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Green Recovery Policies for the COVID-19 Crisis: Modelling the Impact on the Economy and Greenhouse Gas Emissions

B. Lahcen[1,2] · J. Brusselaers[1] · K. Vrancken[1] · Y. Dams[1] · C. Da Silva Paes[3] · J. Eyckmans[2] · S. Rousseau[2]

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Abstract

The COVID-19 pandemic induces the worst economic downturn since the Second World War, requiring governments to design large-scale recovery plans to overcome this crisis. This paper quantitatively assesses the potential of government investments in eco-friendly construction projects to boost the economy and simultaneously realise environmental gains through reduced energy consumption and related greenhouse gas emissions. The analysis uses a Computable General Equilibrium model that examines the macroeconomic impact of the COVID-19 crisis in a small open economy (Belgium). Subsequently, the impact of the proposed policy is assessed through comparative analysis for macroeconomic parameters as well as CO_2 equivalent emissions for four scenarios. Our findings demonstrate that the COVID-19 pandemic damages economies considerably, however, the reduction in emissions is less than proportionate. Still, well-designed public policies can reverse this trend, achieving both economic growth and a disproportionally large decrease in emissions. Moreover, the positive effect of such a decoupling policy on GDP is even stronger during the pandemic than compared to the pre-COVID-19 period. This is the result of a targeted, investment-induced green transition towards low energy-intensive economic activities. Finally, this paper describes how the net effect on the government budget is positive through the indirect gains of the economic uptake.

Keywords CGE model · Climate change · COVID-19 · Economic recession · Greenhouse gas emissions · Pandemic · Policy analysis · Recovery plans · Small open economy · Sustainable investment

✉ B. Lahcen
bart.lahcen@vito.be

[1] VITO, Unit of Sustainable Materials, Boeretang 200, 2400 Mol, Belgium

[2] Center for Economics and Corporate Sustainability (CEDON) KU Leuven, Warmoesberg 26, 1000 Brussels, Belgium

[3] Faculty of Bio-Science Engineering, Ghent University, Coupure Links 653, 9000 Ghent, Belgium

1 Introduction

While it can be expected that the COVID-19 pandemic will serve as a prominent topic in economic research and other fields alike for years to come, the body of quantitative scientific knowledge remains limited at present, particularly in terms of policy proposals aimed at mitigation of greenhouse gas emissions and economic recovery. Nevertheless, this is crucial, as swift government intervention is required to avoid an escalation of the economic damage, which can add to the already severe human tragedy. In addition, the recovery plans that are currently being designed will shape the economic future of countries around the globe. Therefore, the research question in this paper is whether sustainable investment policies, such as green deals, can play a decisive role in governmental recovery plans. To this end, four scenarios[1] are simulated that reflect the 90% economy, a situation in which the economy operates at a 90% level due to lingering social distancing measures. The research is built around a computable general equilibrium (CGE) model, which is calibrated for a small open economy and subsequently applied to Belgium. This paper contributes to the literature by quantifying the effect of an integrated government policy that aims to realise climate ambitions and economic revival simultaneously for the first time following a pandemic. Notably, the research assesses the impact of governmental support for eco-friendly renovations of residential buildings that are aimed at considerable reductions in household energy demand and CO_2 emissions.

Precise estimates of the economic impact of the pandemic and recovery plans are scarce to date due to the high degree of uncertainty that is inherent to this crisis, which is a considerable impediment to economic modelling. Consequently, the assumptions needed for forecasting are strong, with respect to the spread of the disease, and require a greater dependency on estimates instead of data (World Trade Organization 2020). Research by the OECD (2020) underlines this uncertainty, with global growth prospects gyrating between 1.25% in 2020 and 3.25% in 2021, depending on whether the pandemic will last or countries will be able to contain the virus and attenuate its impact on the economy through targeted policies. The IMF expects global growth to decrease by 3% in 2020, exceeding the output loss of the global financial crisis of 2008–2009 (International Monetary Fund 2020). Baldwin and Weder di Mauro (2020a, b) collect a range of papers that address the scale and rate of the economic damage caused by the pandemic and economic contagion mechanisms, urging governments to act fast. This paper contributes to the latter issue by quantifying the economic impact of governmental investments.

To curb the economic downturn and address climate change and environmental concerns, politicians and economists are advocating green deals, climate-neutral and environmentally friendly policy initiatives, as an integrated governmental response to recover from the COVID-19 pandemic, see for instance Allan et al. (2020) and the European Commission (2020a). European Commission President, Ursula von der Leyen, has already reiterated the importance of the Green Deal, especially in the light of the pandemic, claiming that it will be at the hearth of the COVID-19 recovery plan in the EU (EURACTIV 2020). The International Energy Agency (2020) also states that recovery policies should target clean and resilient energy infrastructure investment if countries are to avoid a more than proportional rebound effect of emissions, as witnessed after previous crises. Helm (2020) argues that the correlation between the decline in GDP and the decline in emissions and

[1] These scenarios are inspired by the "*90% economy*" concept from The Economist (2020).

pollution is the most noteworthy lesson from the early stages of the COVID-19 crisis, indicating that population and GDP growth will jeopardise our ability to stay within the 1.5 °C limit for global warming, as set out in the Paris Agreement. Vis (2020) stresses the importance of a renovation wave to cope with this unseen pandemic. Therefore, this paper presents an economic recovery policy, targeting a sustainability transition.

It is clear that this pandemic is severe, affecting human and natural systems, and will continue to play an important role in our daily lives for months to come as a vaccine is not expected until 2021 at the earliest (Heuser et al. 2020). The NBER Business Cycle Dating Committee already declared that the US economy fell into a recession in February 2020, following sharp declines in employment and production (National Bureau of Economic Research 2020). Although the 90% economy concept should be considered as one possible trajectory following the COVID-19 outbreak, it is based on economic forecasts (The Economist 2020), and aligns with provisional data observed by Statistics Belgium,[2] the Belgian statistical office. Furthermore, it considers the lingering effects of social distancing measures in anticipation of herd immunity, either natural or through a vaccine. For these reasons, the 90% economy provides an interesting starting point from both a modelling and policy perspective.

CGE models are useful in the context of the COVID-19 pandemic as they can help evaluate policy options by identifying the economic channels through which the primary effects of the outbreak manifest themselves. As a result, they can advance our understanding of the potential influence of this pandemic on the evolution of economic activities and broader linkages, for example between GDP and greenhouse gas emissions. CGE models are ideally suited to examine the research question of this paper because they consistently consider the effects of a policy measure in all related sectors and markets, including the labour market. In this sense, they are more flexible than input–output models. However, they are not capable of predicting potentially radical changes in preferences and technologies as a result of COVID-19. The aim of this paper, though, is to study a focused green recovery policy measure that aligns with the 90% economy idea and fits well with the modelling capabilities of CGE models in the medium run.

The remainder of this paper is structured as follows. The second part describes the methodology and rationale behind the modelled economic shocks and investment policies. Part three describes the results of the model exercise, which are discussed and interpreted in part four. Finally, part five ends with a conclusion.

2 Methodology

2.1 Use of CGE Models in the Relevant Literature

CGE models are well suited to evaluate technological changes, external shocks, and policies that are expected to affect many sectors, for example through connections between sectors of the economy (Burfisher 2017). These large-scale models use data on the structure of the economy combined with a set of equations grounded in economic theory of general equilibrium to simulate interactions in an economy, allowing insights in its underlying

[2] STATBEL (2020a) observes a decrease in average working time from 37.3 *[21.6]* hours in February 2020 and 37.5 *[22.0]* hours in March 2019 to 32.8 *[19.4]* hours in March 2020 for full-time *[part-time]* jobs, corresponding to a decline of 12.06% *[10.19%]* and 12.53% *[11.82%]* respectively.

mechanisms. There is an extensive body of literature available on the application of CGE models in the context of climate change. Farmer et al. (2015) discuss and present an overview of the available models in this regard. The use of CGE models in the research on pandemics focusses mainly on influenza outbreaks. Keogh-Brown et al. (2010), for instance, estimate the macroeconomic impact of an influenza pandemic for the United Kingdom, France, Belgium and The Netherlands. Smith et al. (2011) highlight the need for balance between social distancing and business-as-usual in their CGE model applied to the UK economy.

McKibbin and Fernando (2020) provide preliminary estimates of the economic cost of the COVID-19 crisis by using a global hybrid of a CGE model and a Dynamic Stochastic General Equilibrium (DSGE) model. Their findings show that, depending on the epidemiological scenario considered, the GDP loss can range from 283 to 9170 billion USD worldwide. Based on the MIRAGE and GTAP CGE models, an in-house analysis of the Directorate-General for Trade, the European Commission expects global trade to fall by 10–16% in 2020 (European Commission 2020b). Maliszewska et al. (2020) use the Envisage CGE model and register a fall in global GDP by 2% due to COVID-19 based on a shock that simulates a decline in trade services, increase in trade costs, and suboptimal use of labour and capital.

2.2 CGE Model Setup and Structure

The model in this paper departs from a fully operational and calibrated static CGE model for the small open economy of Belgium. The economic agents in this model are consumers, activities,[3] government, investment, enterprises, and the EU and Rest Of the World (ROW) as international trading partners. The following overview of the model properties provides a comprehensive account of the CGE model setup and rationale:

- Each sector is modelled as a representative company, with constant elasticity of transformation production functions that are embedded in a nested production function. The production functions are calibrated according to van der Mensbrugghe and Peters (2016);
- Firms maximise profits, subject to labour and capital availability, technology, and input of intermediate products and services;
- Labour is traded on the labour market, wages are dependent upon the household's desire for leisure time. Hence, the CGE model only accounts for voluntary unemployment;
- Consumer decisions are functions of constant elasticity of substitution functions and are nested in consumption structures following Pollak and Wales (1978);
- Government spending is subject to the available budget and is determined by consumption prices and distribution parameters of the government's utility function (see Annex 1);
- Investment demand depends on investment prices and distribution parameters of investment utility functions;

[3] Activities considered in the model (and their related products and services) are: agriculture, fishing and forestry; mining; industry; energy; construction; trade; land transport; water transport; air transport; logistics and mail; market service sector; and non-market sector.

Table 1 Sectors (S) and products/services (G) present in the CGE model

Sectors (supply side)	Products/services (demand side)
S1—Agriculture, fishing, forestry	G1—Agricultural products, fish, forestry products
S2—Mining	G2—Mining products
S3—Industry	G3—Industrial products
S4—Energy	G4—Energy
S5—Construction	G5—Construction products & services
S6—Trade	G6—Trade services
S7—Land transport	G7—Land transport services
S8—Water transport	G8—Water transport services
S9—Air transport	G9—Air transport services
S10—Logistics & mail	G10—Logistical services and mail
S11—Market services sector	G11—Market services
S12—Non-market services	G12—Non-market services

None of the products or services are further defined. Household appliances encompasses all possible kinds of household appliances

- National income is used for aggregate household consumption, public consumption, and savings;
- The exported volume depends on export prices while imported volumes depend on Armington elasticities as they are not perfect substitutes;
- All elasticities are retrieved from the GEM-E3 model description by Capros et al. (2013) except for the substitution elasticities for transport modes which are based upon Mayeres (1999).

The CGE model is calibrated for a standard sectoral disaggregation into 12 basic sectors (S) to capture the supply side, and 12 products/services (G) to capture the demand side of the economy, as presented in Table 1.

2.3 Calibration

The presented CGE model requires a Social Accounting Matrix (SAM) for calibration and simulation of the baseline scenario. The data used to construct this SAM originates from several data sources of which the most important is the 2015 version of the Belgian Supply and Use Tables (SUT), published by the Belgian Federal Planning Bureau (2018). These SUT provide the required monetary information on the supply and use of goods by sectors and encompass 64 sectors and 64 product groups. The data are aggregated for computational feasibility of the CGE model and reconciled with the annual account aggregate data. Some discrepancies arise due to different methodologies used in the SUT and national accounts construction. These are addressed by dividing the discrepancies across the different product groups according to the share of each group in total imports and exports in the SUT, and dividing the discrepancies related to the government finances across the taxes and subsidies in the national accounts and the SUT. This results in a SAM that consistently reports the linkages between the supply and use of products/services and the institutional sector accounts.

Table 2 Overview and description of the simulated scenarios

Scenario	Description
Baseline	Business-as-usual (BAU), i.e. the situation corresponding to the pre-COVID-19 era
Scenario 1	Workforce stays at home, leading to a decrease in working time by *10%*
Scenario 2	Workforce stays at home, leading to a decrease in working time by *20%*
Scenario 3	Overall demand[a] drops to 90% levels, only *essential sectors*[b] remain 100% active
Scenario 4	Overall demand drops to 90% levels

[a]Overall demand is the aggregation of demand by all the economic agents identified in the model (consumers, government, investment, etc.), this decrease is achieved by modifying the intercept of each agent's consumption function

[b]Essential sectors are defined as non-market services, (including health care and education), and agriculture, fishing, and forestry

The novelty of this paper lies in the application of a CGE model that is able to jointly simulate the macroeconomic and climate impact in the context of the COVID-19 pandemic and potential recovery policies. Therefore, the model is extended with CO_2 equivalent emissions per million EUR of spending to estimate the impact on the economy and on the climate. Emissions are based on the level of domestic consumption and production, i.e. territorial emissions are used. Calculations are determined in accordance with the standard emissions coefficient calculations in I/O modelling, making use of the work by Stadler et al. (2018).

2.4 Scenarios and Policy Design

The model is used for comparative analysis of four scenarios to assess changes in GDP and greenhouse gas emissions for the Belgian economy operating at 90% levels in the following the COVID-19 outbreak. Table 2 provides an overview and description of each scenario.

The recovery policy introduced in the model consists of investing in sustainability measures in the construction sector through subsidised renovations aimed at meeting energy efficiency standards. Assessing the policy in four different scenarios provides a robustness check for the calculated results. In 2015, there were 3,006,601 housing units (houses and apartments) in Belgium, 28,172 of these were renovated and 46,181 were newly built. The model simulates the impact of renovating or building 74,353 units annually, i.e. 2.47% of the stock of housing units, according to strict energy efficiency standards, resulting in a 75% decline in households' energy requirements (VITO/Energyville, 2020). However, building or renovating energy-efficient housing units is expected to increase the overall cost of housing by 10% compared to a BAU scenario. The government accounts for these additional costs by means of a subsidy to stimulate both eco-friendly renovations and economic activity in the construction sector. For this, the model departs from the standard Constant Elasticities of Substitution (CES) household utility function:

$$Maxx_0 = \left[\alpha_1^{\frac{1}{\sigma}} \left(x_1 - \bar{x}_1 \right)^{\frac{\sigma-1}{\sigma}} + \cdots + \alpha_n^{\frac{1}{\sigma}} \left(x_n - \bar{x}_n \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$$S.t.p_1x_1 + \ldots + p_nx_n \leq y_0 \tag{2}$$

This maximises utility x_0 in function of the utility components x_i at prices p_i and the subsistence/minimum level of utility components $\bar{x}_i$. In addition, α_i represents the distribution parameters and $\alpha_1 + \ldots + \alpha_n = 1$, while the elasticity of substitution $0 \leq \sigma < \infty$. This leads to the determination of the optimal volume of household consumption of construction products and services x_1 according to:

$$x_1 = \frac{\alpha_1}{p_1^{\sigma} * (1 + cost_{1,env})} \frac{y_0^d}{p_0^{1-\sigma}} + \bar{x}_1 \tag{3}$$

with:

$$p_0 = \left[\alpha_1 (p_i * (1 + cost_{1,env}))^{1-\sigma} + \cdots + \alpha_n p_n^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{4}$$

The household's available budget y_0 is directly augmented through increased transfers from the government if households invest in housing renovations. These transfers are directly linked to the consumption level of construction products and services and equal 9.09% of household spending on this sector (to account for the 10% price increase). The environmental cost of the increased energy standards for residential building projects is captured in $cost_{1,env}$ and set at an average of 10% of the standard cost of residential building projects.[4]

This revised price mechanism will increase the amount received by companies in the building sector and hence encourages economic activity in this sector. The activity surge serves as a proxy for eco-friendly renovations, and consequently, the model determines the number of housing units that are renovated endogenously, apart from the initial level of 74,353 mentioned above in the BAU scenario. Based on this number, it is possible to calculate household energy use and emissions as it is assumed that each renovated unit complies with the energy standards and lowers the household's energy requirements for heating by 75% (VITO/Energyville 2020). This demand drop for energy products is accounted for in the intercept and, just like the transfers, dependent upon the household's consumption volume of construction services and products.

The rationale behind the approach for the recovery plan is twofold. First, investing in construction can boost the domestic economy as both the sector itself and related supply and support sectors are anchored at the local level, creating local green jobs.[5] Construction is also the fifth largest sector in the model (preceded by market services, non-market services, industry, and trade services, respectively), employing 6.15% of the Belgian workforce in 2015 (Federal Planning Bureau 2018). Second, greenhouse gas emissions related to energy consumption, mainly from heating, are responsible for 70.06% of all household emissions, which corresponds with 4.21% of the entire emissions in Belgium Federal Planning Bureau (2018). Hence, the expectation is that the proposed policy contributes to economic growth and reducing emissions.

[4] This 10% cost increase was chosen after consulting with the Flemish Energyville Expert Center on Energy Technology and Policy (VITO/Energyville 2020).

[5] In line with the reasoning by Bowen (2012) that green policies can create green jobs even in sectors with only a secondary relationship to environment.

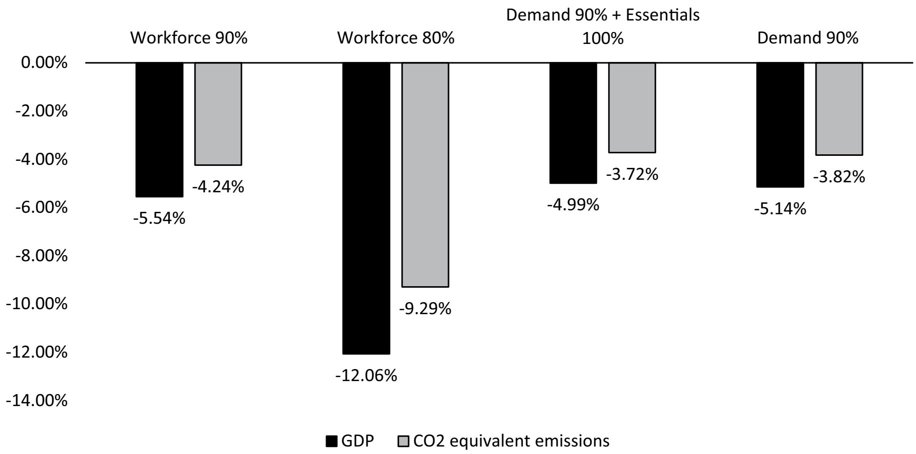

Fig. 1 Evolution of GDP and CO2 equivalent emissions compared to the BAU scenario prior to the policy

3 Results

All results given throughout this section are based on 2015 data, the most recent data available for a detailed SAM of the Belgian economy. As this study uses a comparative static model, the results encompass an annual impact, for instance, on the government budget or reductions in greenhouse gas emissions. The first two subsections cover results prior to the introduction of the policy, whereas the last subsection examines the policy impact in detail.

3.1 Relationship between GDP and Greenhouse Gas Emissions prior to the policy

The first results showcase the impact on GDP for each of the four 90% economy scenarios compared to BAU scenario in the absence of the sustainable investment policy. A decrease in working time by 10% (Scenario 1) leads to a decline in GDP of 5.54%. When working time declines by 20% (Scenario 2), the GDP decrease is more than twice as high, amounting to 12.06%. To put these figures in perspective, 5.54% of the Belgian GDP in 2015 equals more than 23 billion EUR.[6] In the case that overall demand drops to 90% levels (Scenario 4), GDP would fall by 5.14%. If the essential sectors would continue to be fully active while all other sectors slow down to a 90% activity level (Scenario 3), GDP would contract by 4.99%. This is a rather small difference compared to Scenario 4.

Although the evolution of CO_2 equivalent emissions follows a similar trend, the effect of the 90% economy on emissions is proportionally lower compared to the decrease in GDP, as can be seen in Fig. 1. In Scenario 1, emissions decrease by 4.24% compared to BAU scenario. In the other three scenarios, there is a reduction of 9.29%, 3.72%, and 3.82%, respectively. The same observation that can be found for the impact of the pandemic on GDP in Scenario 3 and Scenario 4 holds for emissions: keeping the essential sectors fully

[6] According to NBB.Stat, the online database of the National Bank of Belgium, the GDP of the Belgian economy in 2015 amounts to 416,701.50 million EUR (National Bank of Belgium 2020).

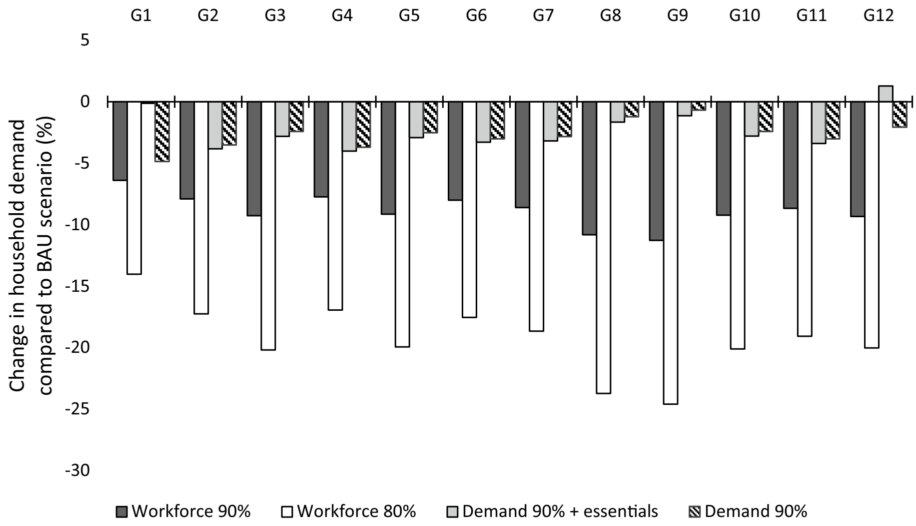

Fig. 2 Evolution of household demand compared to the BAU scenario prior to the policy. NOTE—G1: Agricultural products, fish, forestry products; G2: Mining products; G3: Industrial products; G4: Energy; G5: Construction products & services; G6: Trade services; G7: Land transport services; G8: Water transport services; G9: Air transport services; G10: Logistical services and mail; G11: Market services; G12: Non-market services. See Table 1

active (Scenario 3) leads to a lower decrease in emissions, albeit marginally compared to the importance of these sectors.

3.2 Household Demand and Output per Sector prior to the policy

Before the policy is introduced, the disaggregated results for household demand,[7] captured by Fig. 2, indicate that, though all sectors suffer considerably, a decreased level of economic activity has the largest impact when working time is decreased (Scenario 1 and Scenario 2). Compared to BAU, the demand for goods and services is most affected for air transport (G9) and water transport (G8). As is the case in most other sectors, demand for construction products (G5) suffers most in Scenario 2 (− 19.95%) followed by Scenario 1 (− 9.13%), and to a lesser extent in Scenario 3 (− 2.91) and Scenario 4 (− 2.53%). Note that household demand is not equal to overall demand because governments and firms also acquire these products in addition to investment demand and export.

When looking at the supply side of the economy before introducing the policy, the results for sectoral aggregate output, depicted in Fig. 3, illustrate that construction (S5) is the sector affected most by a 90% economy in all scenarios (−1.91%, −41.84%, −11.13%, and − 11.05% for Scenario 1 to Scenario 4, respectively). In Scenario 1 and Scenario 2, the impact across sectors is generally negative, except for energy (S4) and, even more so, for water transport (S8). In Scenario 3 and Scenario 4 the evolution of sectoral output is negative except for mining (S2).

[7] See Table 1 for a full overview of all products (G) and their related sectors (S).

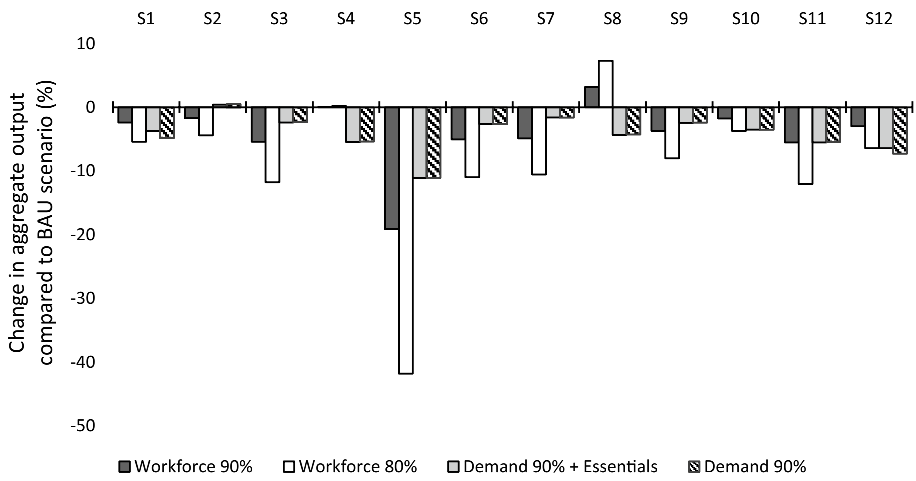

Fig. 3 Evolution of sectoral aggregate output compared to the BAU scenario prior to the policy. NOTE—S1: Agriculture, fishing, forestry; S2: Mining; S3: Industry; S4: Energy; S5: Construction; S6: Trade; S7: Land transport; S8: Water transport; S9: Air transport; S10: Logistics & mail; S11: Market services sector; S12: Non-market services. See Table 1

Table 3 Policy impact on GDP

Scenario	GDP level prior to policy (million EUR)	Policy impact on GDP (million EUR)	Change in GDP due to policy (%)
BAU	411,010	+178	+0.043
Workforce 90%	388,228	+175	+0.045
Workforce 80%	361,453	+173	+0.048
Demand 90% + Essentials 100%	390,513	+179	+0.046
Demand 90%	389,864	+176	+0.045

3.3 Impact of the Sustainable Investment Policy

The results indicate that the impact of the sustainable investment policy on GDP, shown in Table 3, and CO_2 equivalent emissions, shown in Table 4, is positive both in terms of economic growth and emission reductions. In the absence of the pandemic (BAU), GDP would increase by 178 million EUR due to the policy (+0.043%). When looking at the four scenarios, GDP growth ranges from 173 to 179 million EUR. The highest percentage growth occurs in Scenario 2 (+0.048), which is the scenario with the lowest initial GDP level. The second-highest growth takes place in Scenario 3 (+0.046%), which has the highest absolute increase in GDP. In Scenario 1 and Scenario 4 the growth rate is the same (+0.045%), with the lowest initial GDP level in the former scenario.

When looking at the policy impact on CO_2 equivalent emissions (Table 4), emissions would decrease by 0.541 million metric tonnes (Mt) CO_2-eq per million EUR spent in the BAU scenario, more than the emission reductions achieved in the four 90% economy scenarios. However, the increase in GDP is the lowest in the BAU scenario. In this situation,

Table 4 Policy impact on CO_2 equivalent emissions

Scenario	Emission level prior to policy (Mt CO_2-eq per million EUR spent)	Policy impact on total emissions (Mt CO_2-eq per million EUR spent)	Policy impact on emissions from domestic production (Mt CO_2-eq per million EUR spent)	Change in total emissions due to policy (%)
BAU	156.06	−0.541	−0.247	−0.347
Workforce 90%	149.43	−0.504	−0.236	−0.337
Workforce 80%	141.56	−0.456	−0.222	−0.322
Demand 90% + Essentials 100%	150.25	−0.489	−0.230	−0.326
Demand 90%	150.10	−0.491	−0.231	−0.327

the initial level of emissions is also the highest, 156.06 Mt CO_2-eq per million EUR spent. The initial emission levels are the lowest when working time is decreased to 80% (Scenario 2), 141.56 Mt CO_2-eq per million EUR spent, which is considerably lower than the other three scenarios, where emissions range between 149.43 and 150.10 Mt CO_2-eq per million EUR spent. Percentage changes in total emission reductions in a 90% economy are highest in Scenario 1 (−0.337%), followed by Scenario 4 (−0.327%), Scenario 3 (−0.326%), and finally Scenario 2 (−0.322%). The evolution of the policy impact on total emissions and the evolution of emissions from domestic production both follow the same trend. The latter has a share of approximately 46% in the total territorial emission reductions in the BAU scenario, whereas in the four 90% economy scenarios it accounts for a decreased share of 47% of total emissions on average.

The influence of the policy on the government budget, as given in Table 5, is positive in all four scenarios. In Scenario 2, where working time decreases to 80% levels, the cost for government is the lowest (141 million EUR) and the net impact on the government budget available for spending is the highest (+119 million EUR). The multiplier effect of the policy investment, the ratio of GDP to cost for the government, equals 1.22, which is higher than for the other three scenarios, while household spending on construction is lowest, 594 million EUR. In Scenario 3 and Scenario 4 the multipliers are 1.02 and 1.00, respectively. In both cases, the net impact on the government's budget available for spending remains positive (+94 million EUR). Household spending on construction is highest in these scenarios, 734 and 737 million EUR, respectively. Finally, in Scenario 1 the multiplier is 1.08 and household spending on construction 681 million EUR. There is an increase of 109 million EUR on the budget in this case. Note that due to the properties of modelling the government budget in the CGE model, the government is not allowed to overspend and should maintain a savings/deficit rate equal to the one present in the SAM used for calibration. This implies that when a part of the budget is spent on this policy, less money is available for other types of government spending.

The last set of results concerns the policy impact on household demands for (imported) energy products and construction services and how this translates into changes in the level of emissions, as given in Table 6. In Scenario 1, both the change in household emissions (−1.39%) and imports of energy products (−34.80 million EUR) are the highest, with demand for construction services increasing by 14.24%. Scenario 2 has the second-highest decrease in household emissions (−1.35%), while the increase in demand for construction services (+13.30%) and impact on energy product imports (−29.11 million EUR) are the lowest. In Scenario 3 and Scenario 4, the changes in household emissions are lowest (1.29% and 1.30%, respectively). Increases in demand for construction are the highest (+15.34% and +15.36%, respectively) and the impact on imports of energy products (−34.35 and −34.58 million EUR) approaches that of Scenario 1.

4 Discussion

Based on the results and underlying methodology, four main findings can be identified, linking back to the research question, whether sustainable investment policies can play a role in governmental recovery plans, and, more broadly, to the existing literature.

Table 5 Policy impact on the government budget

Scenario	Household spending on construction (million EUR)	Cost for government (million EUR)	Impact on GDP (million EUR)	Multiplier of policy investment (GDP/Cost for government)	Net impact on government budget (million EUR)
Workforce 90%	681	162	+175	1.08	+109
Workforce 80%	594	141	+173	1.22	+119
Demand 90% + Essentials 100%	734	175	+179	1.02	+94
Demand 90%	737	175	+176	1.00	+94

Table 6 Policy impact on household energy demand and construction services

Scenario	Change in household CO_2-eq emissions (%)	Change in household demand for construction services (%)	Impact on imports of energy products (million EUR)
Workforce 90%	− 1.39	+ 14.24	− 34.80
Workforce 80%	− 1.35	+ 13.30	− 29.11
Demand 90% + Essentials 100%	− 1.29	+ 15.34	− 34.35
Demand 90%	− 1.30	+ 15.36	− 34.58

4.1 Pandemic Effect on GDP is Significantly Larger Than on Emission Reductions

First, we find that the decrease in emissions is disproportionally smaller compared to that of GDP as a result of the pandemic because the sectors affected most in the Belgian 90% economy have the smallest carbon intensities. In accordance with Helm (2020), the results exhibit a correlation between GDP and greenhouse gas emissions in the Belgian economy following the COVID-19 scenarios modelled. However, the decrease in GDP, − 6.93% on average for the four scenarios, is disproportionally high compared to that of emissions, − 3.19% on average. The reason for this lies in the relatively low share of emissions stemming from the sectors affected most: construction, market services (e.g. rent), and non-market services (e.g. hotels, restaurants, and bars). Remarkably, the difference between both the GDP and emission reduction in Scenario 3 and Scenario 4 is small. This can be explained by looking more closely at the assumption that certain essential sectors are kept running at pre COVID-19 capacity. In normal conditions, these sectors would also decrease their level of activity in accordance with the general economic trend. Because this is not allowed, however, they virtually overproduce and end up in a less efficient state. Based on preliminary data, STATBEL (2020b) observes a 4% decrease in turnover of businesses in Belgium during the first quarter of 2020 compared to the same period in 2019, with accommodation and food services, manufacturing, and electricity and gas supply and production as the most affected sectors.

The results from the model capture short to medium term effects of a 90% economy in Belgium. Assessing the structural impact is difficult as it remains unclear how long the economy would operate at this reduced level of activity and whether there will be long term structural changes in demand and trade patterns as well as production technologies. The decrease in emissions comes at a high economic, and more importantly, human cost. Matching urgent health care needs and economic recovery with pressing environmental issues and climate change mitigation comprises a major challenge for all affected countries. This has important consequences for policy proposals aimed at growth and meeting targets for the transition to a climate-neutral economy in the new context brought about by the COVID-19 pandemic.

4.2 Green Recovery Policies Can Decouple Growth from Emissions

The second main finding is that the positive impact of a decoupling policy, in this case investing in the renovation of housing units to create local jobs and reduce emissions, is disproportionally large compared to the negative impact of the 90% economy. Specifically, the ratio of GDP growth to emission reduction in the absence of the policy is −2.17. In other words, for emissions to fall by 1 percentage point, GDP has to fall by 2.17 percentage points, whereas if the policy is introduced this ratio becomes positive: GDP increases by 0.2 percentage points for each 1 percentage point reduction in emissions. As such, the policy decouples growth from emissions.

Due to the policy GDP grows by 0.043% in BAU scenario (+178 million EUR), while in the 90% economy scenarios it grows by 0.046% on average, which equals 176 million EUR. This outweighs the 2018 budget for school and study grants (174 million EUR) in Flanders, Belgium's largest region with a population exceeding 6.5 million inhabitants (Vlaamse Overheid 2018). The BAU scenario sees the strongest emission reduction in absolute and relative terms, −0.541 Mt CO_2-eq per million EUR spent and −0.347% respectively. However, the share of reduction in emissions from domestic production is slightly higher (47%) compared to the BAU scenario (46%). The corresponding absolute and relative emission reduction figures for the four scenarios are on average −0.485 Mt CO_2-eq per million EUR spent and −0.328%. During the period 2016–2017, the reduction of CO_2 equivalent emissions was 0.74 Mt in Flanders (Statistiek Vlaanderen 2019). Hence, the policy would amount to more than 65% of this observed reduction.

What these results show is that a green growth strategy can be an effective way to contribute to meeting economic and climate targets following a pandemic. Furthermore, the positive effect of the policy on GDP is even stronger following the COVID-19 scenarios than compared to a business-as-usual scenario where the pandemic did not take place. Central to this is a proper identification of the sectors targeted in the policy. Here, only 2.47% of all housing units were considered as candidates for renovations annually, which causes household emissions to fall by 1.33% on average. Other buildings (e.g. offices and shops) could further add to this decrease if they were to be included in the renovations. Moreover, in case the policy is repeated in the subsequent periods, this will result in a compounding effect on emission reduction. The European Commission (2020c) estimates that around 75% of the entire building stock in the EU is energy inefficient and that renovations could decrease total energy consumption by 5–6%, resulting in a decrease in CO_2 emissions by approximately 5%. Hence, the research illustrates that green policies can be part of the overall recovery strategy following a pandemic. However, in addition to economic and climate effectiveness, it is important to verify whether such policies are also cost-effective.

4.3 GDP Growth and Augmented Government Budget Compensate Policy Costs

This paper provides an argument in favour of the use of government subsidies in well-considered green investment policies by showing that the direct policy cost for the government, averaging 163 million EUR across the four scenarios, is more than compensated by the effect on GDP, which increases by 176 million EUR on average. In addition, the net effect on the government budget available for spending is highly positive due to indirect returns on investment (i.e. the government income increases due to the economic recovery). This results in an investment multiplier larger than one in all four cases. The net impact on the government budget is highly positive, 104 million EUR on average, which further underlines that the investment stimulus can be justified from a macroeconomic perspective.

This provides a solid case for accelerating the green transition in Belgium and other countries alike through well-targeted, calculated policies. In Belgium, the proposed policy also leads to a decrease in the import of energy products by 33.21 million EUR on average. Coupled with investments in renewable energy infrastructure, it is possible to further accelerate the pace of a shift to a climate-neutral economy, create domestic green jobs, and become more energy independent, increasing resilience to foreign supply shocks. Similar policies can be introduced to the model in the same way, allowing further quantitative analysis regarding a green transition. The policy case studied here shows that recovery proposals do not need to come at a cost of lopsided rebounds in emissions. However, it is unlikely that such measures alone will be sufficient to cope with the COVID-19 pandemic. Investing in proper healthcare, for instance, is vital to address the direct effects and create a more robust system when confronted with strong virus resurgence.

4.4 Performance and Limitations of the CGE Model

The CGE model used here to assess the impact of a tailored green investment policy in Belgium provides useful insights on the evolution of this small open economy based on the scenarios considered, sectoral disaggregation and distributional impacts, and inclusion of greenhouse gas emissions. Nonetheless, there are several limitations to this modelling technique, attributable to its theoretical foundations. These are worth mentioning for reasons of transparency and completeness.

First, a critique voiced frequently concerns the credibility of some assumption behind the neoclassical theory of general equilibrium, especially during a crisis of this magnitude. In particular, the assumption that the market clears only holds in the longer run as asymmetries between demand and supply are experienced globally during COVID-19 in the short run. Such imbalances cannot be modelled in this static comparative model.

This CGE model looks at the evolution of an economy active at a 10% level, which can be a valuable source of information for immediate action given the severity and rapid expansion of the outbreak. It remains to be seen, however, to what extent COVID-19 will influence the transition towards a more sustainable global economy. For instance, will historically low oil prices delay a climate-friendly economic expansion? Macroeconomic policy responses, both monetary and fiscal, will be key and should be underpinned by a sustainable investment strategy. The research here shows that there are options that can contribute to this. In addition to how the COVID-19 pandemic and recovery policies will accelerate or delay the realisation of environmental and climate ambitions, it will be necessary to evaluate the social dimension of new policy proposals. For instance, in this research it was assumed that the government accounts for 10% of the total renovation costs. It can be argued that for many families the remaining 90% still exceeds their budget and hence the renovation would not take place. While it was beyond the scope of this paper, the social aspect is important and requires further attention in future research.

5 Conclusion

Since the first reported case of the COVID-19 coronavirus in Wuhan, China's Hubei province, at the end of 2019, the virus has spread across the globe in a matter of months, crippling countries and necessitating impromptu government action. In an attempt to contain the virus, governments have imposed lockdowns and travel bans at an unprecedented scale to safeguard the public's health. Consequently, people's freedom to move and interact was limited to an extent previously unimaginable, especially to liberal democracies. These measures, while justifiable from a human health perspective, also come at a high economic cost and generate changes in the environment and the levels of greenhouse gas emissions.

To our knowledge, no CGE models have assessed the interplay between economic recovery plans in the COVID-19 period and the impact on the environment and the climate. Therefore, we looked at a targeted policy response to support economic activity and simultaneously invest in the transition towards climate neutrality. As a result, our research extends the focus of earlier macroeconomic assessments of the COVID-19 pandemic by quantifying the impact on macroeconomic variables as well as greenhouse gas emissions. As such, this paper further substantiates the need for quantitative evidence to better inform policy decisions. Therein lies its novelty and main contribution to the literature.

Possible future research could focus on other policies that aim for the same outcome, i.e. GDP growth and greenhouse gas emission reduction, to further examine their role in sustainable COVID-19 recovery strategies. Particularly, the potential rebound and multiplier effects of policy measures could provide useful insights in this regard. Adjustments to the existing model could also contribute to a better understanding of such policies and their consequences, for example, allowing for involuntary unemployment. Furthermore, it remains unclear at present how the COVID-19 pandemic will manifest itself in the long run. Hence, keeping track of the economic impact is essential as this might shed a different light on the crisis' properties, which might require modelling and assessing different shocks. Consequently, this might require different policies to address these shocks. Finally, the model assumes optimal agent behaviour according to aggregate utility functions. It would be interesting to compare the outcomes obtained here with studies on behavioural economics, where this assumption does not necessarily coincide with observed data.

Annex 1: Government Budget

Government consumption of products and services is driven by the government utility function, represented by:

$$x_{i,g} = g * \frac{\alpha_g}{p_i^g}$$

With

$x_{i,g}$ = Volume of government demand per commodity / service i;

g = Net government revenue available for spending on commodities i;

α_g = Distribution parameters of level 1 of government utility function i;

p_i^g = Unit price paid by government per commodity / service i;

In addition, it is assumed that the budget available for government spending is such that the same government utility can be obtained as in the base scenario, and that the government deficit remains constant in real terms. However, the overall government budget should be balanced according to the following stipulation:

$$
\begin{aligned}
&= \sum_{i=n} (x_{i,hh} * p_{i,hh} * Prodtax_{i,BEL}) + \sum_{i=n} (x_{i,inv} * p_{i,inv} * Prodtax_{i,BEL}) + \sum_{i=n} (x_{i,int} * p_{i,int} * Prodtax_{i,BEL}) \\
&+ \sum_{i=n} ((x_{i,hh} * p_{i,hh} * \left(1 + Prodtax_{i,BEL}\right) * (1 + Prodtax_{i,EU})) + (TM_i * p_{i,TM}) * (VAT_{i,BEL} + Nonprodtax_{i,BEL})) \\
&+ \sum_{i=n} ((x_{i,int} * p_{i,int} * \left(1 + Prodtax_{i,BEL}\right) * (1 + Prodtax_{i,EU})) + (TM_i * p_{i,TM}) * (VAT_{i,BEL} + Nonprodtax_{i,BEL})) \\
&+ \sum_{i=n} ((x_{i,inv} * p_{i,inv} * \left(1 + Prodtax_{i,BEL}\right) * (1 + Prodtax_{i,EU})) + (TM_i * p_{i,TM}) * VAT_{i,BEL}) \\
&+ \sum_{i=n} ((x_{i,g} * p_{i,g} * \left(1 + Prodtax_{i,BEL}\right) * (1 + Prodtax_{i,EU})) + (TM_i * p_{i,TM}) * VAT_{i,BEL}) \\
&+ \sum_{i=n} x_{i,ROW} * P_{i,ROW} * EX_{ROW} * Tariff_{i,ROW} + \sum_{i=n} x_{i,EU} * P_{i,EU} * EX_{EU} * Tariff_{i,EU} \\
&+ (Income_{HH,BEL} + Income_{HH,EU} + Income_{HH,ROW}) * \left(Socprem_{BEL} + Incometax_{HH,BEL}\right) \\
&+ \left(Income_{F,BEL} * Incometax_{F,BEL}\right) - (Pop_{BEL} * GOVTF_{HH} + 9.09\% * x_{1,HH}) \\
&+ Capincome_G - g + Net\_Transfers_{EU} + Net\_Transfers_{ROW}
\end{aligned}
$$

With

$x_{i,hh}$ = household consumption of product / service i;

$x_{i,inv}$ = investment consumption of product / service i;

$x_{i,int}$ = intermediate consumption of product / service i;

$x_{i,g}$ = government consumption of product / service i;

$x_{i,ROW}$ = imported quantity of product / service i from the ROW;

$x_{i,EU}$ = imported quantity of product / service i from the EU;

$p_{i,hh}$ = household consumption price of product / service i;

$p_{i,inv}$ = investment consumption price of product / service i;

$p_{i,int}$ = intermediate consumption price of product / service i;

$p_{i,g}$ = government consumption price of product / service i;

$p_{i,ROW}$ = import price of product / service i from the ROW;

$p_{i,EU}$ = import price of product / service i from the EU;

EX_{ROW} = exchange rate to ROW currency;

EX_{EU} = exchange rate to EU currency (= 1);

$Tariff_{i,ROW}$ = import tariff for product / service i from the ROW;

$Tariff_{i,EU}$ = import tariff for product / service i from the EU (= 0);

$Prodtax_{i,BEL}$ = product related tax on product / service i by Belgium;

$Prodtax_{i,EU}$ = product related tax on product / service i by the EU;

$VAT_{i,BEL}$ = value added tax on product / service i by Belgium;

$Nonprodtax_{i,BEL}$ = non-product related tax on product / service i by Belgium;

$Income_{HH,BEL}$, $Income_{HH,EU}$,$Income_{HH,ROW}$ = household labour income in Belgium, the EU, the ROW respectively;

$Income_{F,BEL}$ = firm income in Belgium;

$Socprem_{BEL}$ = social premium paid in Belgium;

$Incometax_{HH,BEL}$ = tax on household income in Belgium;

$Income_{F,BEL}$ = tax on firm income in Belgium;

Pop_{BEL} = population in Belgium;

$GOVTF_{HH}$ = government transfers to Belgian households;

$x_{1,HH}$ = household consumption of construction products / services;

$Capincome_G$ = capital income government;

$Net\_Transfers_{EU}$, $Net\_Transfers_{ROW}$ = Net transfers towards governments in the EU, the ROW respectively;

TM_i = volume of trade services per product / service i;

$p_{i,TM}$ = price for trade services per product / service i;

This stipulation basically implies that the government obtains revenues from the sum of product related taxes (on household consumption, intermediate consumption, investment demand, government demand), non-product related taxes (on household consumption and intermediate consumption), value added taxes (on household consumption, intermediate consumption, investment demand, government consumption), import tariffs, income taxes (on household income and firm income), and net transfers to governments abroad (both the EU and the ROW). The government can spend this money by making transfers to the households and by consuming products in function of the government utility function, subject to the available budget for government spending, g.

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