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Assessing the Short Term Macroeconomic Impact of the Net Zero Transition

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ABSTRACT

A method for assessing the macroeconomic impact of a transition toward carbon neutrality is presented. The method utilizes the long-term global economic gain of the transition, and distributes the global gain to individual countries by using the (implicit) pledges made under the Paris Agreement. By considering the quantified gain as a country's maximum investment amount, consistent transition-dependent macroeconomic pathways can be assessed. Unsurprisingly, orderly versus delayed and disorderly transitions produce different macroeconomic outcomes, a difference that indicates that there is a macroeconomic aspect to both the risk and the gains of the transition toward carbon neutrality. The method presented can be used for, for example, understanding the macroeconomic risks during the transition phase, which, in turn, can be used for assessing certain macroeconomic aspects of transition risk. This method is flexible and allows for several different transition periods to be studied and can be used to shed light on different aspects of the risks related to the transition toward carbon neutrality.

Keywords: Climate Change, Economic Growth, Transition Risk
JEL Classifications: E00, H00, Q54, Q58

#The author gives thanks for the support and comments received from several employees working at Swedbank, in particular, Maija Kaartinen.

1. INTRODUCTION

Climate change transition risk refers to the potential financial losses that companies and investors face as the global economy shifts toward a low-carbon future. This shift is being driven by a growing recognition of the need to address climate change and reduce greenhouse gas emissions to avoid the most catastrophic impacts of global warming.

As governments and businesses around the world begin to implement policies and regulations to promote the transition to a low-carbon economy, some companies and investors may be exposed to financial risks (see, e.g., BIS, 2022 and the references therein). For example, companies that are heavily reliant on fossil fuels, such as coal and oil, may see a decline in demand for their products as the world moves toward cleaner energy sources. This could lead to lower revenues and profits and potentially even bankruptcy for some companies. Similarly, investors who have significant holdings in companies that are exposed to climate change transition risk may face financial losses as the value of their investment's declines. This is particularly concerning for investors with long-term investments, such as pension funds and insurance companies, which may be impacted by the transition to a low-carbon economy over the next several decades.

Companies and investors will need to take several steps to address climate change transition risk (OECD, 2021). These could include divesting from fossil fuel companies, investing in clean energy and low-carbon technologies and implementing strategies to reduce greenhouse gas emissions within their own operations. By taking these steps, companies and investors can protect themselves from the potential financial losses associated with the transition to a low-carbon economy (BIS, 2022) and position themselves to benefit from the opportunities that will arise as the world moves toward a more carbon-neutral future.

Climate change will affect the long-term global *potential* GDP. As such, the long-term economic effects of addressing the problem (which will increase said GDP) can be compared with cases in which the problem is ignored or cases in which the world fails in the transition toward carbon neutrality (which will decrease said GDP). The increase in potential future global GDP in the scenario in which the problem is addressed versus a scenario in which nothing is done or in which the world fails to address the problem can thus be seen as the economic *gain* of the investments made for the transition toward carbon neutrality.

The long-run macroeconomic impact of addressing versus not addressing climate change was researched in Kompas et al. (2018) and qualitatively confirmed in a study done for the International Monetary Fund (Kahn et al., 2019).[1] Even though the two studies used different econometric methods, both calculated an expected long-term economic loss if no action is taken (i.e., an economic gain given a successful and effective implementation of greenhouse gas emission-reducing policies) of about 7% of global GDP. In a study made by the Swiss Re Institute (Swiss Re Institute, 2021), it is estimated that the global economy could lose up to 10% of total economic value from climate change if temperature increases stay on the current trajectory and up to 18% if global temperatures rise by 3.2°C.[2] In this study the 7% estimate of potential lost global GDP is used, together with the pledges made during the Paris Agreement to calculate the possible macroeconomic impact of a transition toward carbon neutrality.

The rest of this paper is organized as follows. In the next section, relevant climate change scenarios are discussed, and a method for assessing the relevant investment amounts is presented. This is followed by a section presenting a macroeconomic module that can be used together with macroeconomic forecasts to assess the impact of the transition toward carbon neutrality. This is followed by a section in which the macroeconomic impacts of an orderly versus a disorderly and delayed transition is compared and discussed. The final section discusses the results and concludes.

2. A METHOD FOR ASSESSING THE RELEVANT INVESTMENT AMOUNT

If successfully achieving the goals of the Paris Agreement will keep global warming below 2°C, the economic gains of a successful transition toward carbon neutrality can be calculated. By comparing the long-term economic effect of actions taken in order to prevent climate change (i.e., keeping global warming below 2°C) versus inaction, the gains of climate change action can be assessed. To this end, different carbon pathways are needed, and here, two contrasting scenarios are considered (van Vuuren et al., 2011):

1. A successful implementation of a climate change agreement (e.g., the Paris Agreement) set to slow global warming to less to, or around, 2°C by 2100 (approximately RCP 2.6)
2. A scenario without any action to reduce emissions, resulting in global temperatures increasing by up to 4°C (approximately RCP 8.5).

Kompas et al. (2018) used an intertemporal computable general equilibrium trade model on 2017 world GDP levels and estimated the long-run global GDP effects in the two scenarios. It was found that the global economic gain of keeping global warming manageable (i.e., the difference in the estimated GDP levels in the two above scenarios) is approximately US$17,489 billion per year in the long run (i.e., by the year 2100), which accounts for about 7% of future potential global GDP.[3] As no rational economic agent would be willing to spend more on an investment than the investment's potential gain, the long-term gain of keeping global warming below 2°C can be thought of as a maximum total global amount to be spent on greenhouse gas (GHG)-reducing activities. The amount can also be distributed to each party/country using the party-specific GHG percentages discussed during the Paris Agreement.[4]

Denote the difference in long-run potential global GDP in the two scenarios as ΔGDP_{global} and treat the gain as a perpetuity.[5] Since GHG-reducing climate change actions/investments, by necessity, need to be done in the near term while their gains are obtained in the far future, the present value of the long-run gain needs to be calculated. To this end, let *SDR* be the appropriate Social Discount Rate and let *T= t (end)– t (start)* be the transition period where *t* (*start*) is the year when the transition begins and *t* (*end*) the year when the transition is assumed to be completed. Note also that the gain ΔGDP_{global} is obtained in the year 2100, i.e., many years after the transition is completed. As such, the present value $PV_{\varnothing GDP_{global}}$ of ΔGDP_{global} is given by:

$$PV_{\Delta GDP_{global}} = \left(\frac{\Delta GDP_{global}}{SDR} \Big/ (1+SDR)^{(2010-t(end))} \right) \Big/ (1+SDR)^{T} \quad (1)$$

As such, by simply having some knowledge about the relevant transition period (*T*) and the appropriate social discount rate (*SDR*), the present value of the future gains of the transition can be calculated. Furthermore, by letting each country (*i*) contribute to the needed investment in accordance with the implicit pledges made ($PGfR_i$) in UNFCCC (2015), each individual country's contribution to the total can be written as:[6]

1 The author gives thanks for the support and comments received from Kelly C De Bruin and from several employees working at Swedbank, in particular, Maija Kaartinen.

2 The study done by the IMF used a different method but ended up with an expected long-term economic loss of about 7 percent of global GDP.

3 As discussed in Desmet, K., & Rossi-Hansberg (2021), the task of providing exact estimates on the effect on economic output due to climate change is difficult. Mapping physical risks impact economic output is complex and the slow evolution of climate change over time as well as the global nature of CO2 emissions makes local economic impact assessments challenging.

4 Also, a stochastic growth model study done by the IMF (Kahn et.al.; 2019) found that the economic cost of "inaction" was about 7 percent of long-run global GDP levels.

5 As disclosed in the Appendix of UNFCCC (2015).

6 Arguably, this is a simplifying assumption that will underestimate the calculated gain. This is because it is likely that the economic trajectories in the two scenarios will deviate with time.

7 Distributing the global gains as in Equation (2) implicitly assumes a global utility function.

$$pv_i = PGfR_i \times PV_{\Delta GDP_{global}} \quad (2)$$

3. ASSESSING THE IMPACT ON ECONOMIC GROWTH

The impact of the transition to carbon neutrality on economic growth is calculated considering the long-term economic gains of doing so. For this, an estimate on $PV_{\varnothing GDP_{global}}$ in Equation (1) is needed, from which the individual countries contribution can be found using Equation (2). Equation (1), however, contains two unknown parameters, namely *t (end)* and *SDR*. In a study made by the International Energy Agency, it was assumed that all countries strive toward reaching net zero carbon emissions by 2050 (IEA, 2021), an assumption also made here.[7] As such, the only unknown parameter left in Equation (1) is the social discount rate (*SDR*).

Social discounting is the standard method applied when making financial calculations and the basis of inter-temporal choice in economics. However, in the assessment of public projects, the chosen *SDR* varies substantially between countries, as various approaches are used to determine its value.[8] In a study by Kazlauskiene (2015), it was found that it is common to use values between 3.5 and 11.5 for projects stretching 30 years into the future, with a median of about 5% but the study did not touch upon how investments related to climate change should be treated. Choosing the most appropriate SDR with regard to climate change is tricky, as no consensus on which rate to use yet exists. In a survey of economists (Drupp et al., 2018), it was found that most economics favor a low *SDR,* with the median response being a low 2%.[9] Given the uncertainty with regard to appropriateness, both a high 5% and a low 2% SDR are used when $PV_{\varnothing GDP_{global}}$ is calculated.

Table 1 presents present estimates of $PV_{\varnothing GDP_{global}}$ and of pv_i for the world's three largest GHG-emitting counties and economic regions, China, the US, and the Euro area. Considering that no rational economic agent would be willing to invest more than the expected gain of the investment, the amounts in Table 1 are interpreted as a ceiling of the amounts to be spent and/or invested in GHG emission reduction by a rational economic entity.

As can be seen in Table 1, the calculated amounts are large. If, for example, a 5% *SDR* is used, China should (rationally) contribute to the transition to carbon neutrality with approximately USD 1417.19 billion during the 30-year transition period, the US with approximately USD 1262.64 billion, and the Euro area with about USD 577.33 billion. Furthermore, assuming that the investments are made linearly during the transition period, China should (rationally) invest/spend about USD 47 billion, the US USD 42 billion, and the Euro area about USD 19 billion annually on efforts to reduce the countries/regions GHG emissions.

From Table 1, it can also be seen that the delayed transition, in which the transition is postponed until the year 2030, pv_i is increased by 63%. The increase can be attributed both to a shortening of the transition horizon by 10 years, and due to a larger $PV_{\varnothing GDP_{global}}$ value as it is discounted at a later stage. In the delayed transition, China is estimated to (rationally) invest USD 2 309.63, the US USD 2 056.71 billion, and the Euro area USD 940.41 billion on various GHG-reducing activities. As the transition period is shorted, the annual amounts increase with a factor of 2.4 such that China, the US, and the Euro area, respectively, are estimated to (rationally) invest 115, 103, and 47 billion USD annually over the remaining 20 years of the transition horizon.

Finally, a 2% SDR unsurprising balloons both $PV_{\varnothing GDP_{global}}$ and pv_i as the future is valued higher. In fact, the amount to be spent on decarbonizing the economy increases by a factor of 25 given a 30-year transition and by 19 times in the delayed transition scenario in all studied economies and economic regions. Figure 1 depicts the calculated amounts as a share of the economic region's annual GDP.

3.1. Linking pv_i to Economic Growth

Since no rational economic agent would be willing to invest more than the expected gain, the calculated amounts in Table 1 can be used to understand the transition effect on short term economic growth. When assessing the impact on the economy, it is acknowledged that the amounts in Table 1 can be attributed to both the private and public sides of the economy. However, if the public side becomes heavily involved, consideration needs to be taken with regard to how such investments affect the economy as a whole.

Define GDP from the expenditure side as $GDP_t = G_t + C_t + I_t + (Exp_t - Imp_t)$, where G_t denotes the amount of public spending, C_t the value of private consumption, I_t private investments and Exp_t and Imp_t the value of exports and imports, respectively. Let the parameter ϑ be the share of investments done by the public side of the economy and acknowledge that all investments done during time period t could increase governmental spending (G), while also, possibly, negatively affecting investments made by the private sector. Denote such an effect as μ and interpret it as a parameter describing the *effectiveness* (i.e. a parameter representing the degree of disorderliness of the transition) with which investments are made. As such, GDP from the expenditure side can be rewritten as:

$$(G_t + \vartheta pv_{t,i}) + C_t + (I_t - \mu\vartheta pv_{t,i} + \mu \times (1-\vartheta)pv_{t,i}) + (Exp_t - Imp_t) \quad (3)$$

Continue with acknowledging that the public's share of share investments made needs to be funded and introduce a climate change-motivated tax rate (ω_i). As such, the total government

8 It is noted that not all countries have a target of being carbon neutral by 2050, but a homogonous transition period is chosen for tractability.

9 Its value can be determined using, e.g., the social rate of time preference (SRTP), the social opportunity cost of capital (SOC), the weighted average approach, or the shadow price of capital (SPC) approach.

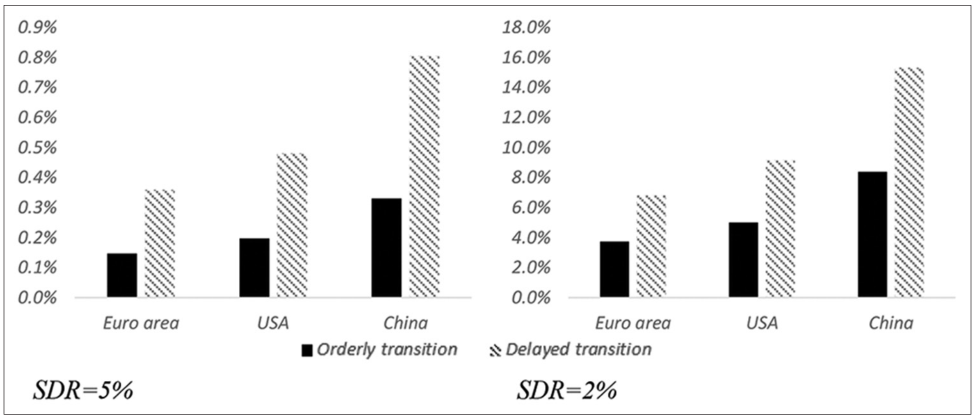
10 There seems to be academic support for a low discount rate, which may be because discounting has a less important role in cost–benefit analysis of climate change than once thought, see e.g., Dietz et al. (2016). As highlighted by Harvard economist Martin Weitzmann, in the case of catastrophic climate change "the severe consequences would override the effect of discounting however low the probability of such an event may be" (see Weitzman, 2009 and Millner, 2013).

Table 1: Large CO_2 emitter emissions and their contribution to the transition

Country	Percentage of GHG for ratification (%)	SDR=5% in billion USD		SDR=2% in billion USD	
		Orderly 30-year transition (2020-2050)	Delayed 20-year transition (2030-2050)	Orderly 30-year transition (2020-2050)	Delayed 20-year transition (2030-2050)
$PV_{\Delta GDP_{global}}$		7 057.79	11 496.39	179 365.48	218 645.52
pv_{China}	20.09	1 417.91	2 309.63	36 034.53	43 925.89
pv_{USA}	17.89	1 262.64	2 056.71	32 088.48	39 115.68
$pv_{Euro\ area}$	8.18	577.33	940.41	14 672.10	17 885.20
$\sum$	46.16	3 257.88	5 306.75	82 795.11	100 926.77

Source: Appendix of UNFCCC (2015) and own calculations. Note: 2019 nominal values in USD, $\Delta GDP\ global$ in Equation 1 is set to US$17489.71 billion, i.e., as in Kompas et al. (2018)

Figure 1: pv_i/T as a share of the GDP



revenue from the climate change-motivated tax scheme can be written as:

$$\omega_i \times (C_t + I_t + (Exp_t - Imp_t)) \quad (4)$$

It is likely that such a tax will result in a sector-specific deadweight loss (dw_j) impacting GDP, which needs to be taken into account.[10] Let the deadweight loss be a percent of the GDP subcomponents such that the revenues in Equation (4) can be rewritten as:

$$\omega_i \times \begin{bmatrix} (1-dw_C)C_t + (1-dw_I)I_t + \\ \left((1-dw_{Exp})Exp_t - (1-dw_{Imp})Imp_t)\right) \end{bmatrix}. \quad (5)$$

Furthermore, assume that only a fraction of $pv_{t,I}$ is funded through taxes and that the remaining part is obtained using global debt markets. Thus, the remaining part that needs funding is simply the difference between the state's part of the rational investment amount and the tax revenue in Equation (5):

$$\varphi = \vartheta \times pv_{t,i} - \omega_i \times \begin{bmatrix} (1-dw_C)C_t + (1-dw_I)I_t \\ +\left((1-dw_{Exp})Exp_t - (1-dw_{Imp})Imp_t)\right) \end{bmatrix}. \quad (6)$$

Finally, an increase in governmental debt also tends to crowd out private investments as more governmental borrowing, in most countries, increases yields on governmental debt securities. This will affect interest rates in general throughout the economy, and thus also the cost of private debt and borrowing, crowding out some private investments. Denote this crowding-out effect as δ and let it be a percentage of φ:

$$GDP_t^p = (G_t + \vartheta pv_{t,i}) + C_t(1-dw_C) + (I_t\left(1-dw_{Exp}\right) - \mu\vartheta pv_{t,i} + \left(1-\vartheta\right)pv_{t,i}) + (Exp_t(1-dw_{Imp}) - Imp_t(1-dw_{Imp}))_t - \delta \times \varphi \quad (7)$$

The annual GDP effect of governmental climate change-motivated GHG-reducing investments is thus given by the difference: $\Delta GDP_t = GDP_t - GDP_t^p$.

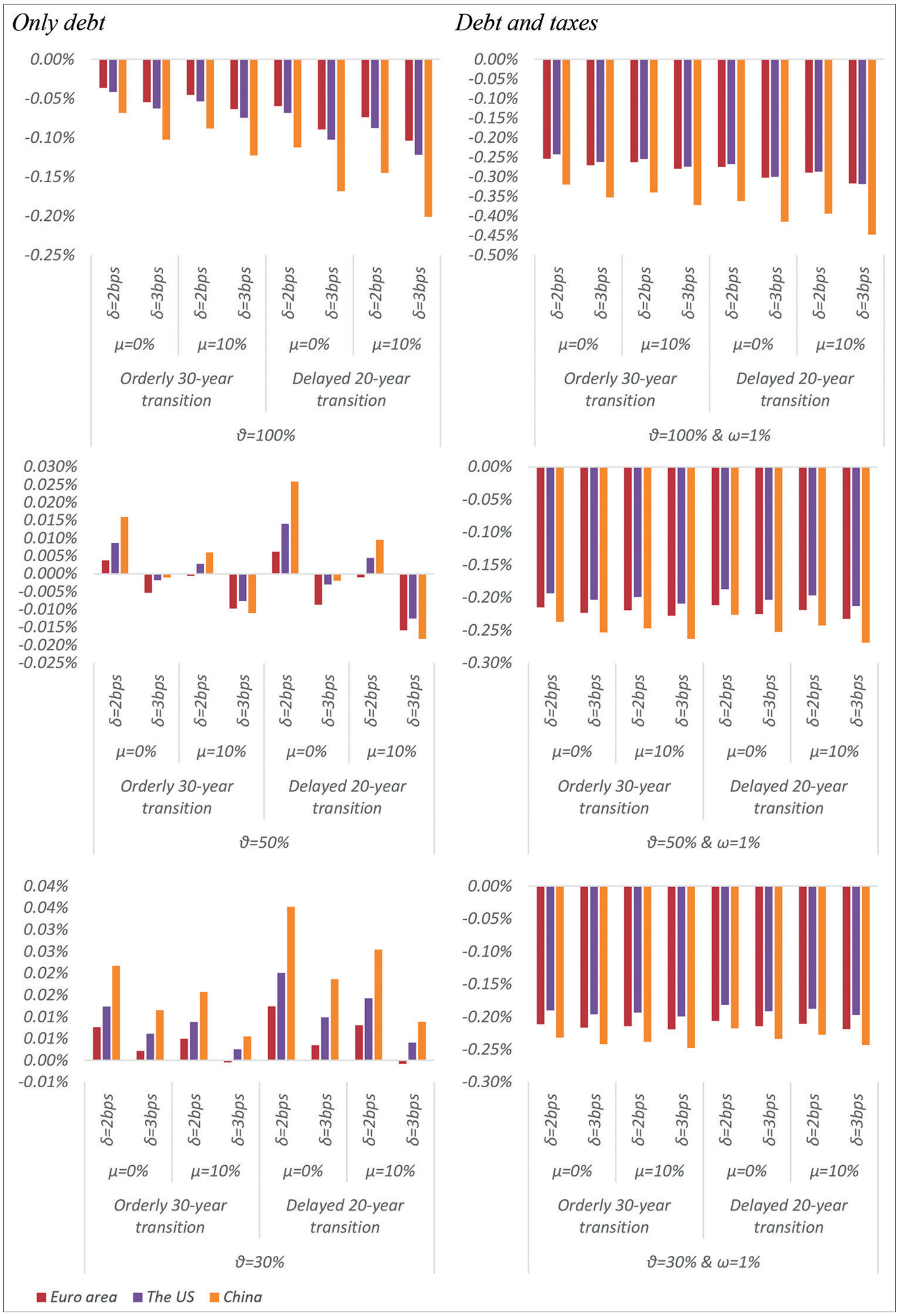
The above framework allows one to elaborate on the economic effects of the transition toward carbon neutrality through how $pv_{t,I}$, affects the economy at large. It also allows for the exploration of the economic effects of different social discount rates, the share of investments done by the public/private side of the economy (ϑ), the effect of different tax rates (ω_i), the share of investment made effectively/degree of disorderliness (μ), and the crowding-out effect due to an increase in public debt burden (δ).

Together with the amounts presented in Table 1, the framework herein gives modelers a holistic top-down macroeconomic assessment tool that can be used to understand the impact of a transition toward carbon neutrality on the economy at large. Note also that the tax rate (ω_i) needed in a pure tax solution to the transition problem can be found by simply equating the annual investment amount (pv_i) with the revenues obtained from taxation:

$$pv_i = \omega_i \times (dw_C \times C_t + dw_I \times I_t + (dw_{Exp} \times Exp_t - dw_{Imp} \times Imp_t)) \quad (8)$$

11 The different GDP components deadweight loss levels are inspired by the findings in Sörensen (2014) such that consumption is assumed to have a deadweight loss of 22 percent, investments 38.5 percent, and imports/exports 49 percent.

Figure 2: Annual GDP growth effect, SDR=5%



Solving for ω_i in Equation (9) results in the lowest tax rate needed in the absence of debt financing. But, since a global carbon tax could be hard to implement in practice, a pure debt-based solution is also investigated.

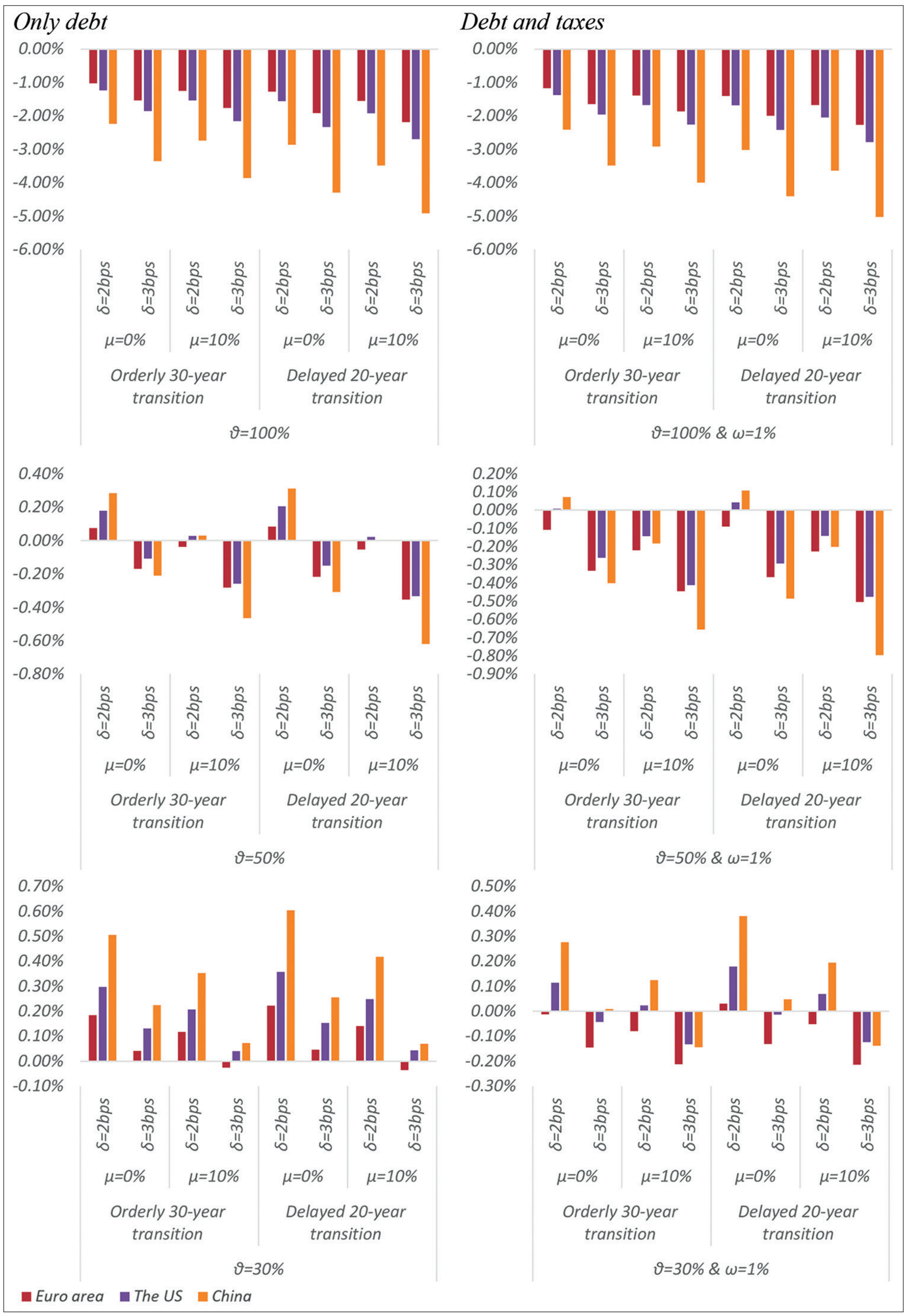
4. EXPLORING THE NET ZERO TRANSITION AND EXEMPLIFYING ITS ECONOMIC IMPACT

The transitions impact on GDP for the three largest global carbon emitters (China, the US, and the Euro area) is explored in both a (pure) debt solution to the public's financing need as well as a combined solution in which taxes are also used to cover the government's increase in expenses. The implied effect of involving the private sector in the transition is explored by calculating the GDP effect for different values of ϑ. Since a debt solution to the public's increased financing need could increase the governmental debt burden, one also needs to acknowledge that interest rates could increase with an increase in public debt burden, pushing up interest rates on other financial products, which, in turn, could crowd out otherwise viable private initiatives (δ). To account for such an effect, the results in Gamber and Seliski (2019) are used such that δ in Equation (7) is set to either 2 or 3 basis points per percentage point in increased public debt in relation to GDP.

For tractability, pv_i is assumed to be constant over the transition horizon, which, in turn, implies that the investments are deployed linearly over time. Both an orderly transition and a delayed transition are studied, and Figure 2 depicts the annual GDP growth effect if SDR=5% and Figure 3 if SDR=2%. The following results are highlighted:

1. Economic growth tends to increase during the transition period if ways are found to also involve the private sector of the economy.
2. The share of investment made effectively/degree of disorderliness (μ) needs to be closely monitored. This is because a large value implies that some otherwise viable private initiatives could be taken over by the state, which in turn could have a severe negative effect on economic growth.
3. It is important to monitor how the rate of governmental borrowing is affected when the public's debt burden increases. At some point, the economic gain of a publicly financed transition becomes negative.
4. A debt solution to the public's financing needs is better than a tax solution.

Figure 3: Annual GDP growth effect, SDR=2%. Note: Using 2020 years GDP in USD



5. If a high discount rate is used in combination with realistic assumptions on the models' parameters, a delayed transition could be harmful for economic growth, unless the private side is heavily involved or if an increase in public debt only marginally affects the general interest rate level ($\delta=2$).

In summary, it is found that the studied economies tend to benefit from the transition toward carbon neutrality if also the private side of the economy is involved in the transition. It is also found that economic growth favors an orderly 30-year transition, and if most of the investments done by the public side of the economy are made effectively and financed using global debt markets, a positive economic growth effect during the transition period is likely. However, if the public side of the economy is forced to take the lead and do most of the investing and financing of these investments using taxes, there could be a short-term economic cost of the transition toward carbon neutrality. Such a cost also increases if the transition is postponed and done in a disorderly. Finally, it is found that the Euro area is highly sensitive to inefficient public investing, that China is the most robust economy when it comes to public participation, and that the US economy is harmed the least by an increase in tax.

5. CONCLUDING REMARKS

In this paper, a method for assessing the short-term economic effect of a transition toward carbon neutrality is presented. The results rests on the implicit pledges made in the Appendix to the United Nations framework convention on climate change (UNFCCC, 2015), which together with long-term economic growth effects of climate change can be used for assessing the macroeconomic growth effects during the transition phase. The method presented herein can be used for understanding both the macroeconomic benefits and the macroeconomic risks related to a transition toward carbon neutrality, which, in turn, can be used, for example, to understand a borrower's transition risks.

The presented method utilizes findings on the long-run economic benefits of keeping global warming below 2° Celsius. This method transforms the long-run economic gain to its present value using different social discount rates. Since the appropriate social discount rate is a debatable topic, results using both a high 5% and a low 2% rate are presented. The global present values are then distributed to different countries/economic regions using the implicit pledges made under the Paris Agreement. By assuming that the investments are distributed linearly over a transition period, the economic impact of greenhouse gas-reducing investments during the transition phase can be found.

The method presented allows for elaboration on who should be making the investments (public or private sector), on different tax rates, on how much (if any) of private initiatives that are replaced by public investments, and on the size of the crowding-out effect due to a potential increase in public debt. The method can thus be used to understand the economic impact of a move away from carbon-intense production and toward a less polluting green economic structure. As such, the method can be used for addressing the macroeconomic impact of a climate change transition, which, in turn, can be used for assessing a firm's' transition risks in relation to climate change.

The method is put to the test by analyzing an orderly 30-year transition and a delayed 20-year transition toward carbon neutrality for the world's three largest greenhouse gas emitting economies and economic regions, namely China, the US, and the Euro area. It is found that GDP growth will most likely be positively impacted if the transition is done in an orderly way, if the private sector is involved, and if the public investments are financed using global debt markets.

If the transition toward carbon neutrality, for some reason, is delayed and thus needs to be rushed and done disorderly, the results are more ambiguous and, for example, the Euro area is found to be highly sensitive to crowding-out effects. Also, if the public's investments are made ineffectively, a less optimistic result is obtained, and if a large chunk of the investments hinders private initiatives from taking place, economic growth is negatively affected. However, if ways are found to include the private side of the economy, economic growth in general is positively affected during the transition period.

In summary, the results presented herein can be used to assess the macroeconomic impact during the transition away from carbon-intense production toward a less polluting and greener economy. They can be used to understand both the economic benefits of the transition and the transition risks of climate change.

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