

# Investigating the double dividend in a neo-Keynesian framework

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## Abstract

This article perform a systematic analysis in order to identify the key mechanisms leading to a double (environmental and economic) dividend in a neo-Keynesian framework. We simulate the impact of implementing a carbon tax in the case of a small open economy by using the ThreeME model calibrated for France. We find that the two main assumptions leading to a DD are the low exposure to foreign competition (which corresponds also to the case where countries cooperate in an international agreement) and the flexibility of the economy (in terms of substitution possibilities). In comparison, the impacts of the implementation scheme of the carbon tax and of the inflation dynamic are small.

Key words: double dividend, neo-Keynesian model

JEL code: E12, E17, E27, E37, E47, D57, D58

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# 1 Introduction

The macroeconomic and welfare effects of the low carbon energy transition is a controversial topic. Is there a trade-off between welfare and climate change? Can a carbon tax generate a double (environmental and economic) dividend? There is no consensual answer in the literature to these questions. The existence of a double dividend is often put forward by policy makers to justify the immediate implementation of climate policy. But economic evaluations often reach divergent conclusions generally depending on the type of models used and on the way the carbon tax is implemented (e.g. regarding the redistribution mechanism implemented).

The conditions of the existence of a double dividend (DD) from the implementation of a carbon tax has been widely discussed in the literature (see e.g. Jaeger, 2012; Freire-González, 2018; Aubert and Chiroleu-Assouline, 2019; Hafstead and Williams III, 2018). Its occurrence is highly sensitive to the hypotheses of the model considered (see Section 2). Most studies use a Walrasian CGE model and find little to no DD. This result mostly stems from the assumption of perfect price flexibility that guarantees that supply is always equal to the maximum production capacity.

In comparison, there are few studies that investigate the question of the DD through the lens of a neo-Keynesian framework. If they often conclude that a double dividend exists, the reasons are often unclear. The first objective of this paper is to perform a systematic analysis in order to identify the key mechanisms leading to a DD in a neo-Keynesian framework. We use the neo-Keynesian CGEM ThreeME (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy) to evaluate the key hypotheses that may lead to a DD in the case of small open economy like France. We investigate thoroughly the role of four leverages often mentioned in the literature: (i) the degree of exposure to foreign competition where a low exposure can be seen as a proxy for the fact that the trading partners are also implementing a carbon policy; (ii) the flexibility of the economy, i.e. the ease with which economic agents can substitute brown to green technology; (iii) the way the carbon tax is implemented (lump-sum redistribution of the proceed of the tax versus a reduction of the employers' social security contribution which is *a priori* more favorable to employment); (iv) the wage setting and inflation dynamic (which play a key role in eviction effects in a neo-Keynesian framework).

We find that the two main assumptions leading to a DD are the low exposure to foreign competition (which corresponds also to the case where countries cooperate in an international agreement) and the flexibility of the economy. In comparison, the impacts of the implementation scheme of the carbon tax and of the inflation dynamic are small.

Section 2 provides a short literature review on the double dividend in theoretical and empirical CGEMs. Section 3 describe the ThreeME model and its main assumptions. Section 4 investigate the key hypotheses that lead to a double dividend. Section 5 concludes.

## 2 The double dividend in the literature

The concept of double dividend (DD) was originally connected to the debate over the acceptability of a carbon tax as opposed to command-and-control tools which has been widely discussed in the economic literature, in particular in Weitzman (1974). Among the pioneering works that transposed the debate to environmental economics and the carbon tax is Pearce (1991). He underlined that not only could a carbon tax help correct the distortions leading to negative environmental externalities (first dividend) but that the recycling of the proceeds of the tax could also be used to reduce other more distorting taxes, and hence lead to a second (economic) dividend. The concept has then developed quickly, leading to confusions around the definition of a double dividend and in particular of the way the second dividend should be defined and analyzed. For instance, Goulder (1995) defines several forms of the double dividend - the weak, the intermediate and the strong forms - depending on whether the economic improvement is in absolute terms or relative to a specific recycling method. Others have suggested to use different criteria from growth such as employment (Bovenberg, 1999).

Beyond definition considerations, the main issue regarding the double dividend remains whether it exists or not and why <sup>1</sup>. Recent works relied on environmental tax reforms that have been implemented around the world to estimate whether they have had positive impacts on the economy or not. Metcalf and Stock (2020) find that the hypothesis of the DD can not be rejected by the data. More specifically, they develop an empirical identification strategy based on the last 30 years in 31 European countries. They find that implementing a carbon tax could lead to a slight positive impact on the economic growth. Most importantly, their results show that the absence of a negative impact on the GDP is statistically significant. Nevertheless, such ex post assessments are the exception. Most works dealing with the existence of the double dividend consist in ex ante studies, be they theoretical models or empirical ones such as CGE models. Even though it has been widely documented, the existence of a double dividend is still very controversial.

The large majority of the theoretical studies on the DD are based on a neoclassical market clearing Walrasian model. If the first theoretical papers often concluded the absence of a double-dividend (see e.g. Bovenberg and De Mooij, 1994a,b; Bovenberg and van der Ploeg, 1994), many studies have then shown that this outcome is highly sensitive to the modelling hypotheses. The list of the key assumptions includes the design of the recycling policy (Parry, 1995), the preexisting tax system and its distortionary features (Babiker et al., 2003), the specification of the wage and price setting process (Marsiliani and Renström, 1997), the possibilities of substitution between labor supply and environmental quality (Kahn and Farmer, 1999) or between labor and energy (Koskela et al., 1998), the presence or not of a fixed factor in the production process of the polluting good (Bento and Jacobsen, 2007). The divergence in results is also found in studies using applied empirical model (Patuelli et al., 2005). Among the empirical studies finding a DD with a Walrasian CGEM, one can quote

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<sup>1</sup>In the recent years, studies have put forward other issues related to the DD and in particular issues of equity and horizontal redistribution (yellow vest movement for instance), (Fullerton and Monti, 2013), (Berry, 2019), (Pizer and Sexton, 2019).

Takeda (2007); Glomm et al. (2008); Sancho (2010); Ciaschini et al. (2012); Orlov et al. (2013); Fraser and Waschik (2013).

Within the neoclassical Walrasian framework, the existence of a DD is largely supply-driven because the assumption of perfect price flexibility guarantees that production is always equal to the maximum production capacity which is determined by the full use of production factors. In other words, Say's law (Say, 1836) where a product always finds its demand is satisfied. Under such an assumption, a DD is possible only if the available production factors increase. Since the capital stock is fixed and generally predefined by previous savings, the key mechanism generally goes through labor supply. A Walrasian CGEM may conclude the existence of a DD if the implementation of a carbon tax leads in one way or another to an increase in labor supply. For this reason, the hypothesis regarding the level of substitution between leisure and consumption or the importance of fossil consumption in the utility function of consumers is generally found to be of critical importance in the theoretically and empirical studies previously reviewed.

Say's law has been widely criticized by Keynesian theories because it rules out demand constraints and situations where production factors are under-used (e.g. involuntary unemployment) and because it is contradicted by stylized empirical facts shedding light on the fact that most companies choose not to produce at their full production capacity. The capacity utilization ratio fluctuates historically around 80 percent <sup>2</sup>. Neo-Keynesian models account for demand constraints. But in comparison to the neoclassical literature, there is few research on the DD performed with a neo-Keynesian framework <sup>3</sup>. They often conclude to the possibility of DD (see e.g. Landa Rivera et al., 2016; Lee et al., 2018) but to the best of our knowledge no research has performed a systematic analysis in order to identify the key mechanisms leading to a DD in a neo-Keynesian framework. This is the main objective of the present paper.

### 3 The ThreeME model and hypotheses

ThreeME is a country-level open source Computable General Equilibrium model (CGE) originally developed to support policymakers in the design and evaluation

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<sup>2</sup>See for instance the historical data for various US industries: <https://fredblog.stlouisfed.org/2019/01/capacity-utilization/> or <http://myf.red/g/1I8W>

<sup>3</sup>"Neo-Keynesian" models are different from the so-called "new Keynesian" models as defined in the Dynamic Stochastic General Equilibrium (DSGE) literature (see e.g. Clarida et al., 1999; Galí, 2008; Goodfriend and King, 1997; Goodfriend, 2007; Woodford, 2011). They have been widely criticised in the recent years for their lack of practical applications (see e.g. Mankiw, 2006; Solow, 2010; Romer, 2015; Stiglitz, 2018). This framework has been recently used to study the impact of climate policy by Annicchiarico and Di Dio (2015, 2017) who do not find a double dividend. The term "new Keynesian" is somehow misleading since most of the model assumptions are more of classical than Keynesian influence: no involuntary unemployment, perfect information (about the future), perfectly rational and forward-looking agent, Ramsey rule defining the optimal climate that maximize the inter-temporal utility. The hypothesis of slow price adjustment is hardly the only Keynesian features of the model but combined with other neoclassical features it does not change fundamentally the results in terms of DD compared to a standard Walrasian CGEM.

of decarbonization pathways in France (Callonnec et al., 2013, 2016)<sup>4</sup>. Since its first release, it has also been adapted to Mexico (Landa Rivera et al., 2016), Indonesia (Malliet et al., 2017) and the Netherlands (Bulavskaya and Reynès, 2018). ThreeME is specifically designed to evaluate the short-, medium- and long-term impact of environmental and energy policies at the macroeconomic and sectoral levels. To this end, the model combines several important features:

- Its sectorial disaggregation allows for analyzing the effect of transfer of activities from one sector to another in particular in terms of employment, investment, energy consumption or trade balance<sup>5</sup>.
- The highly detailed representation of energy flows through the economy allows for analyzing the consumption behavior of economic agents with respect to energy. Sectors can arbitrage between capital and energy when the relative price of energy increases, and substitute between energy vectors. Consumers can substitute between energy vectors, transportation modes or consumption goods.

As a CGE model, ThreeME fully considers feedbacks between supply and demand. Demand (consumption and investment) drives the supply (production). Symmetrically supply drives demand through the incomes generated by the production factors (labor, capital, energy products and materials). Compared to bottom-up energy models such as MARKAL (Fishbone and Abilock, 1981; Heaps, 2008), ThreeME goes beyond the mere description of the sectoral and technological dimensions by integrating these within a comprehensive macroeconomic model.

ThreeME is a neo-Keynesian model. Compared to standard Walrasian-type CGEs that are largely supply-driven, prices do not adjust instantaneously to clear markets. Instead the model is dynamic, and prices and quantities adjust slowly. Producers adjust their supply to the demand. This has the advantage to allow for situations of market disequilibria (in particular the presence of involuntary unemployment). This framework is particularly well suited for policy analysis. In addition to providing information about the long term, it allows for analyzing transition phases over the short and medium terms, which is especially relevant when assessing the implementation of climate policies.

In a Walrasian framework, supply is always at full production capacity. A policy increasing public spending or public investment has a negative impact on the economy: it has an eviction effect on private consumption and investment because it is not possible to increase production. A neo-Keynesian CGEM as ThreeME does not assume full utilisation of available production factors whether this comes from spare

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<sup>4</sup>The documentation and the version used in this study can be retrieved from [www.threeme.org](http://www.threeme.org).

<sup>5</sup>For this study, we used a version of the model with 10 sector: Agriculture and other industries, Manufacture of motor vehicles, trailers and semi-trailers, Construction of buildings and Civil engineering, Rail transport, Road transport, Services, Fossil energy, Transmission and distribution of electricity, Green and blue electricity generation, Fossil fuel electricity generation. The calibration of the base year (2010) is based on data from WIOD National Supply and Use Table (SUT) for France 2010 ([www.wiod.org](http://www.wiod.org))

production capacities or from unemployment. By including slow adjustment on capital and labor, the link imposed by the production function between the levels of labor and capital and the level of production is more a long term optimal relation than a strict constraint. This gives room for a positive multiplier effect of an increase in public spending. The eviction effect is limited and spreads over time. It comes from the inflation pressure generated by a higher utilization of the available production factors. Compared to a Walrasian framework, a neo-Keynesian model therefore accounts for important effects that are supported by empirical evidences such as demand side Keynesian multipliers. This may be an additional mechanism leading to a DD.

## 4 Investigating the key hypotheses leading to a double dividend

### 4.1 Hypotheses under scrutiny

In order to determine whether and to what extent a double dividend can exist in the ThreeME model, we focus on specific equations and parameters of the model. More precisely, we aim at investigating various hypotheses that can be split into two broad categories. On the one hand, the policy hypotheses define the way policies are implemented e.g. whether the carbon tax is redistributed or not and, in the case it is, how. On the other, we also intend to pinpoint the specificity of the ThreeME model and try to critically analyse some of its modelling hypotheses. Among these modelling hypotheses, we can distinguish between functional assumptions and parametric assumptions. The functional assumption we scrutinise consists in the way the wage equation is specified while parametric assumptions are about the degree of flexibility of the economy and the degree of exposure to foreign competition.

#### 4.1.1 Policy hypotheses

Macroeconomic studies dealing with the double dividend usually aim at determining whether the implementation of a specific policy leads to positive impacts both on the economy and the environment. The policy that we choose to focus on is the introduction of a carbon tax. We test two types of redistribution mechanisms. While we always keep the same kind of redistributive framework for households (a lump-sum transfer), we design two types of redistribution scheme for the incomes generated by the carbon tax over firms:

- ◇ *Lump-sum redistribution*: the redistribution to each firm is proportional to its labor share;
- ◇ *Employers' social security contribution*: the redistribution corresponds to a decrease of the labor tax for firms proportionally to their labor shares;

The main intuition driving this modelling alternative is that the firms' consumption and production choices might depend on the way the tax is redistributed, hence potentially impacting in different ways carbon emissions and the economic activity.

The lump-sum strategy reduces costs which could lead firms to reduce their prices and hence increase their competitiveness. The redistribution through a decrease in the employers' social security tax rate also leads to reducing costs. Contrary to the lump-sum strategy, it distorts relative prices and shifts the allocation of production factors. In particular, such a decrease makes the labor production factor appear as more attractive than before as compared to capital and energy. Hence, a lower labor tax for firms could entice them to substitute polluting capital to more labor all the more so as the decrease is proportional to their labor share. In other words, sectors that use the labor factor the most gets the largest decrease in social security contribution. This creates an incentive for firms to hire more people following the introduction of the carbon tax, not only because it is less polluting (hence they will be less taxed) but also because it is more profitable (they will get a bigger transfer *ex post*). Hence, the increase in labor could lead to an overall increase in employment.

#### 4.1.2 Modelling hypotheses

Apart from policy hypotheses, we want to investigate to what extent the existence and magnitude of a double dividend in ThreeME depends on its modelling hypotheses.

**Functional assumptions** Some modelling hypotheses are more structural than others. They are about the way we decide to represent the link between various aggregates such as, for instance, the unemployment rate and wages. The existence of a link between such aggregates and the way they interact is part and parcel of the modelling science. It means that it can also go hand in hand with disputed point of views. This is why we are eager to determine to what extent different structural forms would lead to different results when it comes to the double dividend.

Several studies have shown that the theoretical arguments and empirical estimates difficultly allow choosing between the two specifications. However, this difference of specification has important implications on the definition of the equilibrium unemployment rate or NAIRU (Non Accelerating Inflation Rate of Unemployment) and thus on the inflationary dynamic and the long-term properties of a macroeconomic model (L'horty and Thibault, 1998; Le Bihan and Sterdyniak, 1998; Blanchard and Katz, 1999; Chagny et al., 2002; Reynès, 2006; Heyer et al., 2007; Reynès, 2010). Here, we focus on three representations of the wage equation:

- ◇ *Wage-Setting* (WS) curve according to which the hourly wage level is a decreasing function of the unemployment level;
- ◇ *Phillips curve with constant* NAIRU: this corresponds to assuming there exists a negative relationship between the inflation rate and the unemployment rate in the short term. In the long run, there is no relationship between inflation and unemployment and the unemployment rate stabilizes at a level where the inflation remains stable;
- ◇ *Phillips curve with time-varying* NAIRU which relies on the same assumptions as previously described, the main difference being that the level of the long-term unemployment rate is time-dependent and varies with past inflation levels;

Investigating wage equation specifications derives from the intuition that job creations is an important part of the double dividend narrative. More generally, it is also a good indicator of the dynamic of economic activity. Choosing one specification rather than another comes along with implicit assumptions on the functioning of the labor market, which have in turn implications on the general economic activity and, hence, on the existence or/and magnitude of a double dividend.

**Parametric assumptions** On the other hand, results can also be influenced by the parameters that are chosen for some equations, in particular when it comes to elasticities. Changing some parameters allows to see to what extent the results depend on specific characteristics of the economy, which could in turn serve as an exploratory analysis for public policy recommendations. In particular, we investigate two main features:

- ◊ *Flexibility of the economy*: in the flexible (resp. rigid) case the elasticities of substitution between energy and capital, clean and dirty energy, clean and dirty transports are high (2 ; resp. low: 0.2). If the elasticity between clean and dirty energy is high, for instance, introducing a carbon tax will most probably shift production towards cleaner processes without hurting the economy. On the other hand, a small elasticity means a greater rigidity to adapt and will most likely come along greater difficulties for firms to cope with short term constraints.
- ◊ *Exposure to foreign competition*: the Armington elasticities are respectively 0.6 and 2. In this case, a high elasticity corresponds to a high substitution between domestic and foreign products, that is to say a high exposure of domestic production to the direct competition of products tailored abroad and imported. This could have an impact on the double dividend since the introduction of a carbon tax is likely to increase the price of domestic production which is likely to spur imports and downscale exports in an open economy, leading to a worse trade balance. On the contrary, we could believe less open economies are more protected from these trade balance shifts, leading more probably to a double dividend to exist.

The study of these modelling hypotheses aims at investigating limit cases. We use them as a way to explore the range of possible outcomes and understand to which extent these sensitivity analyses can help interpreting the results of our model in general. More precisely, the goal here is not to provide policy guidelines but rather to evaluate ThreeME as a scientific tool in itself from an epistemological perspective.

## 4.2 Results

Combining the sensitivity analysis of the four variables previously described - type of redistribution, wage equation specification, flexibility of the economy and exposure to foreign competition - leads to 24 different possible cases. Out of this case study, we analyze how the GDP and the emissions evolve, both in the short run (10 years after the carbon tax was implemented) and in the long run (50 years after). The implementation of a carbon tax leads in all cases to a reduction of carbon emissions in



the short and long run as compared to the baseline scenario. Hence, the existence of a double dividend only depends on whether the GDP decreases or increases following the shock and how it evolves over time. In total, 10 combinations out of the 24 under scrutiny lead to a short-term double dividend. When it comes to the long term, the number of double dividend cases rise up to 14. This already shows that implementing a carbon tax does not necessarily entail that a double dividend will follow, even in the long term. It also confirms that chosen assumptions are of cardinal importance while modelling environmental policies in a computable general equilibrium framework.

Table 1: Overview the existence of a short-term dividend depending on various model settings

		Lump-sum			Social security contributions		
		Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
Low flexibility	<i>Low exp.</i>	No	Yes	Yes	No	No	No
	<i>High exp.</i>	No	No	No	No	No	No
High flexibility	<i>Low exp.</i>	Yes	Yes	Yes	Yes	Yes	Yes
	<i>High exp.</i>	Yes	No	No	Yes	No	No

*Notes:* This table sums up the 24 possible settings with regard to whether they lead to the existence of a double dividend or not. For instance, when redistributing the carbon tax as a lump-sum transfer to firms, with a wage-setting equation, low flexibility and low exposure to foreign competition, the model ends up with no short-term double dividend. All other things being equal, switching the flexibility parameter from low to high will result in the existence of a short-term double dividend.

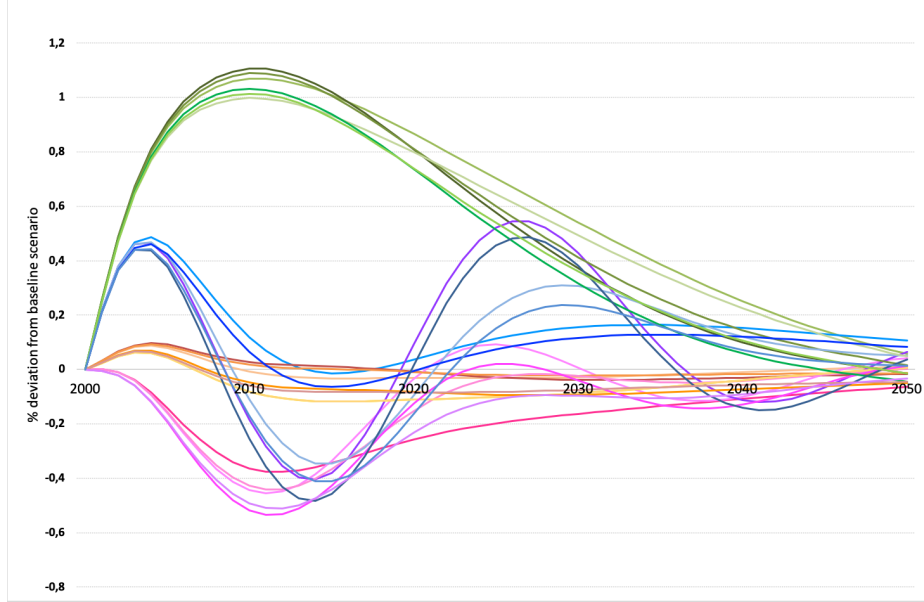
Table 1 sums up the different cases and shows whether they entail a short-term double dividend or not. We can first of all underline the fact that the combination of high flexibility and low exposure to foreign competition always leads to the existence of a double dividend in the short-term. On the contrary, combining low flexibility and high exposure to foreign competition will result in the absence of a short-term double dividend, no matter the type of redistribution and the wage equation specification.

**Long-term properties** Looking only at the binary output of existence of a double dividend ten years following the implementation of a carbon tax may be misleading, not taking into account the overall dynamics can lead to over-simplistic conclusions. On the opposite, it can also highlight in a more straightforward way regular patterns across the settings.

Figure 1 shows the evolution of the GDP in volume following the implementation of a carbon tax for the 24 different settings under scrutiny and up to 50 years after the introduction of the new policy. It depicts quite clearly four main clusters of trajectories:

- ◊ A strong and long-lasting increase of the GDP (green)
- ◊ A moderate short-term increase of the GDP followed by strong oscillations (blue)
- ◊ A small short-term increase of the GDP followed by a smooth return to the equilibrium (orange)

Figure 1: Long-term evolution of the GDP (in volume) following the implementation of a carbon tax (24 scenarios)



- ◇ A moderate decrease of the GDP during the first fifteen years followed by a return to the equilibrium (pink)

Interestingly enough, each cluster gathers six scenarios. Within each cluster, all scenarios show the same combination of the flexibility and exposure parameters. Hence, the green lines corresponds to scenarios where a high degree of flexibility of the economy is combined with a low degree of exposure to foreign competition. The blue cluster gathers scenarios with a high degree of flexibility and a high degree of exposure. The orange cluster is made of scenarios combining a low degree of flexibility and a low degree of exposure. Finally, the scenarios of the pink group are all characterized by a low degree of flexibility and a high degree of exposure to foreign competition. Hence, this result strengthens our conclusions drawn from the short-term analyses. It puts emphasis on the cardinal importance of the two parameters of flexibility and exposure in shaping the evolution of the GDP evolution following the implementation of a carbon tax not only in the short run but also in its long term dynamics.

The type of redistribution and the specification of the wage equation only play a minor role in very peculiar settings. For instance, it is possible to distinguish between three types of oscillations in the “blue” group. These distinct sub-groups corresponds to the different wage specifications (the lines oscillating the less corresponds to scenarios with the WS specification; the ones oscillating the most to scenarios with a Philips curve with constant NAIRU). It is also possible to disentangle two sub-groups in the “orange” cluster, one being slightly above the other. This distinction proceeds from the type of redistribution under scrutiny. A lump-sum transfer combined with

low exposure and low flexibility leads to a lower GDP in average than a decrease of the employers' social security contributions, *ceteris paribus*. The two other clusters (green and pink) show almost no variation between the scenarios.

This stresses further the robustness of the conclusion according to which a high degree of flexibility and a low degree of exposure to foreign competition entail a very high likelihood that a double dividend will appear. On the contrary, with a low flexibility and a high exposure it is very likely that there will be no double dividend at all, no matter the other parameters at stake. Hence, from a public policy point of view, it should be interpreted as different priority levels. One cannot expect to influence much of the economic outcome through the design of the redistribution scheme only. We should first ensure that firms are able to easily switch from dirty to clean ways of production and that there exists an international cooperation (corresponding to a low level of foreign competition) when it comes to environmental policies. These seem to be the main tools that drive the double dividend. It is all the more relevant since these settings also lead to a sustainable drop in carbon emissions, as shown in Table 2.

Table 2: Overview of the CO<sub>2</sub> emissions deviation from baseline scenario 50 years after the introduction of a carbon tax

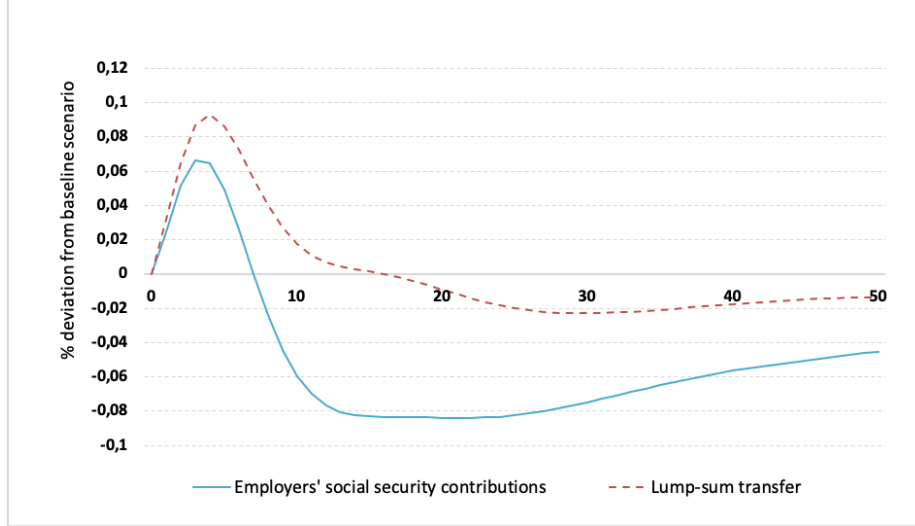
		Lump-sum			Social security contributions		
		Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
Low flexibility	<i>Low exp.</i>	-0.56	-0.60	-0.60	-0.61	-0.68	-0.69
	<i>High exp.</i>	-0.70	-0.61	-0.65	-0.77	-0.70	-0.75
High flexibility	<i>Low exp.</i>	-2.27	-1.73	-1.89	-2.28	-1.75	-1.91
	<i>High exp.</i>	-2.41	-2.66	-2.55	-2.45	-2.70	-2.61

*Notes:* This table sums up the 24 possible settings with regard to the deviations from baseline scenario in terms of CO<sub>2</sub> emissions 50 years following the implementation of a carbon tax. For instance, when redistributing the carbon tax as a lump-sum transfer to firms, with a wage-setting equation, high flexibility and low exposure to foreign competition, the emissions deviate from the baseline scenario by -9.52% ten years following the shock.

**Firm redistribution** The way the carbon tax is redistributed to firms does not seem to be a determining factor regarding the existence of a double dividend. Out of 12 cases, only two differ when considering one type of redistribution rather than another. More precisely, when we opt for a Philips wage specification (be it with constant or time-varying NAIRU), low flexibility and low exposure to foreign competition, a lump-sum transfer to firms leads to the existence of a double dividend whereas there will be none with a redistribution through a decrease of employers' social security contributions. Even though there is a double dividend in both cases on the very short-term, the increase of GDP following the introduction of a carbon tax only lasts 4 years before declining and ending up being negative as compared to the baseline scenario in the case of the decrease of the employers' social security contribution tax rate.

The channel discriminating the two distinct trajectories is the investment channel. Introducing a carbon tax leads to higher production prices for firms. Nonetheless, the increase in production prices is entirely transferred to consumption prices without

Figure 2: Evolution of GDP (in volume) following the introduction of a carbon tax

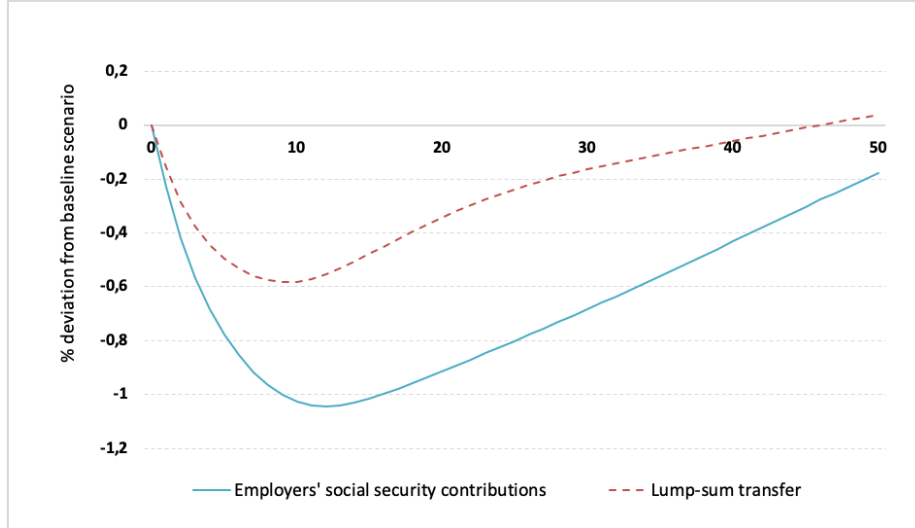


inducing a lower consumption level since the carbon tax is also partly redistributed to households as a lump-sum transfer. Exports follow the same sharp decrease after the tax was implemented, regardless of the redistribution scheme to firms while imports drop way less in the lump-sum transfer case. This might be partly explained by the fact that firms substitute labor to capital when the tax rate on social security contributions is reduced. This is corroborated by the greater increase in total employed people in the aforementioned redistribution scenario. In the end, the trade balance decreases less too. Substituting labor to capital could thus be interpreted as an implicit investment into labor. In any case, the type of redistribution targets some investments as more profitable than others. In the case of the lump-sum transfer, firms' investment decreases way less, most probably because the transfer in itself helps to minimize this decrease as compared to the other case. The very difference in investment levels between the two cases mostly explains why there is still a double dividend ten years after the carbon tax was introduced in the lump-sum transfer case and not in the social security contribution one.

**Wage equation** All other parameters remaining constant, considering various wage equation specifications leads to eight different cases. Out of these cases, only three are sensitive to the wage equation. What is more, none of them is sensitive to varying parameters within the Philips curve specification. In other words, it does not matter for the existence of a short-term double dividend whether we consider a constant NAIRU or a time-varying NAIRU. When differences exist, they arise from the difference of specification between the Wage-Setting and the Philips curve frameworks.

When setting parameters with low flexibility, low exposure to foreign competition and a lump-sum redistribution of the carbon tax, the WS specification leads to no double dividend while a Philips curve specification allow for one. Nonetheless, when

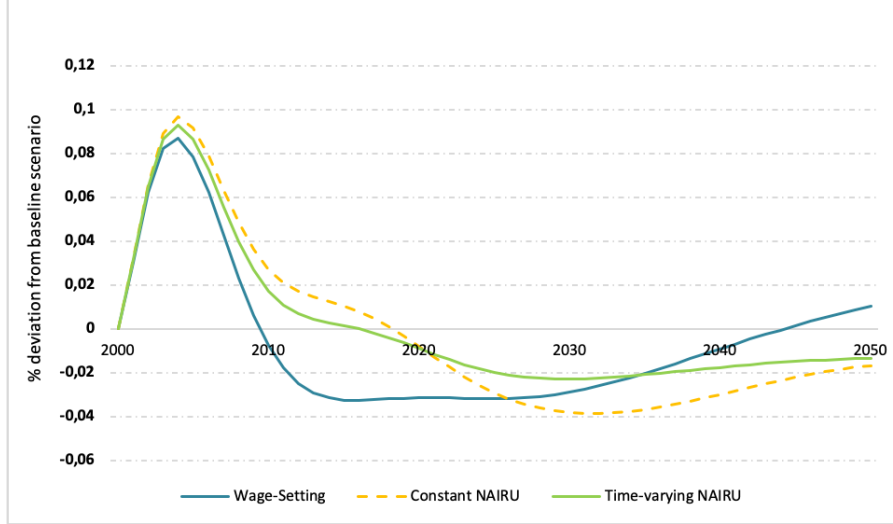
Figure 3: Evolution of firms' investment following the introduction of a carbon tax



having a closer look to the evolution of the GDP in both cases, we barely see any difference. In both cases, there is an increase of the GDP in volume in the very short run, peaking 4 years after the carbon tax was introduced. This increase is followed by a decrease, which seems a bit faster in the WS specification framework. This delay explains why, 10 years following the introduction of a carbon, a double dividend appears in one case and not in the other. Despite this slight delay, the overall trajectory of the GDP in both cases is very similar. Interestingly enough, it appears that the WS specification leads to a long-run GDP level slightly higher than before the introduction of the carbon tax while it is the opposite for the Philips curve specification.

That being said, the very small difference in terms of GDP is far from obvious. Indeed, the wage specification influences a lot the evolution of other determining factors such as prices (both for production, added value and consumption), exports, imports as well as household disposable income and consumption. During the four first years following the shock, the level of employment increases in both cases following the same trajectory. This decrease of the unemployment level feeds a rise in prices way bigger in the Philips framework than in the WS setting, since prices are sensitive not only to the change in unemployment level but also to the level in itself. Higher production prices lead to higher consumption prices. The increase in production prices originally comes from the increase in nominal wages which, on the other hand, sustains household consumption in spite of the price increase. This should lead to a greater increase in GDP in the Philips framework. Nevertheless, the increase in prices and wages also leads to a wider deterioration of the trade balance: exports drop more while the augmentation in imports is also greater. The combination of the two effects leads to similar aggregate GDP trends and explains why the wage specification does not really influence the existence of a double dividend in such a framework.

Figure 4: Evolution of GDP (in volume) following the introduction of a carbon tax with low flexibility, low exposure to foreign competition and lump-sum redistribution

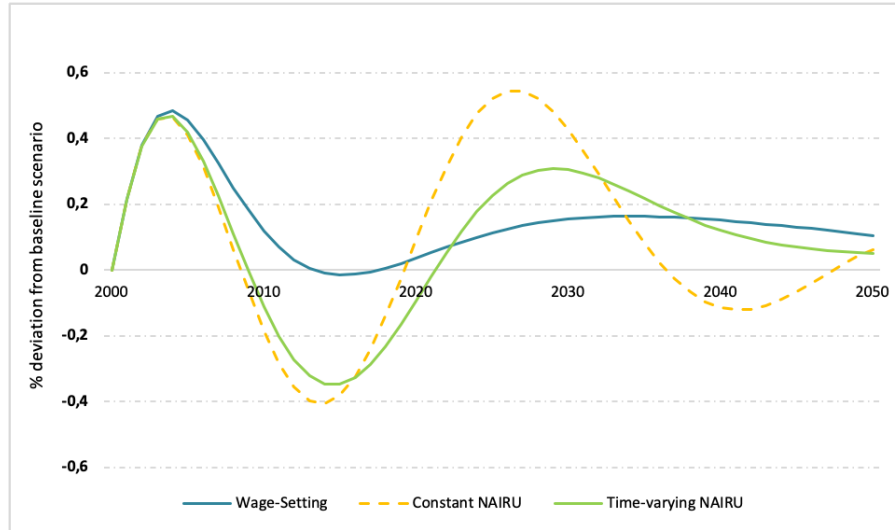


The wage equation specification plays a role in the existence of a double dividend in the short run when setting parameters to high flexibility and high exposure to foreign competition, no matter the type of redistribution considered. More precisely, the wage specification impacts a lot the volatility of the GDP following the introduction of a carbon tax in such a context. In a Philips curve setting, prices fluctuate more than in a WS setting. When the unemployment rate decreases, prices increase more. Conversely, when the unemployment rate increases, prices decrease more. In the Philips curve setting, it is possible that consumption prices decrease enough to become smaller than wages, hence spurring the economic activity again. In the WS setting, prices decrease as slowly as wages, hence smoothing the impact on the economic activity.

In a context where flexibility is high as well as exposure to foreign competition, these oscillations are exacerbated leading to a very erratic response of the economic activity following the introduction of a carbon tax. This explains why, focusing on a specific year, we can observe huge differences in terms of double dividend depending on the wage specification.

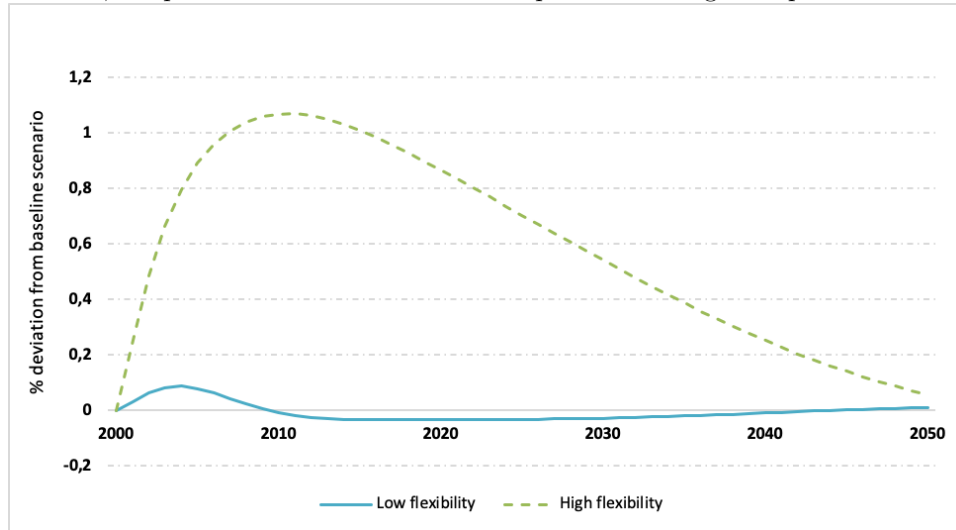
**Flexibility of the economy** The degree of flexibility of the economy appears to be an important factor for the existence of a double dividend in the short run. Half of the twelve cases under scrutiny show different results when considering a high degree of flexibility instead of a low flexibility. More generally, a higher flexibility increases the likelihood that a double dividend will exist in the short run. About three out of four cases lead to a double dividend in the short run when considering a high degree of flexibility against one out of two with a low flexibility. Besides, the two cases where

Figure 5: Evolution of GDP (in volume) following the introduction of a carbon tax with high flexibility, high exposure to foreign competition and lump-sum redistribution



a double dividend exist with a low flexibility still lead to a double dividend while switching to a high degree of flexibility.

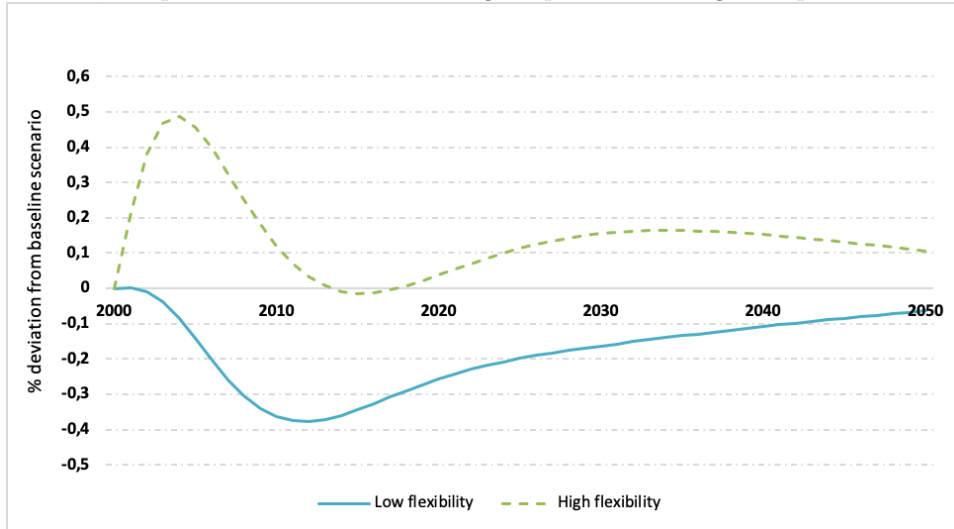
Figure 6: Evolution of GDP (in volume) following the introduction of a carbon tax with WS, lump-sum redistribution and low exposure to foreign competition



This is due to the fact that high flexibility allows for shifting production processes and consumption patterns quickly from dirty energy to clean energy and also, when-

ever profitable, from energy to capital. For instance, a higher degree of flexibility means that firms are more reactive in investing in more energy-efficient capital when energy becomes more expensive. While investment increases following the introduction of a carbon tax in the case where elasticities of substitution are high, it decreases when they are low. Firms can also more easily switch from energy to labor. Firms may want to create more jobs and use less resources since they became less affordable. To this extent, the increase in employment is way bigger when elasticities of substitution are high, hence inducing a greater demand shock that sustains the economic activity. Nonetheless, this implies that the exports also deteriorate more in a flexible framework since higher wages following a higher employment level leads to higher production prices, almost entirely transferred to consumption prices. On the other hand, imports follow a short decrease before increasing greatly again in the flexible case, while they only decrease a little and go back to the previous level in the rigid case. This might be explained by the fact that, when foreign competition is at a low level, foreign goods are somewhat substituted to national goods due to higher elasticities of substitution between factors hence leading to more imports in the flexible framework. In spite of these shifts, the trade balance increases as compared to the baseline and it increases even more in the flexible case. The economic activity generated with high elasticities of substitution is sufficiently high to result in a general short run increase in the GDP in volume ten times bigger than in the rigid case.

Figure 7: Evolution of GDP (in volume) following the introduction of a carbon tax with WS, lump-sum redistribution and high exposure to foreign competition



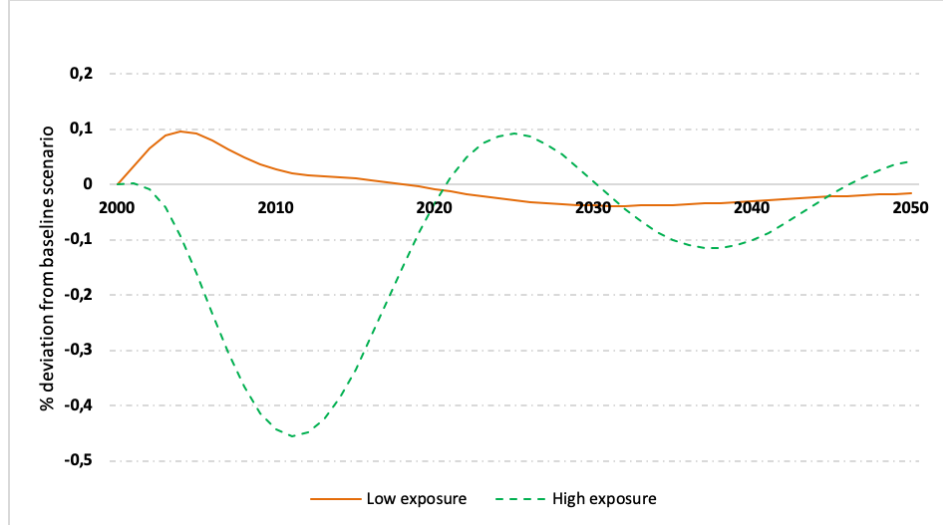
When considering a high level of foreign competition instead, the same drivers are at stake. Nonetheless, the overall positive impacts on the economic activity are smaller in size, leading the short term double dividend to disappear in the rigid case with a Philips curve specification. When considering a wage-setting specification, the double dividend does not exist in the rigid case either since the GDP in volume



remains unchanged the first year following the shock before it starts to decrease. When it comes to dynamics, we can also observe a greater volatility of the evolution of the GDP mainly driven by the volatility on the labor market.

**Exposure to foreign competition** The degree of exposure to foreign competition does not appear to be a determining factor in itself even though the output regarding the existence of a double dividend differs in half of the cases considered. The degree of exposure to foreign competition can discriminate between no short term double dividend and a short term double dividend when the wage equation is specified following a Philips curve (constant or time-varying NAIRU). In these cases, increasing the exposure of the economy to foreign competition leads to no double dividend while it existed, all other things being equal, when the economy was rather protected from foreign competition. When considering the wage-setting specification for the wage equation, switching the degree of exposure to foreign competition from low to high does not impact the outcome in terms of short term double dividend. In other words, it is the combination of the wage specification and the degree of foreign competition that has a determining influence on the evolution of the GDP in the short term, and thus on the existence of a double dividend.

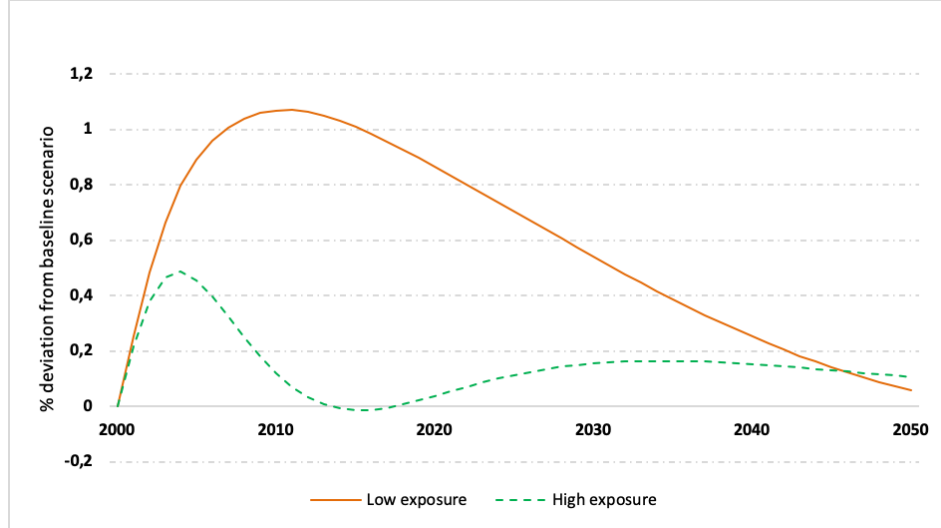
Figure 8: Evolution of GDP (in volume) following the introduction of a carbon tax with constant NAIRU, lump-sum redistribution and low flexibility of the economy



More generally, it is worth underlining that in a state of high exposure to foreign competition, it is not very likely that a double dividend would appear. According to table 1, only two cases out of twelve lead to a short term dividend while exposure to foreign competition is high. These two cases are when there is a high degree of flexibility of the economy and a wage-setting specification, no matter the type of redistribution considered. The combination of the two first parameters allow for a rather large increase in the employment level following the introduction of a carbon

tax. The increase is sufficiently large to last longer than in other settings, hence protecting the economic activity from the high level of foreign competition.

Figure 9: Evolution of GDP (in volume) following the introduction of a carbon tax with wage-setting, lump-sum redistribution and high flexibility of the economy



From this analysis, we can conclude that all parameters do not play the same role when it comes to the existence of a short term double dividend. Among the four parameters under scrutiny, the flexibility of the economy appears as the one that plays the biggest role. Nonetheless, the main result is that a single factor cannot explain in itself the existence or not of a double dividend. It seems that it is rather the combination of these parameters that has to be taken into account. Combining a low degree of flexibility with a high degree of exposure to foreign competition leads to no short term dividend, whatever the other parameters. On the other hand, a high degree of flexibility combined with a low exposure to foreign competition seems enough to ensure the existence of a double dividend in the short run. Other interesting combinations are between the wage specification and the degree of exposure to foreign competition. This should also be taken into account for policy recommendations. The whole framework has to be considered and policies should not focus on modifying only one aspect of the system at stake.

These conclusions are helpful insofar as they systematically analyse which are the combinations of parameters that most probably lead to a double dividend. Nonetheless, they remain simplistic since they do not tackle the issue of the magnitude of this double dividend nor its dynamics which are important as well to describe the differences between the settings.

**Magnitude of the short-term double dividend** In order to understand better the differences between the settings under consideration, we investigate the magnitude

of the evolution of the GDP (in volume) following the introduction of a carbon tax. To quantify the influence of each parameter on the short term GDP, we compute the spread that lies between the results of two distinct modalities of the same parameter, keeping every other parameter constant. For instance, when it comes to the degree of exposure to foreign competition, we compare the short-term (10 years) GDP deviation from the baseline scenario resulting from a low degree of exposure to the deviation resulting from a high degree of exposure, all other things being equal. By “spread” we mean the difference in absolute terms between these two deviations. The bigger the spread, the greater the difference, all other things being equal, between the outputs of two modalities of the same variables. In other words, the bigger the spread, the more sensitive the model to the assumptions made for the given parameter when it comes to the short-term evolution of the GDP.

Table 3: Overview of the GDP (in volume) deviation from baseline scenario 10 years after the introduction of a carbon tax

		Lump-sum			Social security contributions		
		Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
Low flexibility	<i>Low exp.</i>	-0.01	0.03	0.02	-0.08	-0.05	-0.06
	<i>High exp.</i>	-0.36	-0.44	-0.43	-0.42	-0.52	-0.49
High flexibility	<i>Low exp.</i>	1.07	1.11	1.09	1.00	1.03	1.01
	<i>High exp.</i>	0.12	-0.18	-0.11	0.06	-0.25	-0.17

*Notes:* This table sums up the 24 possible settings with regard to the deviations from baseline scenario in terms of GDP (in volume) 10 years following the implementation of a carbon tax. For instance, when redistributing the carbon tax as a lump-sum transfer to firms, with a wage-setting equation, high flexibility and low exposure to foreign competition, the GDP (in volumet) deviates from the baseline scenario by 1.07% ten years following the shock.

This allows us to go beyond a dichotomous approach in terms of existence of the double dividend versus absence of a double dividend. Indeed, in some cases, Table 3 shows there are only a tiny difference in absolute terms between two settings. However, this tiny difference can translate into double dividend results that are poles apart with a double dividend for one setting and no double dividend for the other. This is for instance the case of the type of redistribution with a Philips curve. With a lump-sum redistribution, a Philips curve with constant NAIRU, a low degree of flexibility of the economy and a low degree of exposure to foreign competition, there is a short term double dividend. On the opposite, switching the type of redistribution from lump-sum to a decrease of employers’ social security contributions results in the absence of a short-term double dividend. Nonetheless, in the first case, the double dividend is really small, with a deviation of the GDP from the baseline scenario of 0.03. Conversely, the absence of double dividend is not that clear-cut either in the other setting with a GDP deviation from the baseline by only  $-0.06$ .

Going beyond a dichotomous approach can also help discriminating better between different types of double dividends or non-double dividends. Among the cases where there exists a short-term double dividend, we can find a lot of heterogeneity (*cf.* Table 3). GDP increases range from 0.02 to 1.11 ten years after the implementation of the tax. More particularly, we can distinguish between settings where the increase is greater than 1 and those where the increase is really close to zero but still positive (estimates varying between 0.02 and 0.12). It is worth underlining that the

first group is made exclusively of settings combining a high degree of flexibility of the economy and a low degree of exposure to foreign competition. Settings where no double dividend appear in the short term show less heterogeneity with estimates varying between  $-0.01$  and  $-0.52$ . Settings combining features of low flexibility and high exposure to foreign competition show the biggest deviations to the baseline scenario of the GDP in volume ten years after the shock (between  $-0.36$  and  $-0.52$ ). This confirms the previous results according to which the combination of flexibility and exposure to foreign competition have the strongest impacts on the short term evolution of the GDP, be they negative or positive.

Table 4: Spread in absolute terms of GDP deviations from baseline for the factor of exposure to foreign competition

	Lump-sum			Social security contributions		
	Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
<i>Low flexibility</i>	0.35	0.47	0.45	0.50	0.57	0.55
<i>High flexibility</i>	0.95	1.29	1.20	0.94	1.28	1.18

*Notes:* This table shows the difference in absolute terms between the short-term (10 years) GDP deviations from the baseline scenario following the implementation of a carbon tax when setting a low degree of exposure to foreign competition as compared to a high degree of exposure to foreign competition, all other settings being equal.

*Lecture:* When settings are “lump-sum redistribution”, “constant NAIRU” and “high flexibility of the economy”, the difference in absolute terms between the short-term (10 years) deviations from baseline of the GDP in volume stemming from a low degree of exposure to foreign competition in the one hand and a high degree of exposure on the other is 1.29.

This is confirmed by the fact that the parameters that induce the biggest spreads are the degree of exposure to foreign competition on the one hand and the degree of flexibility of the economy on the other. The average spread for the degree of exposure to foreign competition is 0.81 whereas the one for the flexibility of the economy is 0.72. This means that switching from one modality to another will result in, on average, a difference of 0.81 between the deviations from the baseline scenario of a high degree of exposure to foreign competition on the one hand and a low degree of exposure on the other. More precisely, the spreads for the degree of exposure to foreign competition range from 0.35 to 1.29 and we can distinguish between two clusters depending on the degree of flexibility of the economy (cf. Table 4). Keeping the flexibility of the economy to a low level result in an average spread of the exposure to foreign competition parameter of around 0.48 against an average spread of 1.14 when the flexibility is set to a high level. We can draw the same conclusion from the analysis of the spread for the flexibility factor. Indeed, there is also a great heterogeneity among the spreads but it can be reduced to two main clusters that depend on the degree of exposure to foreign competition. Table 5 shows that the average spread when economy is not highly exposed to foreign competition is around 1.09 against an average spread of 0.36 when it is highly exposed. In other words, it is much more likely that the degree of flexibility of the economy will be a determining factor for the existence and magnitude of a double dividend when the exposure to foreign competition is low.

When the exposure to foreign competition is high, chances that a double dividend appears are already low, and switching to one degree of flexibility or another is less likely to be a determining factor that will influence the final outcome in terms of double dividend, even though it remains possible.

Table 5: Spread in absolute terms of GDP deviations from baseline for the factor of flexibility of the economy

	Lump-sum			Social security contributions		
	Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
<i>Low exposure</i>	1.08	1.14	1.07	1.08	1.08	1.07
<i>High exposure</i>	0.48	0.26	0.32	0.48	0.27	0.32

*Notes:* This table shows the difference in absolute terms between the short-term (10 years) GDP deviations from the baseline scenario following the implementation of a carbon tax when setting a low degree of flexibility of the economy as compared to a high degree of flexibility, all other settings being equal.

*Lecture:* When settings are “lump-sum redistribution”, “constant NAIRU” and “low exposure to foreign competition”, the difference in absolute terms between the short-term (10 years) deviations from baseline of the GDP in volume stemming from a low degree flexibility in the one hand and a high degree of flexibility on the other is 1.14.

Table 6: Spread in absolute terms of GDP deviations from baseline for the factor of type of redistribution

		Wage-Setting	Constant NAIRU	TV NAIRU
Low flexibility	<i>Low exp.</i>	0.07	0.08	0.08
	<i>High exp.</i>	0.06	0.08	0.06
High flexibility	<i>Low exp.</i>	0.07	0.08	0.08
	<i>High exp.</i>	0.06	0.07	0.06

*Notes:* This table shows the difference in absolute terms between the short-term (10 years) GDP deviations from the baseline scenario following the implementation of a carbon tax when setting a lump-sum transfer as compared to decrease of employers’ social security contribution, all other settings being equal.

*Lecture:* When settings are “wage-setting curve”, “low flexibility” and “low exposure to foreign competition”, the difference in absolute terms between the short-term (10 years) deviations from baseline of the GDP in volume stemming from a lump-sum transfer in the one hand and a decrease of employers’ social security contribution on the other is 0.07.

On the other hand, all other things being equal, it appears that the type of redistribution and the specification of the wage equation do not influence the magnitude of deviations from the baseline scenario (*cf.* table 6 and table 7). There are only slight differences in absolute terms between two modalities. This means that we should not over-interpret these parameters when they turn out to make a difference in terms of existence of a double dividend. These differences are in fact stemming from tiny lags between two settings but do not diverge structurally.

In terms of public policy recommendations, we should hence conclude that the key answer do not lie in the type of redistribution we design for firms. Neither should we dismiss, on an epistemological ground, estimations from this model on the sole argument of the way the wage equation is specified. It is true that changing the specification would lead to different dynamics and do impact the results. Nonetheless, these changes are not determining when it comes to the question of the short term double dividend.

Nevertheless, ensuring that a double dividend exists should not be the main priority of a policymaker when it comes to implementing a carbon tax. In particular, environmental public policies firstly aim at fighting against climate change and the

Table 7: Spread in absolute terms of GDP deviations from baseline for the factor of wage specification

		(1)		(2)		(2)	
		Lump-sum	SSC	Lump-sum	SSC	Lump-sum	SSC
flexibility	<i>Low exp.</i>	0.04	0.03	0.03	0.02	0.01	0.01
	<i>High exp.</i>	0.08	0.10	0.07	0.07	0.01	0.03
flexibility	<i>Low exp.</i>	0.04	0.03	0.02	0.01	0.02	0.02
	<i>High exp.</i>	0.30	0.31	0.23	0.23	0.07	0.08

*Notes:* This table shows the difference in absolute terms between the short-term (10 years) GDP deviations from the baseline scenario following the implementation of a carbon tax when setting different wage curve specifications: WS as compared to Philips curve with constant NAIRU (1) or WS as compared to Philips curve with time-varying NAIRU (2) or Philips with constant NAIRU as compared to Philips with time-varying NAIRU (3), all other settings being equal.

*Lecture:* When settings are “lump-sum redistribution”, “low flexibility” and “low exposure to foreign competition”, the difference in absolute terms between the short-term (10 years) deviations from baseline of the GDP in volume stemming from a wage-setting curve (WS) in the one hand and a Philips curve with constant NAIRU on the other is 0.04.

most straightforward way to do it it by cutting carbon emissions. The magnitude of the double dividend not only depends on the magnitude of the reaction of the economic activity but is also impacted by the magnitude of the emission reduction in itself. All other things being equal, the greater the emission reduction, the larger the double dividend. Our estimates for emission reductions following the implementation of the same policy vary a lot in the short run. Table 8 shows that they go from a reduction of 11.9 points as compared to the baseline scenario to a reduction of only 2.4 points. Settings that lead to the biggest emission reductions as compared to the baseline scenario feature a high degree of flexibility of the economy as well as a high degree of exposure to foreign competition. When they are combined with a wage-setting curve, the model also leads to a positive deviation of the GDP (in volume) from the baseline scenario. If the primary aim of the implementation of a carbon tax is to reduce carbon emissions, then we could say we would consider the best situation to be the one that combines the biggest cut in emissions conditional on a non-negative impact on the economic activity.

Table 8: Overview of the CO<sub>2</sub> emissions deviation from baseline scenario 10 years after the introduction of a carbon tax

		Lump-sum			Social security contributions		
		Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
flexibility	<i>Low exp.</i>	-2.37	-2.38	-2.42	-2.57	-2.60	-2.64
	<i>High exp.</i>	-2.89	-3.02	-3.00	-3.07	-3.23	-3.21
flexibility	<i>Low exp.</i>	-9.52	-9.17	-9.41	-9.70	-9.33	-9.57
	<i>High exp.</i>	-11.36	-11.76	-11.71	-11.50	-11.90	-11.85

*Notes:* This table sums up the 24 possible settings with regard to the deviations from baseline scenario in terms of CO<sub>2</sub> emissions 10 years following the implementation of a carbon tax. For instance, when redistributing the carbon tax as a lump-sum transfer to firms, with a wage-setting equation, high flexibility and low exposure to foreign competition, the emissions deviate from the baseline scenario by −9.52% ten years following the shock.

Nonetheless, we could also look for a middle ground, namely the highest increase in economic activity under reasonable decrease of the carbon emissions. Settings combining a high degree of flexibility and a low degree of exposure to foreign competition also ensure significant emission reductions with an average decrease of 9.33 as compared to the baseline scenario. In the meantime, the average GDP deviation ten years following the shock is around 1.05. However, what is deemed to be a sufficient decrease of the carbon emissions depends on political negotiations and international commitments. To this extent, we may want to compare different scenarios and parameters conditional on the magnitude of the emission reduction.

## 5 Conclusion

The objective of this paper was to perform a systematic analysis in order to identify the key mechanisms leading to a DD in a neo-Keynesian framework. We used the neo-Keynesian CGEM ThreeME in the case of small open economy calibrated on France data. We investigated thoroughly the role of four candidates often mentioned in the literature: (i) the degree of exposure to foreign competition where a low exposure can be seen as a proxy for the fact that the trading partners are also implementing a carbon policy; (ii) the flexibility of the economy, i.e. the easiness economic agents can substitute brown to green technology; (iii) the modality of implementation of the carbon tax (lump-sum redistribution of the proceed of the tax versus a reduction of the employers' social security contribution which is *a priori* more favorable to employment); (iv) the wage setting and inflation dynamic (which are a key determinant of eviction effects in a neo-Keynesian framework).

We found that the two main hypotheses leading to a DD are the low exposure to foreign competition (which corresponds also to the case where countries cooperate in an international agreement) and the flexibility of the economy. In comparison, the impacts of the modality of implementation the carbon tax and of the inflation dynamic are relatively small.

These results have two main policy implications. First climate policy is all the more efficient than other country do it too. But border tax adjustment would provide a good protection against free rider. The COVID crisis has shown the vulnerability of full globalization of the economy and the will of governments to be less depends on import. This context makes the adoption of border tax adjustment against free rider more relevant. Second climate policy is all the more efficient that the economy is flexible both in terms economic impact and emission reduction. The higher the flexibility the higher the economic and environment dividends. Investment in RD to enhance technology that improve the substitution between capital and energy.

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