment and informality rates (right panel)



Notes: NER = nominal exchange rate (left axis); RERI = real exchange rate index (right axis)
Source: Colombian Central Bank



Notes: unemployment rate, left axis; informality rate, right axis
Source: Jimenez, D (2012) and Colombian Central Bank (2015)

In a seemingly consistent way with Dutch Disease effects on the economy, the agricultural sector systematically underperformed the economy in terms of growth between 2003 and 2016 (with the only exception of 2013, when a boon in coffee production took place). Manufacturing growth trailed that of the economy as a whole until 2007 (in 2004 it grew much faster than the economy) and have been sluggish since then, with a simple average growth rate of 0.8% (vis a vis a 4% rate for the whole economy), and a 4.1% negative growth rate in 2009 and nill growth in 2012. Services being such a big share of the economy basically show a growth rate that is very close to that of the economy.

In spite of the economy growing in a dynamic fashion (4.6% average annual compound rate between 2003 and 2015), the unemployment rate receded slowly, coming down from 14.1% in 2003 to 8.9% in 2015 with slight increases in 2006, 2008 and 2009, as shown in the right hand side panel of figure 3. In contrast, the informality rate, although with some variability, increased until 2010 and then declined to a level similar to those at the beginning of the 2000s. Therefore, there not only seems to be sluggishness in the response of the unemployment rate to economic growth, decreasing slowly in the face of high growth and sustaining the decrease beyond the start of declining growth rates, but also a procyclical pattern in the informality rate.

[2] This is about the same growth rate that the nominal exchange rate showed between 1990 and 2033 but with the opposite sign, before the oil export boom.

To steer the economy away from the perils of Dutch Disease, in 2012 the government introduced legislation modifying the mining royalties system and creating a Savings and Stabilization Fund, administered by the Central Bank, projected to withhold an average of 24% of total royalties revenue flows between 2013 and 2022. This measure followed the implementation in 2011 of a fiscal rule, aimed at achieving fiscal sustainability by putting a ceiling on governmental indebtedness. Ironically, the measures were implemented in the brink of the abrupt collapse in international oil prices leaving for the moment the question mark about whether they could have been (and to what degree) effective for dealing with the Dutch Disease symptoms that afflicted the Colombian economy until before the unraveling of the strong external shock that hit it.

According to the International Monetary Fund (2016), the external shock afflicting the economy can be characterized by a large oil price drop that delivered a terms of trade shock much larger than the regional average, leading to a drop in national income and a strong peso depreciation. Furthermore, weak growth in key regional markets led to a deterioration of non-traditional exports beyond the expected, helping the current account deficit to reach record levels in 2015 (to 6.5% of GDP), in spite of non-oil FDI and portfolio inflows being robust. Additionally, inflation situated above the 2-4 percent target band due to depreciation and to adverse weather conditions during 2015. Nonetheless, the economy has proved resilient, inflation is expected to get within range, and growth is projected to progressively return to its potential.

1.2 Research questions and objectives

Given the above context, our aim is to inquire about the impact of the plunge in oil prices on: (i) the evolution of the productive structure of the economy, (ii) its implications for employment dynamics in general, and (iii) the evolution of the informal sector.

As for the first issue, the changes in the sectorial composition of the economy documented above and those that may ensue from the unraveling of oil prices, may have a potentially important effect on the structure of labor demand. In this respect, estimating what is the likely path of these changes in the short and medium run is important and instrumental for appraising the evolution of the labor market. With the depreciation of the real exchange rate, non-oil sectors tend to be affected according to their trade position. Non-oil tradable sectors are expected to be positively affected; in the case of exportables due to the improvement in their competitive position, and in the case of importables due to lesser competition as international prices become higher in terms of domestic currency.

On the contrary, non-oil non-tradable sectors are expected to be negatively affected, as decreasing national income translates in lower demand for them and their prices decrease. In the medium run, non-oil sectors should increase production at the expense of the rest of the economy as relative prices favor them. This translates in changes in employment levels according, among other factors, to the easiness of factor mobility, relative labor intensiveness across activities, potential adjustments in technology use, and the cross effect between formal and informal activities within each sector (as the informal sector does not face direct international competition).

Therefore, estimation of the impact of the external shock on employment is not straightforward, especially if it is taken into account that activities decompose in formal and

informal sub-activities. As informality tends to concentrate in the non-tradables sector, we can expect the informal sector to boost if the formal part of the non-tradables sector shrinks in an important manner. Therefore, the likely effect of the shock on the informal sector is mainly an empirical question. From a policy perspective it is clearly relevant to know if the informal sector is bound to further increase in size (i.e. number of workers), what is the likely behavior of income generation within the sector, and how it translates into households' income.

For these purposes, we use a recursive dynamic computable general equilibrium model to run three types of simulations. In the first, we build the baseline scenario, that is, we trace the expected behavior of the economy, arising from its 2011 equilibrium and growing at a fixed rate (the 2011 growth rate). In the second, we simulate the behavior of the economy according to the projected international oil prices to 2025. In the third, we examine the effects of the set of policy instruments that the government put in place for dealing with potential Dutch Disease effects, as briefly described above.

2 Literature review

The fluctuation of international oil prices induced a boom and bust cycle for the Colombian economy. Firstly characterized by a boom between 2001 and 2007, followed by a fall and recovery between 2008 and 2011, and then by a smooth fall until 2016 (the economy is expected to grow 2.4% in 2017, 0.4% up from the 2016 figure), the economy is slowly adjusting to its new external environment. From an analytical perspective, the effects of the boom cycle are akin to Dutch disease economics, a phenomenon that has received broad attention in the economics literature. It has been associated to significant medium term income increases arising from an export boom or enhanced foreign capital inflows, including remittances, international aid, and foreign direct investment. The classic treatment of the subject in Corden and Neary (1982) distinguishes two effects: a spending effect and a resource movement effect. The first occurs as a result of the increased real income accruing from the boom, which, provided tradable and non-tradable goods are not inferior, translates in greater demand for both. Short run effects from this increase in demand, lead to higher prices for non-tradables and larger imports, and a change in relative prices of non-tradables with respect to tradables, implying appreciation of the real exchange rate (which in turn negatively impinges upon the competitiveness of non-boom export sectors).

Higher prices in the non-tradables sector and increased activity in the boom sector, induces reallocation of resources from the rest of the economy. This reallocation has general equilibrium effects that are not obvious and depend mainly on consumer behavior and factor mobility.

In its analysis of one of the several coffee booms of the Colombian economy, Edwards (1985) found that higher coffee prices led to an increase in reserves and to a higher rate of money supply. As a consequence, the inflation rate increased and the dynamics of the nominal exchange rate led to real exchange rate appreciation and loss of competitiveness for tradables other than coffee. If, under these circumstances, the government increases its deficit and finances it (even partially) with foreign borrowing, pressure on the real exchange rate increases and a magnification effect ensues. As pointed out by the

Colombian Ministry of Finance (2011), the Colombian experience in the management of export booms has not been very fortunate and the economy has experienced growth deceleration in the aftermath of these booms.

There is robust evidence that increases in the terms of trade lead to a real exchange rate appreciation in countries rich in natural resources, as illustrated for example in Spatafora and Warner (1995). In contrast, evidence on a deindustrialization process seems to be less conclusive. For instance, Sala-i-Martin and Subramanian (2003) finds no clear cut effects in this direction, while Ismail (2010) claims that a 10% increase in oil income produces an average 3.4% drop in industrial value added. Also, deindustrialization tends to be higher in economies that are more open to capital flows and have less capital intensive manufacturing sectors.

As happens with deindustrialization, evidence on the long term consequences of the Dutch disease is blurred. Sachs and Warner (2001) argues that natural resources abundance has a strong negative effect on economic growth, leading to the infamous "curse of natural resources". Lederman and Maloney (2008) founds a positive effect of natural resources abundance on long term growth. Collier and Goderis (2007),using panel data, tries to reconcile these opposite views; it concludes that price booms have a short term positive impact on growth and that economies with poor governance and natural resource enclaves (like oil and mining) show significantly negative long term growth effects. Treviño (2011) uses a heuristic approach for appraising the CEMAC region economies, finding that in the oil rich ones there is indeed real exchange rate appreciation and factor reallocation but that there is no evidence of a resource curse as oil abundance does not seem correlated with long term performance. Magud and Sosa (2010) argues that there is no mechanism in the literature by which Dutch disease reduces long term growth.

Consistent with the above discussion, we take the view (with Magud and Sousa, 2010) that, from a policy making point of view what is perhaps more relevant is to determine if the appreciation is driven by a permanent (structural) change and then steer the economy away from overshooting, overheating, and the rise of macro imbalances that may prove unsustainable. However, determining whether or not the economy is facing a permanent change is a daunting task and mistakes could be costly. In any case, the short and medium run effects of real exchange rate appreciation, where a host of potentially undesirable consequences of Dutch disease economics concentrate, should be assessed and hopefully addressed. While the development of the international economy has proved the transitory nature of the shock behind the potential Dutch disease effects, this research can certainly contribute to the appraisal of its consequences and those of its unraveling, on the three fronts mentioned above and to usefully inform policy making in the corresponding dimensions.

3 Data

We built a 2011 SAM for Colombia to run the CGE model and the simulations. Activities are distinguished by their formal or informal character and demand formal and informal labor according to it. Only formal activities pay taxes on production and only commodities produced by formal activities pay indirect taxes. The oil and mining sectors use capital and natural resources as composite capital, while the rest of the economy only uses capital.

Rents from natural resources accrue to the government as royalties and the national oil company pays dividends to the government, who also receives dividend payments from other state companies belonging to the rest of the economy.

It is useful to employ the macro data contained in the SAM to provide a summary of the Colombian economy that allows for a better understanding of its structure and some of the features relevant for our study. In this regard, table 1 provides a broad picture of the Colombian economy.

Given the sectorization of the economy we are using, 61% of value added generates from the services sector, 13.5% comes from industry and refinery, 12.2% from the extractive sector, 6.8% from agriculture, and 6.4% from the government. In total 71.1% of value added arises from formal activities, while the remaining 28.9% from informal ones. The sectors with the largest informal component are agriculture (76%), metallic minerals (49%), non-metallic minerals (48%), non-tradable services (37%), and tradable services (31%) while the least informal are oil, refinery, and public administration, which are completely formal, and coal (98% formal).

Table1. Composition of the Colombian economy, 2011

Sector	Type	Sectoral Share in:					Capital-Labor ratio
		Value Added	Total Employment	Unskilled Labor	Skilled Labor	Capital	
Agriculture	Formal	1.6	2.3	4.4	1.4	1.0	0.4
	Informal	5.2	8.2	22.9	2.0	2.0	0.2
Coal	Formal	1.9	0.5	0.4	0.5	3.2	5.5
	Informal	0.0	0.1	0.1	0.0	0.0	0.3
Oil	Formal	9.1	1.1	0.3	1.5	16.7	12.0
Metals	Formal	0.4	0.2	0.3	0.1	0.5	2.5
	Informal	0.3	0.4	1.1	0.1	0.4	0.8
Non-metals	Formal	0.2	0.2	0.3	0.2	0.1	0.4
	Informal	0.2	0.2	0.7	0.0	0.1	0.4
Industry	Formal	8.6	7.4	3.4	9.0	10.0	1.1
	Informal	2.1	3.0	4.7	2.3	1.2	0.3
Refinery	Formal	2.8	0.2	0.1	0.3	6.2	23.3
Tradable services	Formal	17.9	14.5	4.9	18.6	22.0	1.2
	Informal	8.0	12.2	15.7	10.8	3.5	0.2
Non-tradable services	Formal	22.1	21.3	11.6	25.3	23.3	0.9
	Informal	13.0	18.3	28.1	14.2	7.5	0.3
Pub. Admin.	Formal	6.4	9.9	1.0	13.6	2.3	0.2

Source: SAM 2011

The distribution of employment grossly follows value added lines: 66.4% of total employment belongs to the services sector (26.8% to tradables and 39.6% to non-tradables), 10.4% to industry, 9.9% to public administration, and 10.5% to agriculture. Unskilled labor concentrates in the services sector (60.3%, with 20.6% in tradable services and 39.7% in non-tradable services), agriculture (27.3%), and industry (8.1%). The figure corresponding to agriculture indicates a high overrepresentation of unskilled labor in this sector with respect to value added. Skilled labor is mostly employed in the services sector (68.9%, with 29.4% in

tradable services and 39.6% in non-tradable services), the public administration sector (13.6%), and the industry sector (11.3%).

Regarding total labor expenses, 21.7% corresponds to unskilled informal labor, 20.8% to skilled informal labor, 7.9% to unskilled formal labor, and 49.7% to formal skilled labor. In total, informal labor represents 42.5% and formal labor the remaining 57.5%, while unskilled labor represents 29.6% and skilled labor 70.4%.

With respect to capital, its use is conspicuous in the services sector (56.4%, of which 25.6% in tradable services and 30.8% in non-tradable services), the oil sector (16.7%), the industry sector (11.2%), and the refinery sector (6.2%). The cases of oil and refinery show a higher than proportional use of capital with respect to their share in value added suggesting a high capital-labor ratio. This feature is confirmed in the last column of Table 1 where we report the sectorial capital-labor ratios. The highest ratios are found for the refinery sector (23.3), the oil sector (12), the formal coal sector (5.5), and the formal metallic minerals sector (2.5).

As for international trade, the trade dependency ratio[3] of the Colombian economy was 37% in 2011, a year during which it sustained a negative trade balance equivalent to 1.2% of GDP. As shown in table 2, the share of products related to the extractive sectors account for 53.2% of total exports, followed by industrial exports (29.3%), and refinery exports (9.3%). On the import side, the majority of trade is in industrial goods (79%), followed by services (9.1%), and refinery products (7.4%). The set of products with the greatest export orientation, as measured by the export coefficient[4] are coal, oil, metals, and refinery products, all originated in the extractive sectors. Lastly, as shown in the last column of Table 2, the greatest penetration of imports, as measured by the import penetration ratio[5], belong to industrial and refinery products.

Table 2. Main features of Colombian international trade, 2011

Products	Share in total:		Export Coefficient	Import Penetration
	Exports	Imports		
Agriculture	3.7	4.2	0.08	0.08
Coal	12.2	0.0	0.95	0.01
Oil	39.1	0.0	0.72	0.00
Metals	1.6	0.0	0.30	0.01
Non-metals	0.3	0.2	0.13	0.07
Industry	29.3	79.0	0.14	0.26
Refinery	9.3	7.4	0.28	0.23
Tradable services	4.5	9.1	0.02	0.04

Source: Macro SAM 2011

As follows from the above, the economy shows a relatively important dependence on the extractive sectors, which in spite of having a sizeable but not overwhelmingly high share in value added, have a very high share in exports. This is reflected in the rising importance of governmental income originating in these sectors, reaching almost 11% of total government revenue, of which 63% correspond to royalties and 37% to dividends accruing from the

[3] Total trade as a percentage of GDP.
[4] Exports as a percentage of domestic production.
[5] Imports as a percentage of domestic absorption.

national oil company. In the face of a declining international oil price, sectors highly dependent on non-oil products with high export coefficients or with high import penetration ratios are likely to be positively affected.

4 Methodology

As mentioned, we use a dynamic recursive computable general equilibrium model (CGE) for our analysis. CGEs are particularly well suited for the task at hand since they have the capacity of taking into account second round effects of the external shocks on the economy, and to provide sectorial and other economic detail useful for economic analysis and policy making. In particular, we use the single country, recursive dynamic version of the Partnership for Economic Policy (PEP) model, fully documented in Decaluwé et al (2012). The model extends to multiple periods the single-period PEP-1-1 model, through linking successive periods by means of variables that are inherited from the previous one and are transmitted by a set of "dynamic equations". The model belongs to the neoclassical tradition, in a perfect competition setting, where agents' behavior is drawn from optimization problems. As the model has a thorough documentation, we focus here on the features that distinguish our version of the model from the original one.

As the distinction between formal and informal sectors is central to our objectives, we have both types of activities in the model. While the basic layout of their production function is similar, they differ in two main respects. First, informal activities produce to supply the domestic market; that is, they do not export (with the exception of agriculture). Second, informal activities do not pay taxes. The basic structure of both activity types involves a Leontief top nest mixing value added and aggregate intermediate consumption, while in the second nest value added is generated as a constant elasticity of substitution (CES) combination of composite labor and capital. While there is only one type of capital for non-oil and non-mineral extraction activities in the model, oil and mining activities make use of two types of capital: capital and natural resources. On the other hand, composite labor is a CES blend of skilled and unskilled labor, which is of the informal type in the case of an informal activity and of the formal type in the case of a formal activity. Lastly, aggregate intermediate consumption is represented, in the second nest, as a Leontief combination of composite goods.

Given the structure of supply, the implied structure from the demand side assumes imperfect substitution between products produced by formal and informal activities (through a CES aggregator). While informal products come only from domestic (informal) activities, formal products come from domestic formal activities and from the Rest of the World (as imports), once again as imperfect substitutes (CES). Imported products are assumed formal, as are exported products (with the exception of agricultural products that are also exported by the informal sector). Therefore, both, formal and informal activities, demand composite goods for intermediate consumption and this composition is made up of formal domestic and imported products, on one side, and of informal products, on the other. The same is true for other sources of demand (households, government, and investment). Taxes on products are levied only on products originated in formal activities while those coming from informal activities do not pay taxes.

As follows from the production structures depicted above, we assume the labor market is segmented in a formal and an informal sector. However, the distinction between formality and informality has nothing to do with the intrinsic characteristics of workers, in the sense that there are both skilled and unskilled workers in the two segments and what determines their formal or informal character is simply the type of activity that hires them. While equilibrium in the formal segment is attained through equalization of demand for formal employment and its supply (after deducting labor mobility to the informal sector and unemployment), in the informal segment it is achieved through equalization of demand and total supply (i.e. supply of informal labor plus labor coming from the formal segment). Mobility between the two segments follows a Harris and Todaro (1970) mechanism: mobility stops when the informal wage "equates" the expected wage in the formal sector. Lastly, there is unemployment in the formal segment with real wage downward rigidity, and full employment in the informal segment, under fully adjustable wages. However, there is the possibility that market clearing in the formal segment arises through wages. In this case, the unemployment level in the formal segment hits its (calibrated) minimum, labor supply becomes perfectly inelastic, and wages clear the market (in which case there is no labor mobility between the formal and informal segments). This is achieved by using a complementary-slackness condition.

Also, a set of features is added to the model for several purposes. First, we isolate rents accruing to the government from natural resources either in the form of royalties or dividends received from the national oil company. The calculation of dividends is endogenous to the model and the rate at which they are generated depends upon the behavior of international prices.[6] Second, we take into account that investment in oil and mining production is not only dependent on their relative rental rates but also, and mostly, on Foreign Direct Investment (FDI). As a consequence, we single out FDI in the oil and mining sectors and let the market assign new investment only for the remaining part of foreign savings (plus domestic savings), so total investment in these sectors is composed of competitively assigned new capital plus FDI. This feature of the model allows for exogenously shocking FDI in case it is deemed relevant. Third, we model the administration of oil and mining royalties ensuing to the government in a way that allows simulating the implementation of the Savings and Stabilization Fund (FAE for its Spanish language acronym), a policy measure undertaken by the government to help avoid potential Dutch Disease effects on the economy.

In the appendix, we provide a full account of the relevant equations of the model.

5 Simulations and results

With the model described above, we run three sets of simulations. One corresponding to the baseline (BAU), tracing the behavior of the economy along a 15 year-span, in which the economy is assumed to grow at the steady state rate.[7] A second one (EIA), in which international oil prices grow at the rates forecasted by the US Energy Information Administration's International Energy Outlook 2016. In a third simulation (FAE), we add the implementation of the FAE by the Colombian government.

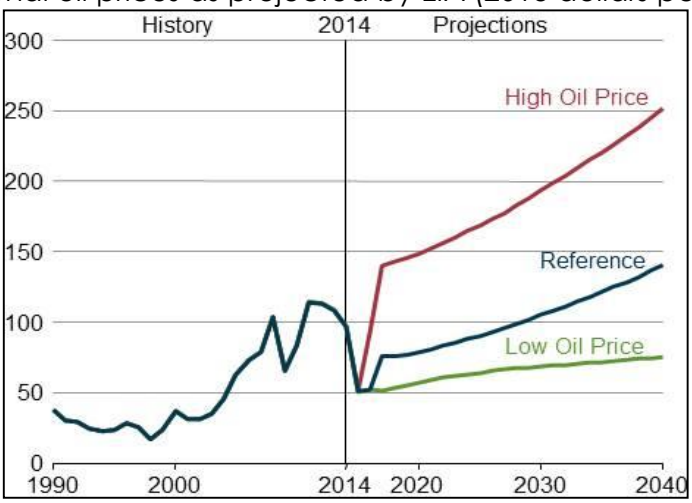
[6] We use an elasticity calculated based in data by Olivera et al (2013).

[7] Which corresponds to the average growth rate along the period 2003-2015 (4.3%).

In all cases we use the following closure rules. The nominal exchange rate is the numeraire, foreign savings is exogenous, real current government expenditure in goods and services is exogenous, foreign direct investment in the oil and coal sectors is exogenous, and investment is savings driven. This way, in the face of changes in international prices, the real exchange rate (defined as the nominal exchange rate over the price index for domestically produce goods) varies in order to clear the current account allowing for capturing the relevant effects of the price drop.

Against the picture depicted in the baseline scenario, in the second one (EIA's reference scenario) the international prices of oil vary according to EIA's price forecasts, which are the prices expected to prevail after the Colombian government designed the policy measures that we simulate in the third scenario. The expected behavior of prices is depicted in figure 4, which implies a decrease of near 21% by 2025 with respect to the base year (2011).

Figure 4. International oil prices as projected by EIA (2013 dollars per barrel)

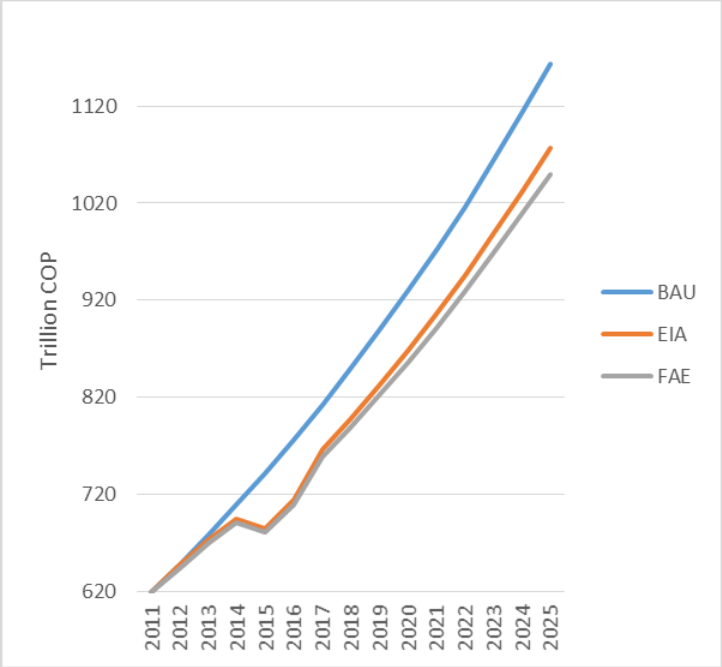


Source: US Energy Information Administration (2016)

Real GDP at market prices grows under the EIA scenario at an annual compound rate 0.6 percentage points below the implied steady state rate (4.6%), while it does so 0.8 percentage points under the FAE scenario. As follows from figure 5, this average difference translates in real GDP levels that are 7.5% and 9.7% below the level under the BAU in 2025, so the cumulative effect of this difference is significant in the medium run.

Given the importance of oil exports, the drop in international prices leads to a sharp decrease in export values. As shown in the left hand side panel of figure 6, total exports decrease by as much as 21% in 2015 with respect to the baseline and by 11.7% in average between 2017 and 2025, blowing a significant shock to the current account. In response, the value of imports decreases too, as shown in the right hand side panel of the same figure. Imports fall 17% with respect to the baseline in 2015 under the EIA scenario and more than 18% under the FAE scenario, while situating 9.4% below in average under the EIA scenario and 11.3% below under the FAE scenario between 2017 and 2025.

Figure 5. Real GDP at market prices under the baseline and the EIA and FAE scenarios



Source: CGE model simulations

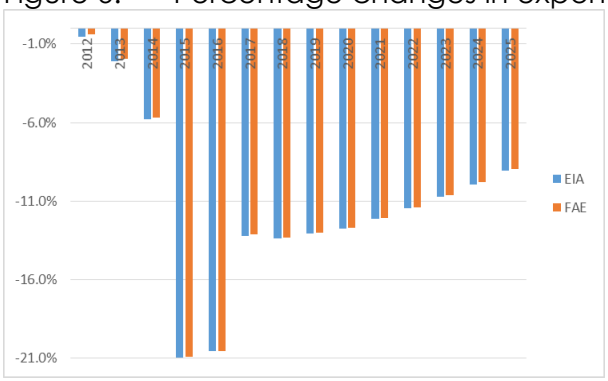
The main equilibrating factor driving these changes is the real exchange rate. As oil prices drop, the real exchange rate appreciates and then, as prices recover and move closer to base year prices, it falls allowing for exports and imports to soften their decline. Under the EIA scenario, the change in the real exchange rate is slightly lower than under the FAE, since in the latter the economy is setting aside the stabilization fund and there is need to make a stronger adjustment to the trade balance. This reflects in the size of percentage deviations from the baseline affecting imports, as evident in the right hand side panel of figure 6.

As mentioned, part of the policy response by the Colombian government in facing potential Dutch Disease effects arising from increased oil exports (in the face of the price boom prevalent roughly until 2012) is the establishment of a saving and stabilization fund (FAE for its acronym in Spanish language). The FAE was targeted to withhold up to 30% of royalties revenue, and these resources are meant to be invested abroad by the Central Bank and kept outside of the economy, as a classic sterilization scheme, unless needed to be used as countercyclical spending, should oil prices or exported volumes decline below an expected threshold. The FAE scenario assumes that 30% of royalty revenue is saved throughout the entire period. The expected effect of this measure is to dump to some degree the spending effect that could arise from oil exports, in this case directly through decreasing demand for investment goods, as the FAE decreases government's savings. The relative size of the FAE ranges between 0.4% and 0.6% of GDP at market prices and from 2.3% to 3.1% of total exports, from the beginning to the end of the period. As seen above, the results from the simulations confirm this expectation as GDP is slightly lower under the FAE scenario.

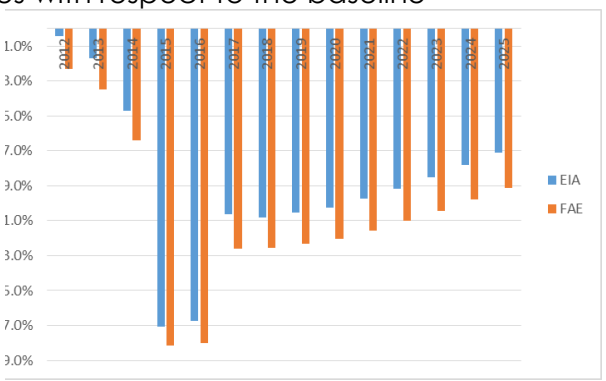
The adjustment in exports and imports leads to changes in their composition. Figure 7 illustrates the way commodities' shares in exports vary from the starting to the ending situations. The left hand side panel of the figure shows the composition of exports at the beginning of the period, while the right hand side panel shows its composition at the end of

the period under the EIA scenario. From there, it can be appreciated that oil exports share decreases 5.5 percentage points (to 33.6%), as industry's share increases 2.4 percentage points (to 31.7%) and coal and refinery products increase their in 1.2 and 1.1 percentage points (to 13.4% and 10.3% respectively). Changes in export composition under the FAE scenario, as compared to the EIA scenario, are marginal. On the other side, changes in the composition of imports between the beginning and the end of the period are almost negligible as there are no changes in their international prices and relative prices for them (with respect to the prices of goods produced by formal sectors) move in unison (with the exception of refinery products whose main input's international price falls).

Figure 6. Percentage changes in export values with respect to the baseline

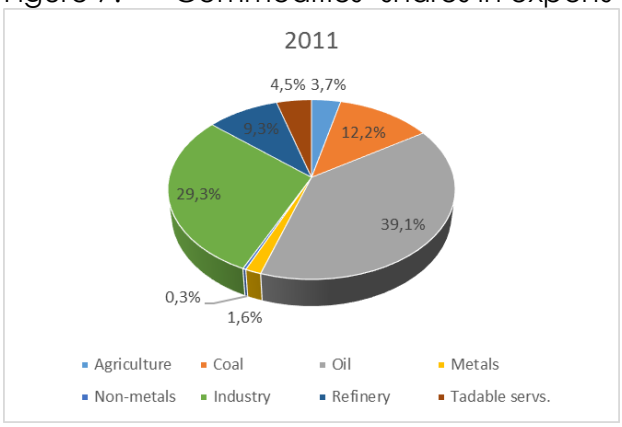


Source: CGE model simulations

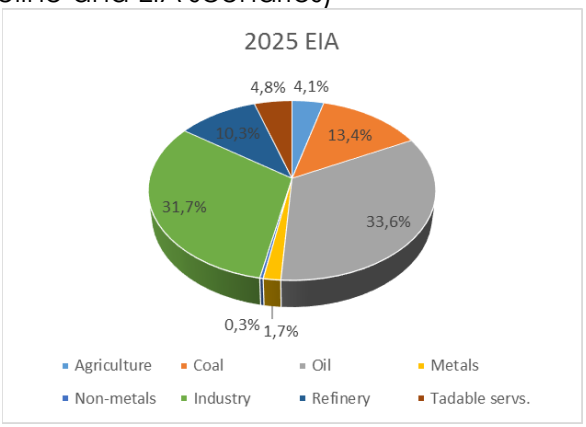


Source: CGE model simulations

Figure 7. Commodities' shares in exports (Baseline and EIA scenarios)



Source: CGE model simulations



Source: CGE model simulations

The relative price of importable goods increases so formal domestic production substitutes for imports across the board. However, quantities produced grow slowly under the EIA scenario, as compared to the baseline, and more so under the FAE. Furthermore, in general, quantities exported grow more under the EIA and under the FAE scenarios (except for oil) than in the baseline (up to a point in time that varies from one activity to the other), so the net effect of the scenarios on production arising from formal activities is basically determined by their export coefficient. Activities with a low export orientation show relatively higher decreases in their production levels with respect to the baseline, while those with a higher export orientation show moderate decreases.

On the other hand, relative prices of composite formal goods (i.e. the composite between imports and goods produced by formal activities) with respect to goods produced by informal activities rise and, as a consequence, goods produced by informal activities tend to substitute for "formally" produced goods. However, the end result in terms of output level is mixed in the sense that some informal activities show increases in their share in output while some show decreases and informal tradable services register higher growth than under the baseline.

Table 3 shows the annual compound growth rates for formal activities and the percentage differences in output levels with respect to the baseline. As follows from the table, all activities but public administration show lower growth rates for output levels under both scenarios as compared to the baseline. The differences are higher for agriculture, non-tradable services, tradable services, and non-metallic minerals. Also, growth rates tend to be lower under the FAE scenario, with the exception of coal which is an activity centered around coal production that has the highest export coefficient in the economy.

Table 3. Annual compound growth rates for formal activities and percentage differences in output levels for 2025 under the EIA and FAE scenarios

Formal activities	Growth rates			Output levels	
	BAU	EIA	FAE	EIA	FAE
Agriculture	4,6%	3,0%	2,4%	-19,1%	-25,7%
Coal	4,6%	4,6%	5,4%	-0,6%	11,5%
Oil	4,6%	4,4%	4,4%	-2,5%	-2,9%
Metals	4,6%	4,2%	3,9%	-5,8%	-8,9%
Non-metals	4,6%	3,9%	3,5%	-9,3%	-13,2%
Industry	4,6%	4,0%	3,7%	-8,1%	-11,4%
Refinery	4,6%	4,6%	4,3%	-0,4%	-3,6%
Tradable servs.	4,6%	3,7%	3,3%	-11,8%	-16,1%
Non-tradable servs.	4,6%	3,6%	3,2%	-12,7%	-17,2%
Public adm.	4,6%	4,6%	4,6%	0,4%	0,5%

Source: CGE model simulations

With respect to informal activities, table 4 shows the corresponding growth rates and output level differences for the period. As shown, even though they register lower growth rates than under the baseline, in average the differences are smaller than for formal activities and in the case of tradable services the growth rate is higher under both the EAI and FAE scenarios. As happens with formal activities, implementation of the FAE results in lower growth rates (with the exception just noted). Therefore, the difference in output levels at the end of the period with respect to the baseline is, in average, smaller than in the case of formal activities.

Changes in sectoral output determine the behavior of labor demand. Demand for labor in the case of formal activities tends to grow slowly under the EIA scenario than under the baseline and more so under the FAE scenario. The slowest growers are oil, agriculture, and tradable services, while refinery and public administration's demand for labor is slightly more dynamic under the EIA and FAE scenarios than under the baseline. Most informal activities' demand for labor is also less dynamic under the EIA and FAE scenarios than under the baseline. This is the case of non-metals, metals, industry, and coal. The remaining informal

activities show labor demands growing at a faster pace than under the baseline (they are agriculture, tradable services, and non-tradable services).

Table 4. Annual compound growth rates for informal activities and percentage differences in output levels for 2025 under the EIA and FAE scenarios

Informal activities	Growth rates			Output levels	
	BAU	EIA	FAE	EIA	FAE
Agriculture	4,6%	4,6%	4,5%	-0,3%	-0,9%
Coal	4,6%	4,2%	4,3%	-5,0%	-4,4%
Metals	4,6%	3,9%	3,7%	-8,5%	-11,1%
Non-metals	4,6%	3,9%	3,7%	-9,2%	-11,5%
Industry	4,6%	4,1%	3,9%	-6,6%	-8,5%
Tradable servs.	4,6%	4,8%	4,9%	2,2%	3,4%
Non-tradable servs.	4,6%	4,5%	4,4%	-1,5%	-2,5%

Source: CGE model simulations

Table 5 shows the annual average compound growth rates for unskilled and skilled labor demand by formal activities. With the exceptions of refinery products and public administration, all sectors show growth rates below those under the baseline and in two cases (agriculture and oil) the rates are negative (i.e. demand for labor actually decreases). Activities for which labor demand is more dynamic along the period, experience a relatively important increase in the cost of capital (vis a vis the cost of labor) during the oil price plunge (until 2015) and then a rapid decrease and stabilization at a level similar to the base year. In contrast, activities that experience a negative growth rate in labor demand, show a relatively important decrease in the cost of capital during the oil price downturn and then a recovery to levels somewhat below the base year level. On the other hand, growth rates are always lower under the FAE scenario, indicating the depressing effect that the policy has on labor demand by formal activities in general.

Table 5. Annual average compound growth rates for formal employment at the sectoral level

Formal activities	Unskilled labor			Skilled labor		
	BAU	EIA	FAE	BAU	EIA	FAE
Agriculture	1,3%	-0,3%	-0,9%	1,3%	-0,3%	-0,9%
Coal	1,3%	1,1%	1,0%	1,3%	1,1%	1,0%
Oil	1,3%	-0,8%	-1,0%	1,3%	-0,8%	-1,0%
Metals	1,3%	1,0%	0,8%	1,3%	1,0%	0,8%
Non-metals	1,3%	0,7%	0,4%	1,3%	0,7%	0,4%
Industry	1,3%	0,8%	0,6%	1,3%	0,8%	0,6%
Refinery	1,3%	1,3%	1,3%	1,3%	1,3%	1,3%
Tradable servs.	1,3%	0,5%	0,2%	1,3%	0,5%	0,2%
Non-tradable servs.	1,3%	0,5%	0,1%	1,3%	0,5%	0,1%
Public adm.	1,3%	1,3%	1,3%	1,3%	1,3%	1,3%

Source: CGE model simulations

With respect to labor demand by informal activities, table 6 shows the annual average compound growth rates for unskilled and skilled workers. As can be appreciated, in the

cases of agriculture and services (both tradable and non-tradable) labor demand is more dynamic under the EIA and FAE scenarios than under the baseline. However, conversely to other situations, the effect of the FAE is positive for labor demand as it grows slightly more in the three sectors and labor types, with the only exception of demand for skilled labor by agriculture. The four remaining informal activities show lower growth rates under the EIA and FAE scenarios than under the baseline. Growth rates are lower, in order, for non-metals, metals, industry, and coal, and (with the exception of coal) are even lower under the FAE scenario.

Table 6. Annual average compound growth rates for informal employment at the sectorial level

Informal activities	Unskilled labor			Skilled labor		
	BAU	EIA	FAE	BAU	EIA	FAE
Agriculture	1,3%	1,4%	1,4%	1,3%	1,3%	1,3%
Coal	1,3%	1,1%	1,2%	1,3%	1,0%	1,1%
Metals	1,3%	0,8%	0,7%	1,3%	0,7%	0,6%
Non-metals	1,3%	0,7%	0,6%	1,3%	0,7%	0,5%
Industry	1,3%	0,9%	0,8%	1,3%	0,9%	0,7%
Tradable servs.	1,3%	1,6%	1,8%	1,3%	1,6%	1,7%
Non-tradable servs.	1,3%	1,4%	1,4%	1,3%	1,3%	1,3%

Source: CGE model simulations

Jointly considered, the behavior of labor demand by formal activities under the EIA scenario can be summarized as follows: demand for unskilled labor shows an annual growth rate of 0.45% (0.85 percentage points below the baseline rate), while demand for skilled labor shows a growth rate of 0.67% (0.63 percentage points below the baseline rate). Growth rates for both types of labor are even lower under the FAE scenario (0.11% and 0.43%, respectively). On the other hand, the behavior of labor demand under the EIA scenario by informal activities leads to an annual growth rate of 1.39% for both unskilled and skilled labor (0.09 percentage points above the baseline rate) and to higher rates under the FAE scenario (1.43% per year for both labor types – 0.13 percentage points above the baseline rate).

Therefore, the drop in international oil prices makes the economy react in such a way that demand for labor by formal activities is less dynamic than in the baseline, yielding an annual growth rate of 0.97% under the EIA scenario. In contrast, labor demand by informal activities is more dynamic than in the baseline, growing at an annual rate of 1.39% under the same scenario. Furthermore, the effect of the policies put in place by the government to face potential Dutch Disease effects on the economy, worsens the performance of labor demand by formal activities and enhances that of informal activities, leading to annual growth rates of 0.85% and 1.43%, correspondingly. In this way, the level of labor demand under the EIA scenario by formal activities is 8.7% below the baseline and 11.9% below under the FAE scenario. In contrast, the level of labor demand by informal activities under the EIA scenario is1.3% above the baseline level and under the FAE is 1.8% above.

Form the stand point of skill level, the price shock negatively affects demand for both skilled and unskilled labor, as under the EIA scenario the annual growth rate for skilled labor is 0.89% and that for unskilled labor is 1.15% (0.41 and 0.15 percentage points below the baseline rate). Additionally, the effect of policy intervention worsen the outcome as growth rates for

both labor types are lower under the FAE scenario (0.56 percentage points below the baseline rate for skilled labor and 0.2 percentage points below for unskilled labor). Therefore, both the price shock and the policy intervention yield larger negative effects for skilled labor. As a matter of fact, the level of unskilled labor demand under the EIA scenario is 2% below the baseline level and it decreases to 2.7% under the FAE scenario, while in the case of skilled labor the differences are 5.5% and 7.5%, respectively.

These figures imply that there are more workers migrating from formal to informal employment than under the baseline. In effect, under the EIA scenario the annual growth rate of skilled workers migrating from formal to informal employment is 1.6% (0.3 percentage points above the baseline rate) and a similar figure (marginally lower) is observed for unskilled workers. Both figures increase under the FAE scenario (to 1.7%) indicating that the policy intervention reinforces the informalization of the labor market. As a result, the level of skilled and unskilled workers migrating from formal to informal employment is 5.6% above the baseline level, while without policy intervention the corresponding figures are 4.1% and 4%, respectively. Lastly, more migration from formal to informal employment means higher unemployment rates in the formal labor market segment. Under the EIA scenario, the unemployment rate increases for both skilled and unskilled labor (6.9 and 5.8 percentage points, respectively), while under the EIA scenario they do so by 9.5 and 8 percentage points. These changes mean that the overall unemployment rate for the economy goes from 9.6% for unskilled workers in the baseline to 10.1% under the EIA scenario and 10.2% under the FAE, while for skilled workers goes from 8.5% in the baseline to 13% under the EIA and 14.5% under the FAE.

6. Conclusions and policy implications

We have examined the likely effects of the expected behavior of international oil prices on labor market dynamics in the Colombian economy, as they were forecasted in the US Energy Information Administration's International Energy Outlook in 2016. The sudden and sizable drop in oil prices, especially from 2013 on, induced an important external shock to the economy as it came from an oil export boom roughly stretching from the mid-2000s to 2012, compounded by capital inflows as FDI and portfolio investments. As the economy started showing signs of Dutch Disease effects, in 2012 the government introduced legislation for facing these situation, mainly by establishing a saving and stabilization fund for sterilizing part of the oil income in what appears to be a relatively late and timid intervention (Arguello et al., 2016).

The plunge in oil prices reduced in an important manner export income, royalties revenue, and inbound FDI, inducing a significant shock to the external balance. Whatever the potential effects arising from this shock, the policy intervention implemented in 2012 continues to be in place and will exert some influence on the likely outcomes.

Results from the analysis show that the economy experiences a drop in export value that must be compensated by a drop in imports, achieved through an appreciation of the real exchange rate. As a consequence, the economy grows at a lower pace than under the baseline scenario, leading to an annual compound rate 0.6 percentage points below the implied steady state rate (4.6%). The oil sector loses export share while industry, coal, refinery products, and tradable services increase theirs.

Relative prices move in favor of production by formal activities substituting for imports and also in favor of production from informal activities substituting for the composite of imports and production from formal activities. As a result most activities show lower growth rates of labor demand than in the baseline, with the exception of informal tradable services and public administration. This translates in a less dynamic labor demand for most activities (eight out of ten formal activities and four out of seven informal activities), although in the cases of refinery products and public administration (both formal activities) and informal services (both tradable and non-tradable) the outcome leads to higher growth rates of labor demand.

Jointly considered, these behaviors imply that demand for unskilled and skilled labor by informal activities grow more under the EIA scenario (drop in oil prices without policy intervention) than in the baseline, while demand for skilled and unskilled labor by formal activities grows less. With this, it is observed that demand for unskilled and skilled workers in general is less dynamic than in the baseline, but is less so in the case of skilled labor. On the other hand, labor demand by informal activities is more dynamic than in the baseline while demand by formal activities is less dynamic. Therefore, the plunge in oil prices leads to an increased informalization of the labor market in the sense that it favors labor demand by informal activities and discourages labor demand by formal activities. Furthermore, while it depresses labor demand for both unskilled and skilled labor, it does so more in the case of skilled labor. To accommodate these effects on the labor market, the unemployment rate increases with respect to the baseline and a larger share of workers migrate from formal to informal employment.

Lastly, although with some nuances, the effect of the policy intervention implemented by the government for dealing with Dutch Disease effects on the economy, tends to deepen the consequences arising from the fall in oil prices. It increases demand for labor by informal activities and decreases that by formal activities, while decreasing demand for both unskilled and skilled labor, with a larger effect on demand for skilled labor. Therefore, the government should consider either temporarily suspending the operation of the FAE or implementing alternative measures aimed at avoiding the informalization of the labor market that arise from the oil price drop and the operation of the FAE.

References

Arguello, R., D. Jimenez, E. Torres, and M. Gasca (2016) Dutch Disease, Informality, and Employment Intensity in Colombia, PEP Research Network, MPIA Working Paper 2016-07.

Banco de la República (2015) La Informalidad en el Mercado Laboral Colombiano. Reportes del Emisor, Investigación e información económica. Subgerencia Regional de Estudios Económicos de Medellín y Unidad de Investigaciones-Gerencia Técnica, October

Collier, P. and B. Goderis. (2007), *Commodity Prices, Growth and the Natural Resources Curse: Reconciling a Conundrum*, The Centre for the Study of African Economies Working Paper Series, Working Paper 276. Oxford.

Corden, W.M. and P. Neary (1982), "Booming sector and deindustrialization in a small open economy", Economic Journal, 92: 835-848.

Edwards, S. (1986), "Coffee, money and inflation in Colombia", en V, Thomas (ed.) Linking Macroeconomic and Agricultural Policies for Adjustment with growth: the Colombian Experience, Johns Hopkins University Press, Baltimore, MD.

Decaluwe, B., A. Lemelin, H. Maisonave and V. Robichaud (2012), The PEP Standard Computable General Equilibrium Model. Single Country, Recursive Dynamic Version, PEP-1-t, version 2.0, Partnership for Economic Policy (PEP) Research Network, Québec, mimeo, May.

Harris, J and M. Todaro (1970) Migration, unemployment and development: A two sector analysis, American Economic Review, 60, 126-142.

International Monetary Fund (2016) Colombia. Arrangement under the flexible credit line and cancellation of current arrangement –press release; and staff report. IMF Country Report No. 16/154, June.

Jimenez, Diana (2012) La informalidad laboral en América latina: ¿Explicación estructuralista o institucionalista? Cuadernos de Economía, 31(58), June-December

Lederman, D. and W.F. Maloney (2008) "In Search of the Missing Resource Curse." World Bank Policy Research Working Paper, WPS 4766. Washington, DC.

Magud, N. and S. Sosa (2010), When and Why Worry About Real Exchange Rate Appreciation? The Missing Link Between Dutch Disease and Growth, IMF Working Paper, WP/10/271, December.

Ministry of Finance and Public Credit (2011), ¿Por qué es necesaria la creación de un Sistema General de Regalías? J.C. Echeverry, G. Masmela, and A: García, Notas Fiscales, No. 2, January.

Olivera, Mauricio, Sandra Cortes, and Tatiana Aguilar (2013), Ingresos Fiscales por Explotación de Recursos Naturales en Colombia, Resumen de Políticas No. IDB-PB-196, Banco Interamericano de Desarrollo.

Sachs, J.D. and A.M. Warner (2001), "The Curse of Natural Resources", *European Economic Review*, 45(4–6):827–38, May.

Sala-i-Martin, X and A. Subramanian (2003), "Addressing the Natural Resource Curse: An Illustration from Nigeria", IMF Working Paper 03/139, International Monetary Fund, Washington, DC, July.

Spatafora N. and A. Warner (1995), Macroeconomic Effects of Terms-of-Trade Shocks: the Case of Oil Exporting Countries, Policy Research Working Paper, 1410, the World Bank.

Treviño, J.P. (2011), Oil Price Boom and Real Exchange Rate Appreciation: Is There Dutch Disease in the CEMAC?, IMF Working Paper, WP/11/268, November.

US Energy Information Administration (2016) International Energy Outlook 2016, May 11.

Annex

Implementation of the composite commodity

$$QF_{i,t} = B\_M_i * \left[\beta\_M_i * IM_{i,t}^{-\rho\_M_i} + (1 - \beta\_M_i) * DDF_{i,t}^{-\rho\_M_i} \right]^{\left(-1/\rho\_M_i\right)}$$

$$IM_{i,t} = \left[\frac{\beta\_M_i}{(1 - \beta\_M_i)} * \frac{PDF_{i,t}}{PM_{i,t}} \right]^{\sigma\_M_i} * DDF_{i,t}$$

$$Q_{i,t} = B\_Q_i * \left[\beta\_Q_i * QF_{i,t}^{-\rho\_Q_i} + (1 - \beta\_Q_i) * DDI_{i,t}^{-\rho\_Q_i} \right]^{\left(-1/\rho\_Q_i\right)}$$

$$QF_{i,t} = \left[\frac{\beta\_Q_i}{(1 - \beta\_Q_i)} * \frac{PDI_{i,t}}{PQF_{i,t}} \right]^{\sigma\_M_i} * DDI_{i,t}$$

$$DD_{i,t} = B\_DD_i * \left[\beta\_DD_i * DDF_{i,t}^{-\rho\_DD_i} + (1 - \beta\_DD_i) * DDI_{i,t}^{-\rho\_DD_i} \right]^{\left(-1/\rho\_DD_i\right)}$$

$$DDF_{i,t} = \left[\frac{\beta\_DD_i}{(1 - \beta\_DD_i)} * \frac{PDI_{i,t}}{PDF_{i,t}} \right]^{\sigma\_DD_i} * DDI_{i,t}$$

$$PDF_{i,t} = (1 + ttic_{i,t}) * \left[PL_{i,t} + \sum_i PC_{i,t} * tmrg_{ij,i} \right]$$

$$PDI_{i,t} = \left[PL_{i,t} + \sum_i PC_{i,t} * tmrg_{ij,i} \right]$$

$$PC_{i,t} * Q_{i,t} = (PQF_{i,t} * QF_{i,t}) + (PDI_{i,t} * DDI_{i,t})$$

$$PQF_{i,t} * QF_{i,t} = (PDF_{i,t} * DDF_{i,t}) + (PM_{i,t} * IM_{i,t})$$

Where:

$QF_{i,t}$: $Quantity\ demanded\ of\ "formal"\ composite\ commodity\ i$
$IM_{i,t}$: $Quantity\ of\ product\ i\ imported$
$DDF_{i,t}$: $Demand\ for\ domestic\ formally\ produced\ commodity\ i$
$Q_{i,t}$: $Quantity\ demanded\ of\ composite\ commodity\ i$
$DD_{i,t}$: $Domestic\ demand\ for\ commodity\ i\ produced\ locally$
$PDF_{i,t}$: $Price\ of\ "formal"\ composite\ commodity\ i$
$PM_{i,t}$: $Price\ of\ imported\ product\ i\ (including\ all\ taxes\ and\ tariffs)$
$PDI_{i,t}$: $Price\ of\ "informal"\ domestic\ product\ i\ sold\ in\ the\ domestic\ market$
$PQF_{i,t}$: $Price\ of\ "formal"\ composite\ commodity\ i$
$PL_{i,t}$: $Price\ of\ local\ product\ i\ (excluding\ all\ taxes\ on\ products)$
$PC_{i,t}$: $Purchaser\ price\ of\ composite\ comodity\ i\ (including\ all\ taxes\ and\ margins)$
B_M_i: $Scale\ parameter\ (CES\ -\ composite\ "formal"\ commodity)$
β_M_i: $Share\ parameter\ (CES\ -\ composite\ "total"\ commodity)$
ρ_M_i: $Elasticity\ parameter\ (CES\ -\ "formal"\ composite\ commodity)$
σ_M_i: $Elasticity\ (CES\ -\ composite\ "formal"\ commodity)$
B_Q_i: $Scale\ parameter\ CES\ (composite\ "total"\ commodity)$
β_Q_i: $Share\ parameter\ (CES\ -\ composite\ "total"\ commodity)$
ρ_Q_i: $Elasticity\ parameter\ (CES\ -\ "total"\ composite\ commodity)$
σ_Q_i: $Elasticity\ (CES\ -\ composite\ "total"\ commodity)$
B_DD_i: $Scale\ parameter\ (CET\ -\ "composite\ domestic\ formal-informal"\ commodity$
β_DD_i: $Share\ parameter\ (CET\ -\ "composite\ domestic\ formal-informal"\ commodity)$
ρ_DD_i: $Elasticity\ parameter\ (CET\ -\ "composite\ domestic\ formal-informal"\ commodity)$
σ_DD_i: $Elasticity\ (CET\ -\ "composite\ domestic\ formal-informal"\ commodity)$
$ttic_{i,t}$: $Tax\ rate\ on\ commodity\ i$
$tmrg_{ij,i}$: $Rate\ of\ margin\ i\ applied\ to\ exported\ commodity\ i$

Implementation of the labor market

$$\left(LS_{lf,t} - MIGR_{lf,t}\right) * \left(1 - UERAT_{lf,t}\right) = \sum_{j} LD_{lf,j,t}$$

$$\left(LS_{li,t} + \sum_{lf} MIGR_{lf,t}\right) = \sum_{j} LD_{li,j,t}$$

$$MIGR_{lf,t} = \zeta_{lf} * \left\{\frac{\sum_{li} W_{li,t}}{\left(1 - UERAT_{lf,t}\right) * W_{lf,t}}\right\}^{\psi_l}$$

$$WREAL_{l,t} = \frac{W_{l,t}}{PIXCON_t}$$

$$WREALMIN_{lf,t} = \frac{WO_{lf,t}}{PIXCONO}$$

$$WREAL_{lf,t} \geq WREALMIN_{lf,t}$$

$$min(UERAT_{lf,t}) = ueratmin_{lf}$$

Where:

$LS_{l,t}\ Supply\ of\ type\ l\ labor$
$MIGR_{lf,t}: Formal - informal\ "migration"$
$UERAT_{l,t}: Unemployment\ rate\ factor\ l$
$LD_{l,j,t}: Demand\ for\ type\ l\ labor\ by\ industry\ j$
$W_{l,t}$
$WREAL_{l,t}: Real\ wage\ rate\ factor\ l$
$PIXCON_t: Consumer\ price\ index$
$WREALMIN_{lf,t}: Minimum\ real\ wage\ rate\ factor\ l$
$WO_{lf,t}: Wage\ rate\ of\ type\ l\ labor\ (base\ year)$
$PIXCONO: Consumer\ price\ index\ (base\ year)$
$ueratmin_{lf}: Minimum\ unemployment\ rate\ factor\ l$

Implementation of royalties and oil dividends payments

$$YGREG_t = \sum_{nr}\left[\lambda\_RK_{gvt,nr} * \sum_{j}\left(R_{nr,j,t} * KD_{nr,j,t}\right)\right]$$

$$YGDIP_t = \sum_{f} FDIP_{f,t}$$

$$YGDIO_t = \omega\_DV_{gvt,dio} * \sum_{f} FDIO_{f,t}$$

$$YROWDIV_t = \omega\_DV_{row,div} * \sum_{f} FDIV_{f,t}$$

$$YHDIV_t = \omega\_DV_{h,div} * \sum_{f} FDIV_{f,t}$$

$$FDIV_{f,t} = \omega\_FD_{div,f} * YFK_{f,t}$$

$$FDIO_{f,t} = \omega\_FD_{dio,f} * YFK_{f,t}$$

$$FDIP_{f,t} = \omega\_FDIP_f * \sum_{ka,joil} TDIP_{ka,joil,t} * KD_{ka,joil,t} * R_{ka,joil,t}$$

$$TDIP_{ka,joil,t} = tdipO_{ka,joil}\left[\frac{e_t * PWX_{coil,t}}{PE\_FOB_{coil,t}}\right]^{\sigma\_REG_{joil}}$$

Where:

$YGREG_t: Government's\ income\ form\ royalties$

$R_{nr,j,t}$: $Rental\ rate\ of\ type\ k\ capital\ in\ industry\ j$
$KD_{nr,j,t}$: $Demand\ for\ type\ k\ capital\ by\ industry\ j$
$YGDIP_t$: $Government's\ income\ form\ oil\ dividends$
$FDIP_{f,t}$: $Firms´payments\ of\ oil\ dividends$
$YGDIO_t$: $Government's\ income\ form\ non-oil\ dividends$
$FDIO_{f,t}$: $Non-oil\ governmental\ firms\ dividends$
$YROWDIV_t$: $ROW's\ income\ from\ dividends$
$FDIV_{f,t}$: $Firms'\ payments\ for\ dividends$
$YHDIV_t$: $Households'\ income\ from\ dividends$
$YFK_{f,t}$: $Capital\ income\ of\ type\ f\ businesses$
$TDIP_{ka,joil,t}$: $Tax\ rate\ on\ oil\ (endogenous)$
e_t: $Exchange\ rate\ (price\ of\ foreign\ currency\ in\ local\ currency)$
$PWX_{coil,t}$: $World\ price\ of\ exported\ product\ i\ (expressed\ in\ foreign\ currency)$
$PE\_FOB_{coil,t}$: $FOB\ price\ of\ exported\ commodity\ i\ (in\ local\ currency)$
$\lambda\_RK_{gvt,nr}$: $Share\ of\ type\ k\ capital\ income\ received\ by\ agent\ ag$
$\omega\_DV_{gvt,dio}$: $Agents\ share\ in\ income\ from\ dividends$
$\omega\_FD_{div,f}$: $Dividends\ share\ in\ firms\ capital\ income$
ω_FDIP_f: $Firm's\ type\ share\ in\ oil\ dividends$
$tdipO_{ka,joil}$: $Tax\ rate\ on\ oil\ (gov´t\ dividends)$
σ_REG_{joil}: $Elasticity\ of\ oil\ dividends\ to\ international\ prices$

Implementation of FDI for oil and mining

$$CAPFLOW_t = SROW_t - FDIMIN_t$$

$$GFCF_t = IT_t - \left(\sum_i PC_{i,t} * VSTK_{i,t}\right) + FDIMIN_t$$

$$IT_t = \sum_h SH_{h,t} + \sum_f SF_{f,t} + SG_t + CAPFLOW_t$$

$$IT\_PRI_t = IT_t - IT\_PUB_t - \left(\sum_i PC_{i,t} * VSTK_{i,t}\right) + FDIMIN_t$$

$$IT\_PRI_t = PK\_PRI_t * \left(\sum_{k,bus} IND_{k,bus,t}\right) + FDIMIN_t$$

$$KD_{k,j,t} = KD_{k,j,t-1} * \left(1 - \delta_{k,j}\right) + IND_{k,j,t-1} + fdishr_{k,j} * FDIMIN_t$$

Where:

$CAPFLOW_t$: $Capital\ flow\ from\ ROW\ net\ of\ Foreign\ Direct\ Investment\ in\ mining$
$SROW_t$: $Rest-of-the-world\ savings$
$FDIMIN_t$: $FDI\ in\ the\ oil\ and\ mining\ sectors\ (in\ local\ currency)$
$GFCF_t$: $Gross\ fixed\ capital\ formation$
IT_t: $Total\ investment\ expenditures$
$PC_{i,t}$: $Purchaser\ price\ of\ composite\ comodity\ i\ (including\ all\ taxes\ and\ margins)$

$VSTK_{i,t}$: $Inventory\ change\ of\ commodity\ i$
$SH_{h,t}$: $Savings\ of\ type\ h\ households$
$SF_{f,t}$: $Savings\ of\ type\ f\ businesses$
SG_t: $Government\ savings$
IT_PRI_t: $Total\ private\ investment\ expenditures$
IT_PUB_t: $Total\ public\ investment\ expenditures$
PK_PRI_t: $Price\ of\ new\ private\ capital$
$IND_{k,bus,t}$: $Volume\ of\ new\ type\ k\ capital\ investment\ to\ industry\ j$
$\delta_{k,j}$: $Depreciation\ rate\ of\ capital\ k\ in\ industry\ j$
$fdishr_{k,j}$: $Share\ of\ sector\ j\ in\ capital\ type\ k\ accruing\ as\ FDI$

Implementation of the FAE

$$YGFAE_t = faeintrat * FAEACC_t$$

$$FAE_t = faerat_t * YGREG_t$$

$$SROW_t = YROW_t - \left(\sum_i PE_{FOB\,i,t} * EXD_{i,t}\right) - \left(\sum_{agd} TR_{agd,t}\right) + FAE_t - YGFAE_t$$

$$FAEACC_{t1} = FAEACCO$$

$$FAEACC_t = FAE_{t-1} + FAEACC_{t-1}$$

Where:

$YGFAE_t$: $Government\ interest\ income\ from\ the\ FAE$
$FAEACC_t$: $Funds\ cumulated\ in\ the\ FAE$
FAE_t: $Fondo\ de\ Ahorro\ y\ Estabilizacion$
$YROW_t$: $Rest - of - the - world\ income$
$EXD_{i,t}$: $World\ demand\ for\ exports\ of\ product\ i$
$TR_{agd,t}$: $Transfers\ to\ domestic\ agents$
$FAEACCO$: $Initial\ funds\ accumulated\ in\ the\ FAE$
$faeintrat$: $Interest\ rate\ for\ the\ FAE$
$faerat_t$: $share\ of\ royalties\ income\ destined\ to\ the\ FAE$