INVESTIGATING THE ECONOMIC AND ENVIRONMENTAL EFFECTS OF A CARBON TAX IN A QUANTITATIVE MACROECONOMIC FRAMEWORK

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ABSTRACT

This article performs a systematic analysis in order to identify the key mechanisms leading to a double (environmental and economic) dividend in a quantitative macroeconomic 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 redistribution mechanisms of the carbon tax and of the inflation dynamic are small.

KEYWORDS

Double dividend, macroeconomic model.

JEL

E12, E17, E27, E37, E47, D57, D58.

Investigating the economic and environmental effects of a carbon tax in a quantitative macroeconomic framework

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Abstract

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1 Introduction

The macroeconomic and welfare effects of the low carbon energy transition are a controversial topic. If it is widely recognized that global warming is going to lower global welfare, the net cost of phasing-out fossil fuels and other sources of carbon emissions is subject to a much fiercer debate. Is there a trade-off between income 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. Policy-makers often put forward the existence of a double dividend to justify the immediate implementation of climate policy. However, economic evaluations often reach divergent conclusions generally depending on the type of models used and how 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 Computable General Equilibrium (CGE) models built upon a neoclassical framework 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 contrast, few studies investigate the question of the DD adopting a different theoretical framework that relax some key assumptions of the neoclassical framework. If they often conclude that a double dividend exists in the model, the reasons are often unclear. This paper's first objective is to perform a systematic analysis to identify the fundamental mechanisms leading to a DD. We use the dynamic macroeconomic model 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 a small open economy like France. This model integrates neo-Keynesian features that allows for assessing short and medium - term impacts of economic policy in addition to the long term impacts. We investigate thoroughly the role of four levers 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 crucial role in crowding out 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 also corresponds to the case where countries cooperate in an international agreement) and the economy's flexibility. In comparison, the impacts of the carbon tax implementation scheme and the inflation dynamic are minor.

Section 2 provides a short literature review on the double dividend in theoretical and empirical CGE and macroeconomic models. Section 3 describes the ThreeME model and its main assumptions. Section 4 investigates the key hypotheses that lead to a double dividend. Section 4.2 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 have been widely discussed in the economic literature, in particular 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 [1]. The concept has then developed quickly, leading to confusion around the definition of a double dividend and, in particular how 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 using different criteria from growth such as employment (Bovenberg, 1999).

Beyond definition considerations, the main issues regarding the double dividend remain whether it exists or not, why and for whom [2]. 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. They develop an empirical identification strategy based on the last 30 years in 31 European countries and find that implementing a carbon tax could lead to a slightly positive impact on 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 exceptions. Most works dealing with the existence of the double dividend consist in *ex-ante* studies, be they theoretical or empirical models 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 modeling 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

[1] The existence of a DD from an environmental policy should not been seen as a necessary condition of implementing it since important non economic benefits from environment preservation are also at play.

[2] In recent years, studies have put forward the issues of equity and horizontal redistribution (Yellow Vests Protests for instance), (Fullerton and Monti, 2013; Berry, 2019; Pizer and Sexton, 2019). Adopting a multi-agents framework in the analysis may relativize conclusions on the existence of DD, highlighting the heterogeneity of impacts and by corollary, the need to implement redistribution measures. In this paper, we adopt a representative agent setting, bearing in mind the redistributive implications that an environmental policy might have.

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 are also found in studies using applied empirical models (Patuelli et al., 2005). For a survey on the different modelling framework used in the study of energy transition, refer to (Hafner et al., 2020). Among the empirical studies finding a DD with a CGE model, one can quote Takeda (2007); Glomm et al. (2008); Sancho (2010); Ciaschini et al. (2012); Orlov et al. (2013); Fraser and Waschik (2013).

Within the neoclassical framework, the existence of a DD is largely supply-driven. 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 neoclassical CGE model may conclude the existence of a DD if the implementation of a carbon tax through various mechanisms 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 theoretical 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 rationally choose not to produce at their full production capacity. The capacity utilization ratio fluctuates historically around 80 percent, with some heterogeneity among the different sectors of production though [3]. Neo-Keynesian macroeconomic models account for demand constraints. But in comparison to the neoclassical literature, there is little research on the DD performed with a neo-Keynesian framework. "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 criticized in the recent years for their lack of practical applications (see e.g. Mankiw, 2006; Solow, 2010; Romer, 2015; Stiglitz, 2018). This framework has recently been used to study the impact of climate policy by Annicchiarico and Di Dio (2015, 2017) who do not find a DD. 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 trajectory that maximizes the inter-temporal utility. The hypothesis of slow price adjustment (due

[3] See for instance the historical data for various US industries: `https://fredblog.stlouisfed.org/2019/01/capacity-utilization/` or `http://myf.red/g/lI8W`.

to frictions in the price setting) is hardly the only Keynesian features of the model. But combined with other neoclassical features, it does not fundamentally change the results in terms of DD compared to a standard CGE model.

On the contrary neo-Keynesian macroeconomic models often conclude to the possibility of a DD (see e.g. Landa Rivera et al., 2016; Lee et al., 2018). Pollitt and Mercure (2018); Meyer and Ahlert (2019) identify and discuss important hypothesis that are likely to explain this difference in result. In particular, assumptions about the financial system where investment can only be financed by previous savings leads to "crowding out" of investment in the neoclassical framework. The role of the bank system in neo-Keynesian framework allows instead for "crowding in" effects. However to the best of our knowledge, no research has performed a systematic analysis confronting various key assumptions that generate or preclude a DD in a neo-Keynesian macroeconomic framework. This is the main objective of the present paper.

3 The ThreeME model and hypotheses

ThreeME is a country-level open-source multi-sector macroeconomic model originally developed to support policymakers in the design and evaluation of decarbonization pathways in France (Callonnec et al., 2013, 2016; Malliet et al., 2020) [4]. Since its first release, it has also been adapted to other countries, in particular 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- term impacts of environmental and energy policies at the macroeconomic and sectoral levels, assuming a steady-state equilibrium in the long-term as in standard CGE models. To this end, the model combines several important features:

- Its sectoral 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 [5].
- The highly detailed representation of energy flows through the economy allows for analyzing the consumption behaviour 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 macroeconomic 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

[4] The full documentation of ThreeME can be found on `www.threeme.org`. The version used in this study can be retrieved from the Git Hub repository `https://github.com/fosem/ThreeME_V3-open`, Branch FRA-DDIVIDEND-OFCEWP2021.

[5] For this study, we used a version of the model with 10 sectors: 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`).

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 demand-driven macroeconomic model. Standard neoclassical CGE models are largely supply-driven because of the so-called Walrasian closure assumption where prices and quantities adjust instantaneously to clear all markets. Instead, ThreeME uses a neo-Keynesian closure where prices and quantities adjust slowly and where producers adjust their supply to the demand. It has the advantage of allowing for situations of market disequilibria (in particular, the presence of involuntary unemployment). This framework is particularly well- suited for policy analysis in the short-term. 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 climate policies' implementation.

In a neoclassical framework, supply is always at full production capacity. A policy increasing public spending or public investment hurts the economy: it has an eviction effect on private consumption and investment because it is not possible to increase production. Macroeconomic models as ThreeME does not assume full utilization of available production factors, whether from spare production capacities or 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 higher utilization of the available production factors. Compared to a standard neoclassical framework, a neo-Keynesian model therefore accounts for important effects supported by empirical evidence such as demand-side Keynesian multipliers, that may be an additional mechanism leading to a DD.

4 Investigating the key hypotheses leading to a double dividend

4.1 Hypotheses under scrutiny

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 analyze some of its modeling hypotheses. Among these modeling hypotheses, we can distinguish between functional assumptions and parametric assumptions. The functional assumption we scrutinize consists of how 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 to determine whether the implementation of a specific policy leads to positive impacts on the economy and the environment. The policy that we chose 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 applies 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 modeling 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 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. Compared to the lump-sum strategy, it additionally distorts the relative prices between inputs which provides an incentive to shift the allocation of production factors. In particular, labor becomes more attractive compared to capital and energy. Hence, a lower labor tax for firms could entice them to substitute polluting capital for 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 get the most significant decrease in social security contribution. It creates an incentive for firms to hire more people after 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 Modeling hypotheses

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

Functional assumptions: Some modeling 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 an essential aspect of modeling science. It means that it can also go hand in hand with the disputed points of view. This is why we are eager to determine to what extent different structural forms would lead to different results regarding to the DD.

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 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 creation is an important part of the DD 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 with greater difficulties for firms to cope with short-term constraints.
- ◇ *Exposure to foreign competition*: the Armington elasticities are respectively 0.6 (high) and 2 (low). 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 DD since the introduction of a carbon tax might increase the price of domestic production, which is likely to spur imports and downscale exports in an open economy, leading to deterioration in the balance of trade. On the contrary, we could believe less open economies are more protected from these trade balance shifts, leading more probably to a DD to exist.

The study of these modeling 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 interpret the results of our model in general.

4.2 Results

Combining the sensitivity analysis of the four variables previously described - the 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 DD 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 DD. When it comes to the long-term, the number of DD cases rises up to 14. It already shows that implementing a carbon tax does not necessarily entail that a DD will follow. It also confirms that chosen assumptions are of cardinal importance while modeling 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	*Low exp.*	No	Yes	Yes	No	No	No
	High exp.	No	No	No	No	No	No
High flexibility	*Low exp.*	Yes	Yes	Yes	Yes	Yes	Yes
	High exp.	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 DD 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 DD 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 DD, no matter the type of redistribution and the wage equation specification.

Long-term properties: Looking only at the binary output of the existence of a DD 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 straightforwardly regular patterns across the settings.

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

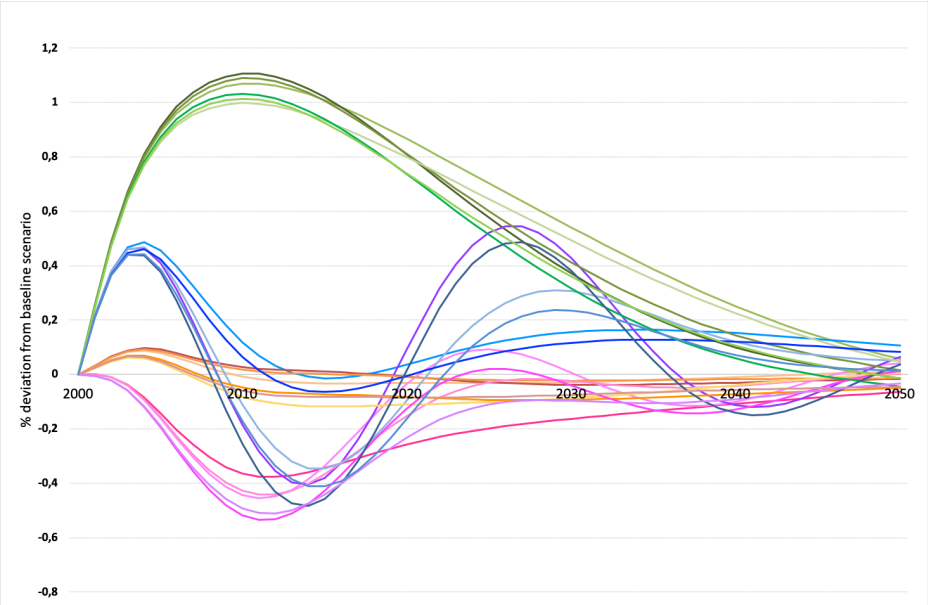


Figure 1 shows the evolution of the GDP in volume following the implementation of a carbon tax for the 24 different settings under scrutiny and up to 50 years after introducing the new policy. It depicts quite clearly four main clusters of trajectories:

- ◇ 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)
- ◇ 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 correspond 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 wage equation specification 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 correspond 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 on 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.

It stresses 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 DD will appear. On the contrary, with a low-flexibility and a high-exposure, it is very likely that there will be no DD 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 switch from dirty to clean ways of production easily and that there exists 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 DD. It is all the more relevant since these settings also lead to a sustainable drop in carbon emissions, as shown in Table 2.

Firm redistribution: The way the carbon tax is redistributed to firms does not seem to be a determining factor regarding the existence of a DD. 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 DD. In contrast, there will be none with a redistribution through a decrease of employers' social security contributions. Even though there is a DD in both cases in 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

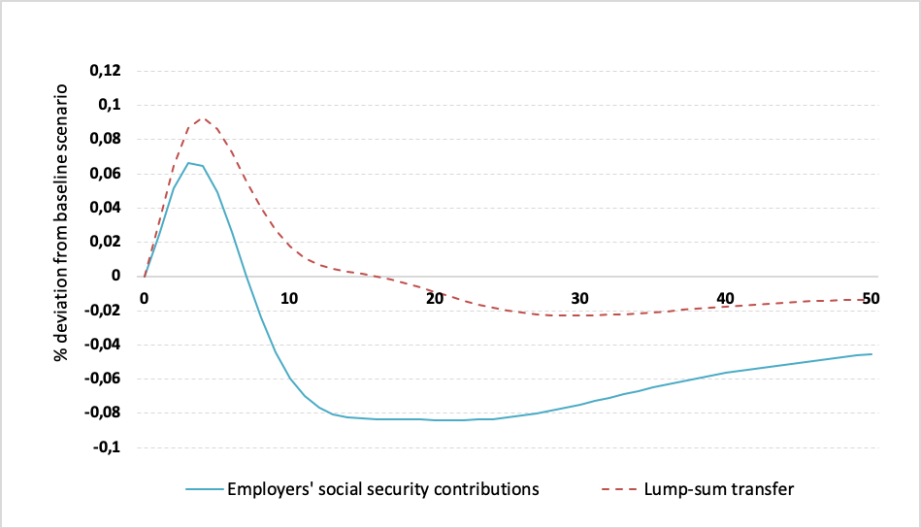
Table 2: Overview of the CO_2 emissions deviation from baseline scenario 50 years after the introduction of a carbon tax

		Lump-sum			**Social security contributions**		
		Wage-Setting	Constant NAIRU	TV NAIRU	Wage-Setting	Constant NAIRU	TV NAIRU
Low flexibility	*Low exp.*	-0.56	-0.60	-0.60	-0.61	-0.68	-0.69
	High exp.	-0.70	-0.61	-0.65	-0.77	-0.70	-0.75
High flexibility	*Low exp.*	-2.27	-1.73	-1.89	-2.28	-1.75	-1.91
	High exp.	-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_2 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.

decrease of the employers' social security contribution tax rate (Figure 2).

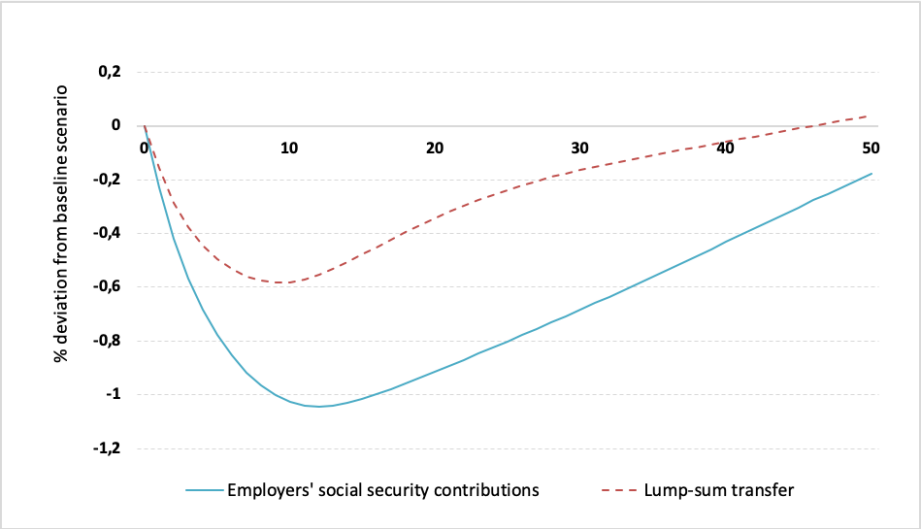
Figure 2: Evolution of GDP (in volume) following the introduction of a carbon tax



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 inducing a lower consumption level since the carbon tax is also 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. It 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 (Figure 3) because the lump-sum transfer does not induce a price distortion between the costs of labor and capital to the detriment of capital. The very difference in investment levels between the two cases mostly explains why there is still a DD ten years after the carbon tax was introduced in the lump-sum transfer case and not in the social security contribution one (Figure 2).

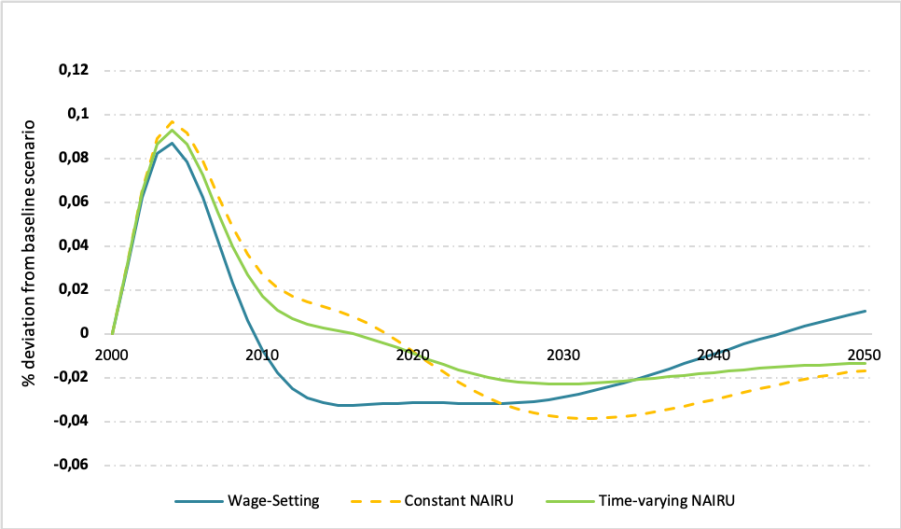
Figure 3: Evolution of firms' investment following the introduction of a carbon tax



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 DD 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 DD while a Philips curve specification allows for one. Nonetheless, when having a closer look to the GDP evolution 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 tax, a DD 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.

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

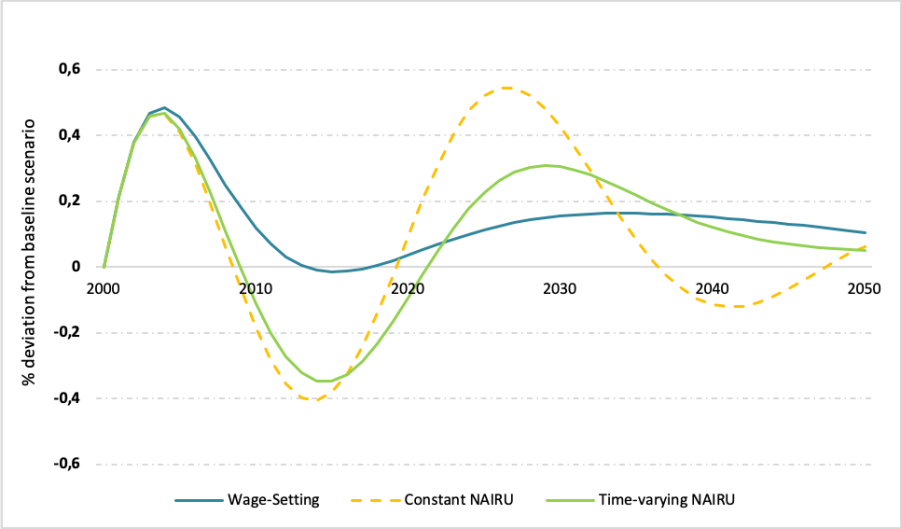


That being said, the minimal difference in terms of GDP is far from obvious. Indeed, the wage specification influences a lot the evolution of other determining factors such as prices (both for production, added value and consumption), exports, imports as well as household disposable income and consumption. 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 despite the price increase. It 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 DD in such a framework.

The wage equation specification plays a role in the existence of a DD 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.

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

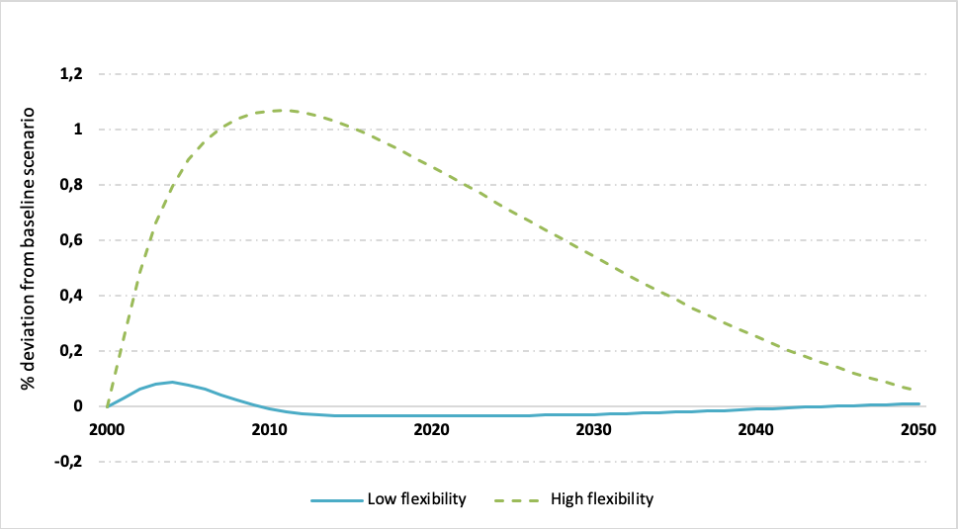


In a context where flexibility is high as well as exposure to foreign competition, these oscillations are exacerbated, leading to a very erratic response of the economic activity following the introduction of a carbon tax. This explains why focusing on a specific year, we can observe huge differences in terms of DD 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 DD 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 DD will exist in the short-run. About three out of four cases lead to a DD 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 a DD exist with a low-flexibility still lead to a DD while switching to a high degree of flexibility.

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, whenever 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

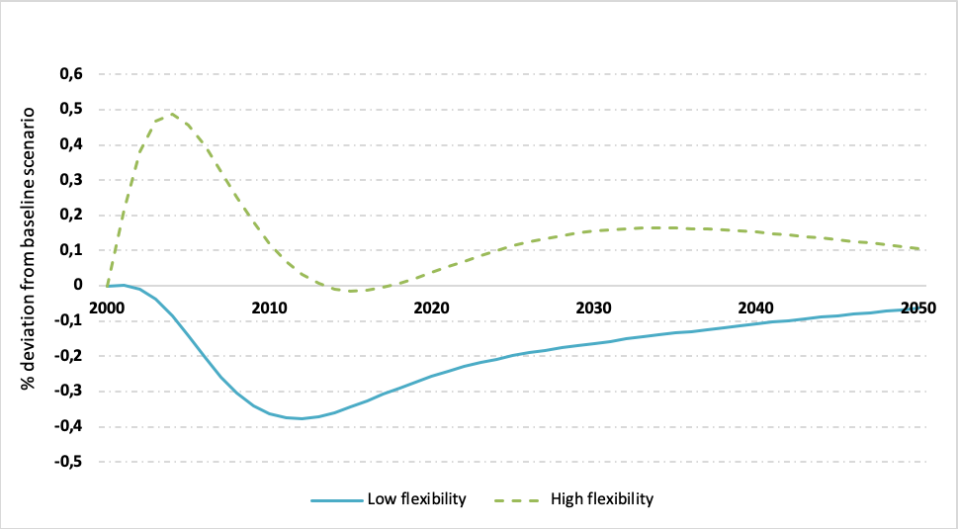
Figure 6: Evolution of GDP (in volume) following the introduction of a carbon tax with WS, lump-sum redistribution and low exposure to foreign competition



may want to create more jobs and use fewer 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. It 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.

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 DD to disappear in the rigid case with a Philips curve specification. When considering a wage-setting specification, the DD 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.

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



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 DD differs in half of the cases considered. The degree of exposure to foreign competition can discriminate between no short-term DD and a short-term DD when the wage equation is specified following a Philips curve (constant or time-varying NAIRU). In these cases, increasing the economy's exposure to foreign competition leads to no DD 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 DD. 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 DD.

More generally, it is worth underlining that in a state of high exposure to foreign competition, it is not very likely that a DD 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. Combining the two first parameters allows 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.

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 DD. Among the four parameters under scrutiny, the flexibility of the economy appears like the one that plays the most

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

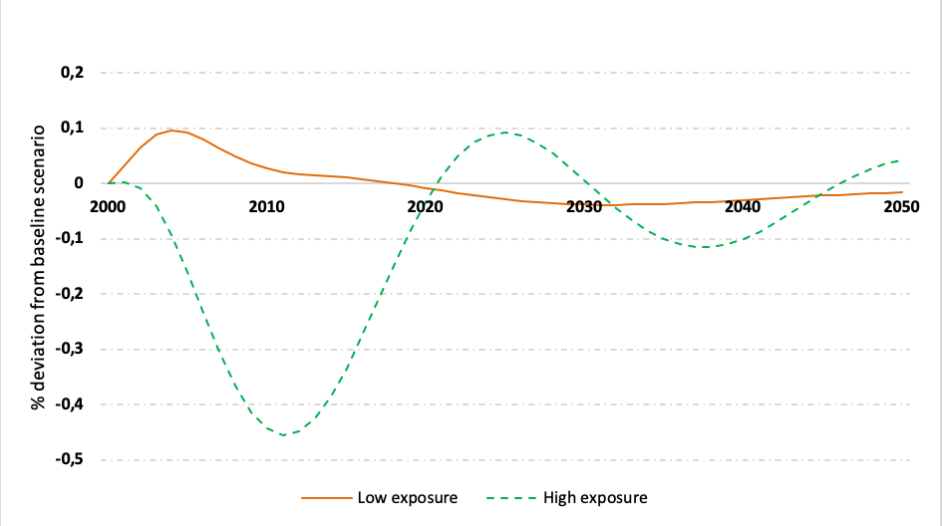
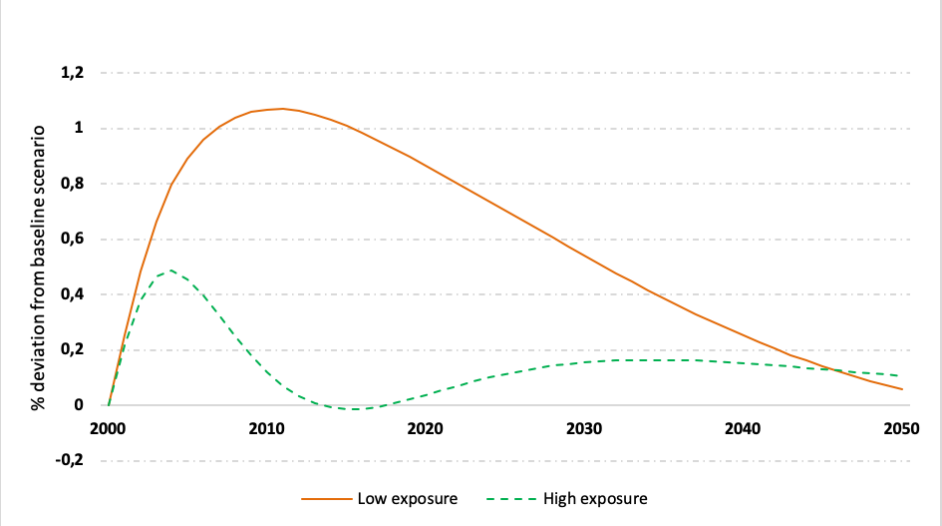


Figure 9: Evolution of GDP (in volume) following the introduction of a carbon tax with wage-setting, lump-sum redistribution and high flexibility of the economy



prominent role. Nonetheless, the main result is that a single factor cannot explain in itself the existence or not of a DD. It seems that it is rather the combination of these parameters that have 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 low-exposure to foreign competition seems enough to ensure the existence of a DD 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 analyze which are the combinations of parameters that most probably lead to a DD. Nonetheless, they remain simplistic since they do not tackle the issue of the magnitude of this DD nor its dynamics which are important as well to describe the differences between the settings.

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 framework integrating neo-Keynesian features. We used the multi-sector macroeconomic model ThreeME in the case of small open economy calibrated on France data[6]. 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 lead 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 countries does it too. However, border tax adjustment would provide 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 dependent 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 of economic impact and emission reduction. The higher the flexibility the higher the economic and environmental dividends. Investment in R&D to enhance technologies that improve the substitution between capital and energy.

[6]To be noted that the near absence of fossil fuels related industries in the production sectors for France has direct implication on the results.

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Appendix: Magnitude of the short-term double dividend

To better understand 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	*Low exp.*	-0.01	0.03	0.02	-0.08	-0.05	-0.06
	High exp.	-0.36	-0.44	-0.43	-0.42	-0.52	-0.49
High flexibility	*Low exp.*	1.07	1.11	1.09	1.00	1.03	1.01
	High exp.	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 volume) 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 DD versus absence of a DD. Indeed, in some cases, Table 3 shows there is only a tiny difference in absolute terms between two settings. However, this tiny difference can translate into DD results that are poles apart with a DD for one setting and no DD for the other. It 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 DD. 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 DD. Nonetheless, in the first case, the DD is really small, with a deviation of the GDP from the baseline scenario of 0.03. Conversely, the absence of a DD 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 DD appears 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). It 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
Low flexibility	0.35	0.47	0.45	0.50	0.57	0.55
High flexibility	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.
Key: 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.

It 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. It 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 results 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 exposure to foreign competition. Table 5 shows that the average spread when the 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 when the exposure to foreign competition is low.

When the exposure to foreign competition is high, chances that a 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 , even though it remains possible.

On the other hand, all other things being equal, it appears that the type of redistribution and the specification of the wage equation does not influence the magnitude of deviations from the baseline scenario (*cf.*table 6 and table 7). There are only

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
Low exposure	1.08	1.14	1.07	1.08	1.08	1.07
High exposure	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.
Key: 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	*Low exp.*	0.07	0.08	0.08
	High exp.	0.06	0.08	0.06
High flexibility	*Low exp.*	0.07	0.08	0.08
	High exp.	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.
Key: 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.

slight differences in absolute terms between the two modalities. This means that we should not over-interpret these parameters when they turn out to make a difference in terms of the existence of a DD. 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 does 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. Changing the specification would indeed 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 .

Nevertheless, ensuring that a exists should not be the main priority of a policy-maker when it comes to implementing a carbon tax. In particular, environmental public policies firstly aim at fighting against climate change and the most straightforward way to do it by cutting carbon emissions. The magnitude of the 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 DD. Our estimates for emission

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
Low	*Low exp.*	0.04	0.03	0.03	0.02	0.01	0.01
flexibility	*High exp.*	0.08	0.10	0.07	0.07	0.01	0.03
High	*Low exp.*	0.04	0.03	0.02	0.01	0.02	0.02
flexibility	*High exp.*	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.
Key: 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.

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_2 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
Low	*Low exp.*	-2.37	-2.38	-2.42	-2.57	-2.60	-2.64
flexibility	*High exp.*	-2.89	-3.02	-3.00	-3.07	-3.23	-3.21
High	*Low exp.*	-9.52	-9.17	-9.41	-9.70	-9.33	-9.57
flexibility	*High exp.*	-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_2 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 a reasonable decrease of 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 com-

pared 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 carbon emissions depends on political negotiations and international commitments. To this extent, we may want to compare different scenarios and parameters conditional upon the magnitude of the emission reduction.

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