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Contacts:

CIFREL
Università Cattolica del Sacro Cuore
Via Necchi 5
20123 Milano
Telephone: 0039.02.7234.2976
e-mail: dip.economiaefinanza@unicatt.it
web: https://centridiricerca.unicatt.it/cifrel_index.html

Green stimuli and brown taxation: How to finance sustainable business?

Cristian Carini[1], Nicola Comincioli[*,1,2], Ivan Gufler[3], Paolo M. Panteghini[1,4,5], and Sergio Vergalli[1,2]

[1]Department of Economics and Management, University of Brescia, Italy
[2]Fondazione Eni Enrico Mattei, Italy
[3]Department of Economics and Finance, LUISS Guido Carli, Italy
[4]Interuniversity Research Centre on Local and Regional Finance (CIFREL)
[5]CESifo and AccounTax Lab, Munich, Germany

Abstract

Subsidies are fundamental policy tools that can effectively accelerate the green transition. This article focuses on the impact of such subsidies on investment timing. We compare the investment decisions in a green start-up and a brown one, where subsidies are not permitted. Specifically, we employ a real-option approach to model the investment decision of a representative firm and evaluate the expected tax revenue. Understanding the effects on the latter variable resulting from the presence of incentives is of crucial importance as it enables policy makers to measure the minimum environmental benefit required to maintain the same welfare level under subsidization. Additionally, we employ a numerical simulation calibrated with real data to compare the effects on both green and brown investments. Specifically, the green subsidy may lead to a considerable time gap between green and brown investments, and this gap is inversely proportional to the volatility of profits. This result holds crucial policy implications. While granting a green subsidy imposes a cost on public finance, this strategy anticipates the establishment of new firms, ensuring a flow of taxable profits and, most importantly, fostering positive

[*]Corresponding author: Department of Economics and Management, University of Brescia, Via San Faustino 74/B, 25122 Brescia (BS), Italy, Tel.: +39 030 2963815, Mail: nicola.comincioli@unibs.it

environmental externalities generation. Finally, this situation presents a policy dilemma. When volatility reaches a certain threshold, the expected investment time increases. However, green projects are always initiated earlier than brown ones. This dilemma arises because achieving the Net Zero Emission (NZT) target requires promoting both green and brown investments.

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1 Introduction

The "green-brown" dichotomy provides a convenient taxonomy for navigating the contemporary socioeconomic and technical landscape. Green technology, either explicitly or as a by-product, generates or facilitates the reduction of environmental externalities (Lehmann & Söderholm 2018, Allan et al. 2014).

The ongoing energy transition towards a more sustainable economy, in response to the challenges posed by climate change, is an ambitious and complex goal. Achieving this objective requires significant financial and policy efforts to promote the adoption of green technologies. Despite a wide range of policy instruments available,[1] few have garnered significant attention in the scientific literature, apart from carbon taxation, as noted by Timilsina (2022) and the referenced articles. Fiscal policy is one such instrument.

This manuscript aims to investigate the effects of a subsidy on the timing of green investments compared to brown investments. Specifically, we explore, through theoretical and numerical approaches, the impact of introducing a targeted green investment subsidy on start-up investment decisions. Our analysis reveals a delay in brown investments. Moreover, we find that the green-brown investment time gap is highly sensitive to factors such as profit volatility and interest rates. However, our results present a dilemma: while the presence of a green incentive encourages the establishment of green start-ups, generating taxable income earlier than brown ones and yielding positive externalities, it also imposes a burden on the public budget. As a result, policymakers must strike the optimal balance between financing green businesses and sustaining tax revenue from brown ones, which may still be necessary until the Net Zero Emissions (NZE) target is achieved. Moreover, during a transition towards NZE, both brown and green investments are necessary. The use of a green subsidy may crowd out brown investments.

The remainder of this manuscript is organized as follows: Section 2 provides a detailed explanation of the model for start-up decision-making. We present the results of numerical simulations and offer insightful interpretations in Section 3. Finally, Section 4 summarizes our findings and discusses their policy implications.

[1] For a comprehensive review, see Al-Saleh & Mahroum (2015).

2 The model

Let us consider a representative firm endowed with a start-up option, that can chose between a traditional brown investment and a green one, which might be subsidized by the government.[2] Upon start-up option exercise, a sunk cost I is paid. As a consequence, production starts and therefore an Earning Before Interest and Taxes (EBIT), denoted as Π, begins being earned. In line with Goldstein et al. (2001) and related literature, we let Π follow a Geometric Brownian Motion (GBM):

$$d\Pi = \mu \Pi dt + \sigma \Pi dz,$$

where $\Pi_0 > 0$ is its initial level, μ and σ are the drift and diffusion coefficients, respectively, and dz is the increment of a Wiener process.[3] Let $\tau \in (0,1)$ be the statutory tax rate and $\Omega \in [0,1)$ the subsidy ensured to start-up companies: an Ω equal to (greater than) 0 denotes a brown (green) company. This subsidy is modeled as a tax discount equal to a fraction of I. The value of the start-up option, as shown in Appendix A.1, is therefore:

$$O(\Pi, \overline{\Pi}) = \left(\frac{\Pi}{\overline{\Pi}}\right)^{\beta_1} \left[\frac{(1-\tau)\,\overline{\Pi}}{\delta} - (1-\Omega)\, I\right], \tag{1}$$

where $\beta_1 > 1$ and $\overline{\Pi}$ is the EBIT trigger point above which investment is profitable. Accordingly, the start-up problem is as follows:

$$\max_{\overline{\Pi}} O(\Pi; \overline{\Pi}),$$

whose solution is:

$$\overline{\Pi} = \frac{\beta_1}{\beta_1 - 1} \frac{\delta\,(1-\Omega)\, I}{1-\tau}.$$

that is the so-called investment trigger, i.e. the level of EBIT in corresponding to which the start-up option is exercised. It is worth noting that, by construction, $\overline{\Pi}$ is always higher for a brown firm than in the case of a green one. Moreover,

[2] See Comincioli et al. (2021) for further details about mature companies. These firms can however exercise other investment options, e.g., incremental investment or capacity choice (See Dixit & Pindyck (1994).

[3] According to Dixit & Pindyck (1994), we let the so-called dividend yield $\delta \equiv r - \mu$ be positive. According to Lucchetta et al. (2019), by replacing the actual growth rate of cash flows with a certainty-equivalent growth rate, we can evaluate any contingent claim on an asset (or EBIT). According to Shackleton & Sødal (2005), this condition is needed to allow the early exercise of a start-up option.

this gap is increasing with the amount of subsidy paid to green firms.[4]

Following the establishment of the new company, regardless of its environmental behavior, it begins generating and EBIT and, therefore, a tax revenue for the government, which is defined as:

$$R(\Pi, \overline{\Pi}) = \left(\frac{\Pi}{\overline{\overline{\Pi}}}\right)^{\beta_1} \left[\frac{\tau\overline{\Pi}}{\delta} - \Omega I\right].$$

3 A numerical analysis

3.1 Calibration

Table 1 collects the relevant parameter values used in this numerical exercise. As concerns EBIT's parameters, we use a null drift, i.e. $\mu = 0$ in line with Comincioli et al. (2021), allowing us to focus on the pure effect of volatility, of which we test four values $\sigma \in [0.1, 0.4]$. This choice is driven by the fact of both using $\sigma = 0.2$, which is the standard benchmark value in theoretical literature (Dixit & Pindyck 1994) as well as consistent with the empirical evidence (Jorion & Goetzmann 1999, Dimson et al. 2002), and accounting for the variability of volatility observed in recent years. We also set $r = 0.025$ and $r = 0.05$. The statutory tax rate is $\tau = 0.25$, in line with the average level used by developed countries. Investment cost is arbitrarily set as $I = 100$: we then test a subsidy percentage level equal to either 0% (brown firm) or 10% and 50% (green firm). As regards EBIT, its initial level Π_0 is calibrated using the Orbis dataset.[5] More specifically, we focus on active manufacturing companies belonging to the NACE class, letter C, from 10 to 33. Moreover, we restrict our sample to companies located in Europe *latu sensu*, namely listed in the EU as well as the United Kingdom and Turkey. Finally, to avoid the dramatic effects due to Covid-19 and Russia's invasion, we have chosen the average value of EBIT between 2011 and 2019. The criteria used to disentangle brown and green companies are described in Appendix A.2. Using these data, green and brown firms have an

[4]The investment trigger $\overline{\Pi}$ can be interpreted also in terms of expected investment timing $\mathbb{E}[T]$. The relation between these variables, according to Wong (2007), is:

$$\mathbb{E}[T] = \ln \frac{\overline{\Pi}}{\overline{\Pi}_0} \left(\mu - \frac{\sigma^2}{2}\right)^{-1}.$$

[5]Orbis is one of the most used data sources on private companies and provides information on close to 450 million entities worldwide. See: `https://www.bvdinfo.com/en-us/our-products/data/international/orbis` for further details.

Variable	Parameter	Value(s)
Growth rate	μ	0
Volatility	σ	0.10, 0.20, 0.30, 0.40
Interest rate	r	0.025, 0.05
Tax rate	τ	0.25
Investment	I	100
Subsidy	Ω	0, 0.10, 0.50
Initial EBIT	Π_0	6.56 (green), 8.08 (brown)

Table 1: Summary of variables used in the numerical simulations.

	Brown No Subsidy $\Omega = 0\%$			**Green Low Subsidy** $\Omega = 10\%$			**Green High Subsidy** $\Omega = 50\%$		
$r = 2.5\%$									
	$\overline{\Pi}$	$\mathbb{E}[T]$	R	$\overline{\Pi}$	$\mathbb{E}[T]$	R	$\overline{\Pi}$	$\mathbb{E}[T]$	R
$\sigma = 10\%$	5.19	0.00	178.30	4.67	0.00	94.61	2.60	0.00	-319.15
$\sigma = 20\%$	7.93	0.00	81.88	7.14	4.23	53.06	3.97	0.00	-24.62
$\sigma = 30\%$	11.72	8.26	69.70	10.55	10.55	49.17	5.86	0.00	10.06
$\sigma = 40\%$	16.67	9.05	67.42	15.00	10.34	49.79	8.33	2.99	24.72
$r = 5\%$									
	$\overline{\Pi}$	$\mathbb{E}[T]$	R	$\overline{\Pi}$	$\mathbb{E}[T]$	R	$\overline{\Pi}$	$\mathbb{E}[T]$	R
$\sigma = 10\%$	9.13	24.53	29.01	8.22	45.14	13.49	4.57	0.00	-103.77
$\sigma = 20\%$	12.42	21.50	24.55	11.18	26.66	14.52	6.21	0.00	-21.32
$\sigma = 30\%$	16.67	16.09	24.93	15.00	18.38	16.38	8.33	5.32	-5.59
$\sigma = 40\%$	21.98	12.51	26.13	19.78	13.80	18.23	10.99	6.45	2.36

Table 2: Results of numerical simulations with $\mu = 0\%$.

average EBIT equal to $\Pi_0 = 6.56$ and $\Pi_0 = 8.08$, respectively.

3.2 Simulation results

Table 2 collects the result of the numerical simulations based on the parameters detailed above. The value of investment trigger $\overline{\Pi}$, investment timing $\mathbb{E}[T]$ and tax revenue R are shown for a brown start-up ($\Omega = 0\%$) and for a green one, with a low and a high level of subsidy ($\Omega = 10\%$ and $\Omega = 50\%$, respectively). These results are shown for different levels of uncertainty σ and interest rate r.

Regarding investment trigger $\overline{\Pi}$, we observe that (by construction) it is always increasing in σ, regardless of the level of r and Ω. This reflects the higher (expected) EBIT needed to justify the risk associated to investment decision in a more uncertain environment. Regardless of this, a subsidy ($\Omega > 0$) facilitates investment decision of green start-ups, thereby lowering the level of Π required to the exercise of the start-up option, proportionally to the subsidy level. It is worth noting that, $\overline{\Pi}$ is always lower in the case of green firms than in the case of brown ones, despite the fact that the latter have a higher Π_0.

The presence of a subsidy has the effect of anticipating the investment timing $\mathbb{E}[T]$. This effect is less pronounced the lower the volatility parameter σ. In the case of low incentive ($\Omega = 10\%$) we observe that $\mathbb{E}[T]$ is inversely proportional to σ. This seemingly counterintuitive effect is due to the fact that a very high volatility might increase the probability of hitting the raising investment trigger (Sarkar 2000). In addition, it is worth noting that $\mathbb{E}[T] = 0$ means that the immediate investment is optimal.

The dynamics of investment decision are inevitably reflected in R which, as from (2), is the difference between what the government obtains through direct taxation and any amount paid as a subsidy, both conditional to the exercise of the start-up option. This happens as without investment decision, no EBIT is generated and therefore taxed. Hence no subsidy is paid to green firms. Comparing the results of green and brown start-ups highlights the trade-off for the policy maker. On the one hand, paying an incentive to finance the establishment of green companies expedites both the "natural" investment timing and the positive externalities (e.g., reduced emissions, lower resource requirements, etc.). On the other hand, this has a negative impact on the public budget. In this case, especially in the case of generous green incentives, the policy maker level must fund the measure from general taxation. As part of the political and economic effort to facilitate the green transition, this negative impact must therefore be taken into account. In particular, the cost to public finance can be considered as the minimum value that the externalities generated must have, from a cost-benefit analysis perspective, to justify the intervention.

These conclusions are valid for both interest rates shown in the Table 2 and they have also been shown to be robust to the other parameters of the model.[6]

4 Conclusions and policy implications

In this article, we study how the introduction of a targeted green investment subsidy can lead to a significant time gap in the decision-making process between undertaking green and brown investments. Our findings reveal that when green subsidies are present, firms tend to prioritize and anticipate green investments while postponing brown ones. This effect is particularly pronounced during

[6] The results of the robustness checks are available upon request.

periods of high volatility and when facing higher interest rates. Consequently, the trigger point at which such investments become profitable increases, but this impact is more pronounced for brown investments, which are ultimately delayed. This situation gives rise to a policy dilemma, as a successful transition towards NZE necessitates simultaneous investments in both brown and green sectors.

A noteworthy caveat is essential to consider: our analysis does not account for varying design times, which can significantly differ between different types of projects. For instance, infrastructure projects like pipelines often require long planning periods, while some green initiatives may have shorter lead times. Additionally, when governments announce new green policies, they should be mindful of potential adverse economic effects resulting from the drop in brown investments, leading to worsened labor market conditions among brown firms.

Furthermore, in periods of high volatility, the expected investment time rises. However, green projects are initiated earlier than brown ones under these circumstances. Once again, this presents policymakers with a dilemma, as achieving NZE demands concurrent investments in both green and brown sectors.

A Appendix

A.1 The calculation of equation (1)

Let us first expand the RHS of the value of the start-up option. Omitting the time variable we obtain:

$$O(\Pi;\overline{\Pi}) = (1-\tau)\Pi dt + (1-rdt)\left[O(\Pi) + dO\left(\Pi\right)\right] + o(dt), \qquad (2)$$

where $o(dt)$ is the summation of all terms that go to zero faster than dt. As shown in Dixit & Pindyck (1994) and Panteghini (2007), (2) has the following general closed-form solution:

$$O(\Pi;\overline{\Pi}) = \begin{cases} \frac{(1-\tau)\Pi}{r} + \sum_{j=1}^{2} A_j \Pi^{\beta_j} & \text{for} \quad \Pi < \overline{\Pi} \\ \frac{(1-\tau)\Pi}{r} & \text{for} \quad \Pi \geq \overline{\Pi} \end{cases} \qquad (3)$$

with $\beta_1 > 1$ and $\beta_2 < 0$ defined as:

$$\beta_{1,2} = \frac{1}{2} - \frac{\alpha}{\sigma^2} \pm \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}}.$$

Notice that $\Pi = 0$ is an absorbing barrier, and therefore, we must set $A_2 = 0$. Using the value matching condition, we obtain (1) for $\Pi < \overline{\Pi}$.

A.2 Selection of green and brown firms

The green-brown classification is based on the Environmental Pillar score from Thomson Reuters. The rating ranges between 0 and 100, where the latter indicates the maximum level of "greenness". This score accounts for three environmental dimensions: (i) resource use, (ii) emissions and (iii) innovation. For comparability across industries, the score is constructed using firm's industry average score as benchmark. For instance, a score of 80 indicates that the firm performs better than the 80% of firms within the same industry.[7]

To classify firms as green or brown we refer to Pastor et al. (2019). In particular we rewrite the environmental score as:

$$G_{i,t} = -(100 - EnvScore_{i,t}), \qquad (4)$$

[7] Additional details can be found on https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf

where the term $100 - EnvScore$ indicates how far is firm i at time t from a "perfect" score of 100. The environmental score used to classify the grenness of a firm is then:

$$g_{i,t} = G_{i,t} - \overline{G}_t \tag{5}$$

where $\overline{G}_t$ is the average (rescaled) environmental score at time t. In other words, we compute the score as deviations from sample mean in each year. Finally, firms are classified as green if their score $g_{i,t}$ is above the 70th percentile. Similarly, brown are those belonging to the 30th or below. The rest of the firms is not classified. Overall, out of 1388 firms, 428 are classified as green and 623 are brown.

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