A green investment integration in a growth model: An empirical investigation

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Abstract

The purpose of this paper was to investigate the relationship of investment and growth from an ecological perspective. To fulfill this purpose, at first, the framework of the Bhaduri-Marglin (1990) model was extended by accounting for the role of green capital, a factor which had not been included in the model so far. This was done in the following steps: At first, capital stock was decomposed to "green" and "brown" capital. By saying green capital we refer to the capital stock that is environmental sustainable, where brown capital refers to the conventional one. Afterwards, an environmental variable (x) that indicates green capital share and captures the environmental impacts was defined. Thus, the capacity utilization as also the capital productivity of the economy were determined as a function of green capital share. Green capital share (x) was also introduced in equation of investment indirectly through capacity utilization. All the original assumptions of Bhaduri-Marglin (1990) model did not change, but in our case we also assumed that investment also depends positively to the capacity utilization rate as a function of the share of green capital stock. According to the theoretical considerations this paper utilizes the extended Bhaduri-Marglin (1990) model and specific data from the European Union countries to examine the role of 'green' capital stock in investment and thereby economic growth. To achieve that investigation we focus on capital stock, capacity utilization rate and their interaction. Our study suggests that a rising 'green' capital stock is favorable in capital accumulation, investment and growth.

Introduction

The importance of environment in our lives is great, as the World Commission on Environment and Development (WCED) graphically describes in “Our Common Future” report (1987), “*The Earth is one but the world is not. We all depend on one biosphere for sustaining our lives*.” For decades states and their policy makers acted and decided caring only for their prosperity, survival and development and with no regard on the impacts of their actions on nature. As a result, nowadays, we have to face the environmental stress that humanity caused and continues to cause.

Thus the last years, environment has also a significant role in the development of mainstream and heterodox economic thought as a parameter of economic system. The Post-Keynesian economists despite decades of wide contribution to the heterodox school of thought in topics like macroeconomics, financialization, debt, public policies etc., their contribution on the interdisciplinary field of economics and environmental protection is limited. (Mearman, 2007)

Clive Spash and Anthony Ryan (2012), also, argue that post-Keynesian economists in their attempt to be consistent with the tradition of capital accumulation and full-employment have totally ignored environmental problems likewise resource and energy constrains. They also underline the fact that the heterodox macroeconomics of Post-Keynesian offer good opportunity for a more ecological approach in economics.

The basic Post-Keynesian features, as they are presented by the majority of the post-Keynesian literature[1], can also be used in an environmental post-Keynesian macroeconomic approach. Those characteristics are:

1. Historical time, stressing the asymmetric and deficient knowledge because of the unknown future
2. Uncertainty, referring to the unknown future
3. The crucial role of economic and political institutions in terms of income distribution and its role in human lives and economic process.
4. Effective demand

Those features allow a more realistic approach to the problem of environmental degradation and give us all the necessary instruments to deal with it from a perspective compatible with the laws of nature and away from the unrealistic framework of mainstream economics.

This paper investigates the relation between investment, growth and environment. We will keep all the post-Keynesian economic features and extend them

[1] (Davidson, 1981) (Kalecki, 1971) (Kalecki, 1954)

in an ecological perspective. To do so, we will extend the Bhaduri/Marglin (1990) model which is eminent among the post-Keynesian theory. The theoretical fundamentals for the model is the post-Keynesian literature[2] on growth and especially the Bhaduri/Marglin (1990) model as it is approached by Onaran and Stockhammer (2004) and Hein (2016).

Thus, for the basic model, we assume a closed economy without a government activity, which consists of two classes: the working class and the capitalist class. The two main components of the aggregate demand is private expenditure on consumption and on investment and consequently in order to achieve a demand expansion private consumption and private investment should be stimulated. (Keynes, 1936)

The working class offers its labor power to the capitalists and in exchange receives wages which are being funneled in goods' consumption – workers own no property income. So, we assume the familiar post-Keynesian hypothesis of no saving from wages. On the other side, capitalists own and exploit the means of production in order to receive profits. From the amount of profits they receive from production, they consume and they save. In our economy only the capitalists save, so we assume saving from profits to be positive and not zero. They also decide about the investment and they control capital stock. It must be stressed out that workers have greater marginal propensity to consume than capitalists, and that's why it was previously assumed that workers spent all their wages on consumption. (Hein, 2016) (Kalecki, 1971) (Kalecki, 1954) (Bhaduri & Marglin, 1990)

As it was described by Kalecki (1954) "*It is their* (capitalists') *investment and consumption decisions which determine profits, and not vice versa*" (Kalecki, 1954, p. 46) Thus, capitalist's desired accumulation depend on expected profitability because profits are the returns to investment but at the same time they are the primary source of finance for investment.[3] (Blecker, 1989) Therefore, it is clear that the source of a change in rate of profit may be crucial for the investment decisions. (Bhaduri & Marglin, 1990)

Thus, in our model economy, total output (Y) is produced by combining labor force and capital stock provided by capitalist. Rate of profit (r) is defined as flow of profits (Π) over nominal capital stock (K). We can decompose profit rate as we see in equation (1) with Y^p referring to the potential output given by the capital stock. (Hein, 2014)

[2] (Kalecki, 1971) (Kalecki, 1954) (Steindl, 1981)**Invalid source specified.Invalid source specified.** (Blecker, 1989)**Invalid source specified.** (Hein, 2016)

[3] The external sources of finance are not considered in this section of the analysis but it should be noted that the availability of internal finance flow is crucial for the acquisition of external finance. (Blecker, 1989)

$$r = \frac{\Pi}{K} = \frac{\Pi}{Y}\frac{Y}{Y^p}\frac{Y^p}{K} \qquad (1)$$

Equation (1) can be also written as follows:

$$r = h\,u\,k \qquad (2)$$

In equation (2) rate of profit (r) is decomposed: in the profit share (h) that relates the flow of profits (Π) with nominal capital stock (K), in the capacity utilization rate (u) that expresses the strength of effective demand in the economy and relates actual output (Y) with potential output (Y^p), and in capital productivity (k). Also, profit share (h) and capacity utilization (u) is between 0 and 1 ($0 < h < 1$ and $0 < u < 1$) (Hein, 2016) (Stockhammer & Onaran, 2004)

Theoretical conciderations

In the first attempted model extension of Bhaduri and Marglin (1990) model, we will bring into the center of the analysis the factor of the environment. To do so, we will focus on embedding the environmental dimension into the factor of capital stock of the economy. Capital stock is a major factor of production and refers to the total value of equipment, buildings, inventories and other real assets in the economy. Starting from the classical economists until now capital stock is in great concern. In Post-Keynesian literature capital stock is crucial element of the analysis because of its effect on profit share therefore on investment. Capital stock is treated by Post-Keynesian economists to be heterogeneous, in opposition to neoclassical economists who treat capital as homogeneous. (Mearman, 2009) (Felipe, 2002)

A green/brown capital model

In economics, capital is one of the key elements of the analysis irrespective of the economic school of thought. Many economists insisted on the importance of having a clear definition of capital.[4] The core of the concept of capital is that it is a stock capable of creating flows of goods and services, in most of the cases through transformation. (Ekins, et al., 2003) (Serafy, 1991) Capital is not referring to a specific kind of wealth, and it can be distinguished to 'capital stock' and 'capital flow'.

Classic economists[5] in their first attempt to capture the notion of capital identified three different types, land, labor and human-made capital. The neoclassical school of thought in the production function focus only on labor and human-made capital. (Ekins, et al., 2003) Through the years of economic research, the concept of capital has extended in many directions: financial capital, social/organizational capital, and human capital – the quality of labor. One of the most known classifications of capital is this of Ekins in 1992, the "four-capital model". According to this proposition, that

[4] (Krall & Gowdy, 2012) (Daly, 1977)
[5] (Smith, 1776) (Marshall, 1890)

was widely adopted, capital can be separated to manufactured capital, human capital, social capital and natural capital (Serageldin & Steer, 1994) or ecological capital (Ekins, et al., 2003). (Ekins, et al., 2003) (Serageldin & Steer, 1994) This classification was possible by broadening the notion of capital at it was firstly captured by Fisher. A broader notion of capital is "*a stock that yields a flow of valuable goods or services into the future*". (Constanza & Daly, 1992)

As economic theory evolved through the years, it respond to the continuously increasing awareness on environmental devastation by embodying in production functions natural resources inputs. Alfred Marshall, the father of neoclassical economics, was one of the first economists who captured the importance of land, as an element of nature, in the production process: "*All that lies below the surface has in it a large element of capital.*" (Marshall, 1890) (p. 432) (Serafy, 1991) Distinguishing natural from human-made capital managed to bring into the focus of the economic analysis its biophysical context. (Krall & Gowdy, 2012)

Through the years of academic research the main way used in order to establish a linkage among those environment and economic system, is by using and accounting for 'natural capital'. Nevertheless, the establishment and use of 'natural capital' was not accepted by ecological economists and environmentalists with no oppositions for many reasons. Firstly, the use of natural capital had reduced all the economic questions of environment and biophysical systems to just a matter of economic accounting. Through the economic accounting, natural capital is adjusted for depreciation like all kinds of capital, so the vision of human well-being, that should be the focus, is collapsing to the traditional income accounting. In this context, it is obvious that measurement problems of traditional capital apply also for natural capital. (Krall & Gowdy, 2012)Those shortcomings are due to the fact that on the one hand ecological economists tried to introduce natural capital as a biophysical limit but on the other hand they did not reformulate the concept of traditional capital. (Krall & Gowdy, 2012) (Daly, 1977)

In this context, it emerges the twofold character of the notion of capital stock. On the one hand we have the financial character and on the other hand we deal with the physical aspect of capital. (Krall & Gowdy, 2012) When we talk about capital stock the twofold character is more easy and clear to understand, for example everyone can recognize that capital in the form of wealth can be lost, while the physical capital, could stay intact. The undisputable example of this argument is the 2008 world crisis. But when we refer to natural capital the differentiation is not so easy to be recognized. Mainstream economics, as we already saw, use natural capital as an easy way to embed the environmental dimension into an economic model. Although, by accepting the duality of capital we recognize that the physical dimension is totally ignored and natural capital is a pecuniary fact with slight differences with man-made capital. Pecuniary facts refer to matters of property and ownership, rights of property, profit and rent, in general vested interest. Facts that are in total contradiction with the biophysical stability where natural capital should remain intact. (Krall & Gowdy, 2012) (Veblen, 1908)

Overall, it could be argued that ecological economists failed in their attempt to decrease the distance among economy and ecology as the majority limited their focus on the examination of 'natural capital'.

In this context we attempt to approach a different capital separation. The heterogeneity of capital stock allows us to assume that capital stock consists of green capital stock (K_g) and brown capital stock (K_b).

Thus, by saying green capital stock we refer to the capital stock that is environmental sustainable: investments in renewable energy and resource efficiency (manufacturing, waste, buildings, transport, and cities) and in natural capital (agriculture, fisheries, water resources, forests). (UNEP, 2011) Further, brown capital stock refers to the conventional investment where we deal with environmental impacts while green capital stock has no environmental impacts. To be more precise we will give an example. A renewable energy fixture for electricity or hot water inflow for a production line, is considered to be green capital stock, whereas a conventional combustion unit for the same purpose is brown capital stock.

The separation between what is considered to be "green" capital stock and "brown" capital stock could be really complex if it is not well defined. In this paper, green capital stock is considered to follow the features of strong sustainability. The defenders of "strong" sustainability set on priority the human well-being rather than the economic process. Also, the key idea behind strong sustainability is that: "*The substitutability of natural capital by other types of capital is severely limited*." So, according to this core idea, with the intention of being consistent with strong sustainability, we consider that capital in order to be green capital stock apart from no environmental impacts it should also be manufactured with no environmental impacts. Nevertheless, it must be pointed out that the argument in favor of "strong sustainability" does not state that all natural resources, and every ecosystem should stay untouchable. On the contrary it states that every human activity should be carefully planned so that future human life and present human well-being is not jeopardized. (Pelenc, et al., 2015)

So we assume that a transition to a more "green" economy, with less environmental impacts, requires the value of the green capital growing and suppressing the value of brown capital. Also, we capture this assumption by requiring that carbon emissions as we move to green capital stock to be lower than before in order to avoid the devastating effects of climate change.

In the context of transition of the economy we assume that one type of capital cannot be converted to another, in contrast with mainstream economic models which assume that capital can switch from one task to another. (Kemp-Benedict, 2014) (Lecocq & Shalizi, 2014) This assumption arises from the fact, that each type of capital stock (brown and green) has different environmental impacts. Although, at the same time those two types of capital can be added together – as in equation 3 – because they are made of the same "stuff". According to the previous example we understand that it is not feasible to convert a conventional energy unit to an environmental friendly one without investing in a new machinery.

$$K = K_b + K_g \qquad (3)$$

We also construct a variable x, as it is also proposed by Kemp-Benedict (2014) so that:

$$x = \frac{K_g}{K} = 1 - \frac{K_b}{K} \qquad (4)$$

The introduction of the share of green capital in the total economy, by constructing variable x, is the cornerstone of this model. As variable x rises from zero to 1, green capital is growing while brown capital diminishes. So, the closer variable x is to 1, the lesser environmental impacts we have. By less environmental impacts we mean less carbon emissions, less use of water resources, less waste and no biodiversity loss. Likewise, when variable x equals 1 we have the case where an economy operates only with green capital stock. The possibility of variable x to reach the value of 1 could be very idealistic for some audiences but the reality is that it is physically possible despite the fact that it could be absolutely challenging. (Pelenc, et al., 2015) (Costanza & Daly, 1992) (Kemp-Benedict, 2014)

According to equation (4) we can define average capital intensity in terms of x, as follows:

$$k(x) = (1 - x)k_b + xk_g \qquad (5)$$

We also define the average composition of the capacity utilization in terms of x, as follows.

$$u(x) = (1 - x)u_b + xu_g \qquad (6)$$

In the model presented in this paper, variable x plays a significant role as it changes across the transition to a green economy. As indicated in equations (5) and (6) we assume that green capital productivity/capacity utilization and brown capital productivity/capacity utilization are affected by the mix of green capital x but they can change in the long run through build up investments.

The decomposition of capital stock to brown and green allows us to deal with two different capacity utilization rates and two different capital productivity rates.[6] We use different capital productivity rates (k_b, k_g) and different capacity utilization rates (u_b, u_g) for each type of capital because of the earlier assumption that each type of capital has different environmental impacts. In both cases, we consider green capital stock to be more productive than brown capital stock, so for the same amount of capital, green capital productivity and green capacity utilization is greater. Nevertheless, in an economy that green capital stock is dominated by brown capital stock brown capital stock appears to be more productive. Accordingly, when green capital stock of an economy is greater than brown capital stock ($K_b < K_g$) we observe that capacity utilization rate of green capital is greater than capacity utilization of brown capital ($u_b < u_g$), while the same applies for capital productivity ($k_b < k_g$). We further assume that brown capital stock depreciates more rapidly, through early retirement, than green capital stock as it considered to be older and technologically obsolete.

We, also, adopt that profit share (h) remains unaffected as, in Kalecki's distribution theory, profit share is explained by relative economic powers of capital and labor affecting the mark-up pricing, or otherwise profit share is determined by the degree of monopoly. (Kalecki, 1954) (Hein, 2014) (Sawyer, 1985) So we can rewrite equation (2) as:

$$r = h\, u(x) k(x) \quad (7)$$

In the center of the analysis stands the relation of profit rate and capacity utilization with investment. What is new in the present framework of the model here, is that we deal with two different issues: the first is the total volume of the investment and the second is its allocation between green and brown capital.

According, to (Kalecki, 1954) and (Steindl, 1981) the elements of the profit share are included in the investment function. Also, Bhaduri and Marglin (1990) were the first who contradicted the Robinsonian (1962) proposition that investment simply depends on rate of profit and argued that it also depends on the rate of capacity utilization. (Araujo & Teixeira, 2012) (Stockhammer & Onaran, 2004) (Hein, 2016)

Therefore, we assume that investment depends positively on the rate of profit and the rate of capacity utilization. (Bhaduri & Marglin, 1990) Investment also depends positively to the share of green capital stock through equation (6). Hein (2016) argues that the effect of a rise in capital productivity or potential output – capital ratio on the investment are not clear as on the one hand an increase could lead to a lower profit share which should stifle investment, or on the other hand could lead to an increase

[6] In this case depreciation rate of both types of capital stock should be taken into account but in the present section we deliberately detach from all financial compilations because this is not our immediate purpose, for the time being.

in demand and an increase in profit share that should boost investment. In our case, at first, the effect of green capital share on investment is examined through equation (6) that captures its indirect effect on capacity utilization. Secondly, it is clear that a growing share of green capital stock in the economy means ex ante a boost for the investment, whether it means a transformation of the existing capital stock or an acquisition of new one. As it is stated before conventional capital or brown capital cannot be converted to green capital stock without new investment.

$$g = g(r) = g(h, u(x), k(x))$$

$$\frac{\partial g}{\partial h} > 0,\ \frac{\partial g}{\partial k} >< 0, \frac{\partial g}{\partial u(x)} > 0 \qquad (8)$$

So, investment decisions will positively depend on the profit share, the rate of capacity utilization and the utilization rate as a function of the share of green capital stock. Each of the above will increase the expected rate of profit, ceteris paribus. In what follows we will discard any direct effect of changes in the average capital productivity on investment, because there are not clear ex ante. (Hein, 2016) Therefore, we have included profit share and capacity utilization into the Bhaduri/Marglin (1990) accumulation function, as follows:

$$g = g(r) = g(h, u(x)) \qquad (9)$$

Based on that aspect of the accumulation function we will try to find evidence that support our main hypothesis that the economic transition to a more 'green' economy is favorable for investment. We will try to capture this effect through the term of capacity utilization and its components as their presented above.

Capacity utilization approach

Capacity utilization is an issue of great importance in economic theory because is a concept highly related to many economic factors such as labor, capital and technology. As we already saw, capacity utilization is used as a determinant of investment. (Hilton & Dolphin, 1970)

In our model approach, the measurement and definition of capacity utilization is really crucial as it is the 'instrument" through which we will try to identify the relation of 'green' capital stock and investment. Subsequently we will try to present the way we empirically approached capacity utilization for our model.

Hence, recalling equation (6), we deal with two different capacity utilization rates: the capacity utilization that refers to the productive capacity that is used by an economy and it has no environmental impacts (u_g) and the productive capacity that an economy uses that has environmental impacts (u_b). The essential idea to proceed is that "capacity" is the visible feature of output that alter with the capital stock over the long-run. (Shaikh & Moudud, 2004) Consequently, we could argue that "capacity" is also characterized from the environmental 'character' of the capital stock.

In order to approach a capacity utilization rate we need to define the actual output (Y) with potential output (Y^p), according to relationship (1). Potential output is defined in this paper as the capacity output that could be produced if all available inputs are fully utilized. In order to be consistent with the environmental assumptions of our model and in order to test our assumption of economic growth originating from a transition to a more environmental friendly economy, we turn to the data of the energy balances. (Eurostat, 2019) There is a direct connection between the fixed capital of the production sector and the available energy that serves all economic processes. The available energy of a country is characterized, nowadays, by the energy mix. Energy mix determines the processes through which any form of energy (electricity, heat) is being primary produced. Those processes could easily been separated into environmental friendly and non-friendly. Environmental friendly energy production is production through solar thermal plants and wind, wave, hydro installations, which have no environmental impacts while non-friendly energy production is the conventional combustion (fuels, oil, carbon) plants that have several environmental impacts, especially the large amount of carbon dioxide (CO_2) released to the air. (World Energy Council, 2016) So as the energy production is the cornerstone of any activity within an economy, we understand that the energy mix used is the most eminent feature for searching the relationship between investment and the capacity utilization rate as a combination of green and brown capacity utilization rate for a closed economy as a whole. Continuing actual output is defined in this paper as the capacity output that is produced given the utilization of available inputs. Once again we treat actual output as we did for potential output, we separate it to 'green' and 'brown' following the same path through energy data.

Capital utilization is different from capacity utilization. Capital utilization measures how much capital stock input is used compared to how much is available, while capacity utilization measures how much economic output is produced in an economy versus how much output could be produced. Capacity utilization ratio is a measure of the realized output relative to the potential output of an economy. In other words, we could say that the capacity utilization refers to the extent to which the productive capacity of an economy is being used. (Hilton & Dolphin, 1970) (Beaulieu & Mattey, 1995) However, we could also measure capacity utilization as the used capital stock (K_u) over the total capital stock (K_T), as it is shown in equation (10)

$$u = \frac{K_u}{K_T} \qquad (10)$$

(Tipper & Warmke, 2012) (Nelson, 1989) (Berndt & Morrison, 1981)

So in order to measure the potential output we need all that data of the installed energy plants, the environmental friendly and the non-friendly ones. The potential capacity and the actual capacity measurement was based on the interaction of engineering and economic considerations within an economy. (Anxo & Sterner, 1994)

Total capital stock (K_T) and used capital stock (K_u) were derived from the energy statistics of Eurostat and have been separated as we said before to 'green' and 'brown' depending on the source of energy production. So to estimate the total 'green' capital stock we used the installed available energy produced by renewables, and to estimate the total 'brown' capital stock we used the installed available energy produced by non-renewables. Respectively, to estimate the 'green' used capital stock we used the energy consumption produced by renewables sources, and to estimate the 'brown' used capital stock we used the energy consumption produced by non-renewables sources. To get the green capital share (x) we used the dataset of Eurostat on installed energy capacity.

To get the capacity utilization as a function of green capital share, we faced the problem that the data of installed energy capacity and the data of production and available for consumption energy were in different units. The data of installed energy capacity were in megawatt (Mw) while the data of available and consumed energy were in gigawatt-hours (Gwh). So we had to transform the Mw to Mwh to solve that problem. The transformation of Mw to Wwh is not a simple procedure as we have to deal with engineering facts like the capacity factor. The capacity factor of an energy plant is the maximum output that it could produce under specific conditions while the capacity factor embodies the relation between what an energy plant could produce and what it actually produces. So by taking the proposed capacity factors[7] for each type of energy plant and doing the math[8] we come up with the Gwh that are finally produced.

It must be stressed out that the way we are estimating green and brown capacity utilization and capacity utilization as a function of green capital share is just a way to approach better our theoretical framework in order to test it through econometric analysis and find some evidence on our assumption. An attempt of trying to reproduce exactly the theoretical considerations of our model, in other words trying to separate all the fixed capital that it is used in the economic process into environmental friendly and non-friendly given the datasets available it seems really hard for a macroeconomic analysis. For this reason we focused our attention on energy mix which is a determinative factor on characterizing the economic process whether 'green' or 'brown' and finding evidence on the transition from 'brown' to 'green'.

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[7] (Kwon, 2015)

[8] Mw * Capacity Factor * 365days * 24 hours = Mwh
& 1Mwh = 1000 Gwh

Empirical Data Analysis

Utilizing the above theoretical framework, we will try to find evidence on our main hypothesis though an econometric analysis for the 28 countries that participate in European Union for the period 1995-2017. The data are annual and all from the Eurostat and OECD.

For capital accumulation, as investment, we used the ratio of gross fixed capital formation of non-financial corporations over gross value added by non-financial corporations and we also tested using the growth rate of gross fixed capital formation by non-financial corporations. Profit-share is the profit share of non-financial corporations as it is given by Eurostat. For the calculation of capacity utilization we used data from the energy statistics of Eurostat, and we calculated the green capital share (x) and respectively the capacity utilization of 'green' capital and of 'brown' capital and finally the total capacity utilization of the economy as an average function of green capital share– as it is described above. Finally we constructed a dummy variable D2 in order to describe an economy as 'brown' capital dominated or 'green' capital dominated. (Stockhammer & Onaran, 2004) The variables used are presented in table 1, while their description in the appendix 1 and their covariance matrix in appendix 3.

Variable				**Source**
investment	capital accumulation	Gross Fixed Capital formation of non financial corporations/Gross value added by non financial corporation	log_accu2	EUROSTAT
	capital accumulation	growth rate of gross fixed capital formation of non financial corporations	gr_GCF2	EUROSTAT
profit-share	profit-share of non financial corporations	profit-share of non financial corporations	pr_sh	EUROSTAT
capacity utilisation		capacity utilization as a function of green capital share (x)	CU_x	estimated using EUROSTAT-Energy Statistics
		the weighted factor of 'green' capacity utilization	CUg_x	
		the weighted factor of 'brown' capacity utilization	CUb_x	
Dummy variable		green' or 'brown' capital dominated economy	D2	

Table 1. *Data Sources*

The model that has been selected as a first investigation for empirical evidence is presented in equation (11) and (12) and in equation (13) with a small interpretation of the investment variable.

$$\text{Investment} = \beta_1 + \beta_2\text{Profit Share} + \beta_3\text{Capacity Utilization} + \mu_i + t + \varepsilon_{it} \quad (11)$$

$$log\_accu2_{it} = \beta_1 + \beta_2 pr\_sh_{it} + \beta_3\ CU\_x_{it} + \mu_i + t + \varepsilon_{it} \quad (12)$$

$$gr\_GCF2_{it} = \beta_1 + \beta_2 pr\_sh_{it} + \beta_3\ CU\_x_{it} + \mu_i + t + \varepsilon_{it} \quad (13)$$

We used the fixed (fe) and random effects (re) method, as it is used in panel data accounting for heterogeneity issues. In addition, pooled ordinary least squares (pols) were used when it was appropriate. Trying to account for endogeneity issues and dynamic effects the generalized method of moments (gmm) was applied using the first differences of the variables, which are denoted with letter D on equation (14) & (15).

$$log\_accu2_{it} = \beta_1 + \beta_2 \, log\_accu2_{it-1} + \beta_3 \, Dpr\_sh_{it} + \beta_4 \, DCU\_x_{it} + u_{it} \quad (14)$$

$$gr\_GCF2_{it} = \beta_1 + \beta_2 \, gr\_GCF2_{it-1} + \beta_3 \, Dpr\_sh_{it} + \beta_4 \, DCU\_x_{it} + u_{it} \quad (15)$$

The results are corrected for heteroscedasticity and autocorrelation using a VCE model. There was no evidence of multicollinearity, as it is presented in Appendix 2.1. Also, in appendix 2.2 all the tests are presented.

Dependent Variable: Investment						
estimation method	fe		re		gmm	
	gr_GCF2	log_accu2	gr_GCF2	log_accu2	gr_GCF2	log_accu2
const	-27.12714** (10.61896)	2.011464*** (0 .071101)	-7.738335* . (4.002011)	2.038791*** (0.0654239)	-60.26871*** (8.400581)	0.7639618*** (0.0748302)
pr_sh	45.34484** (22.01909)	0.4315495** (0.1831088)	24.00466*** (8.408121)	0.4039626** (0.1673788)	118.8855*** (16.65892)	0.24087*** (0.0780441)
CU_x	16.66158*** (4.530608)	0.1797059*** (0.0477078)	1.493067 (1.975875)	0.156382*** (0 .0399044)	15.95085*** (4.854549)	0.0751368*** (0.0237248)
gr_gcf2 L1					0.2723971*** (0.0369911)	0.6032109*** (0 .0354022)
obs	589	592	589	592	539	942
Countries	28		28		28	
R^2	0.0477208	0.11600591				
R^2 adj	0.0444707	0.11300423				

Table 2. *Panel regressions results*

The results of our main estimation are presented in Table 1. Although our data may have endogeneity issues like the majority of economic data, we could argue that it is possible to draw some evidence. In this direction, in table 1, we decide to present all the estimates we get from all the different methods that were applied, but we have to notice that the fixed effects method came up as the most appropriate econometric method for those data. It seems that our main hypothesis is valid. The average capacity utilization as a function of green capital share appears to be significant (with $P<0,05$) and with a positive effect to our accumulation variable. In other words, there is strong evidence that capacity utilization in the presence of a growing green capital share appears to positively affect investment. The same results we get about profit share, which is also significant (with $P<0,05$) and appears to has a positive effect on investment.

Subsequently, by using the decomposition of equation (6) we tried to empirically find evidence on the effect of the two terms of capacity utilization, which define capacity utilization as a function of green capital share, on capital accumulation and investment. So this time, the model that has been selected to find those evidence is presented in equations (16) and (17) and in equation (18) with a small interpretation of the investment variable.

$$Investment= \beta_1 + \beta_2 Profit\ Share + \beta_3\ weighted\ capacity\ utilization\ of\ brown\ capital + \beta_4\ weighted\ capacity\ utilization\ of\ green\ capital + \mu_i + t + \varepsilon_{it} \quad (16)$$

$$log\_accu2_{it} = \beta_1 + \beta_2 pr\_sh_{it} + \beta_3\ CUb\_x_{it} + \beta_4\ CUg\_x_{it} + \mu_i + t + \varepsilon_{it} \quad (17)$$

$$gr\_GCF2_{it}= \beta_1 + \beta_2 pr\_sh_{it} + \beta_3\ CUb\_x_{it} + \beta_4\ CUg\_x_{it} + \mu_i + t + \varepsilon_{it} \quad (18)$$

The results of this secondary empirical investigation are presented in tables (2) and (3).

Dependent Variable: Investment							
estimation method	fe	re	gmm	fe	re	gmm	pols
	gr_GCF2	gr_GCF2	gr_GCF2	gr_GCF2	gr_GCF2	gr_GCF2	gr_GCF2
const	- 26.28211 (11.49722)	-6.468326 (4.421134)	-59.4867*** (8.518143)	-28.29986*** (11.67191)	-5.520763 (4.421676)	-62.9782 (9.662108)	-17.12788* (9.919408)
pr_sh	45.94219*** (22.17525)	23.20241*** (8.661134)	119.8053 (16.75443)	45.6839*** (22.08049)	24.50549*** (8.969582)	119.2633*** (16.76113)	43.05331*** (17.66651)
CUb_x	15.98327*** (5.756362)	0.958668 (2.015275)	15.42666*** (4.945071)	15.79348*** (5.730646)	2.40958 (1.588479)	15.1457*** (4.958852)	4.816245 (5.463559)
CUg_x	11.27348 (17.66337)	-3.082808 (4.977724)	9.524178 (12.87101)	12.57469 (17.89407)	-4.712892 (5.184086)	12.49596 (13.45478)	12.77716 (14.9157)
gr_GCF2 L1.			0.2697282 (0.0373398)			0.2687452*** (0.0373612)	
D2				2.446978* (1.403962)	-2.446764 (1.606715)	4.140159 (5.446553)	
obs	589	589	539	589			589
Countries	28			28			
R^2	0.04808851			0.04922937			0.3848
R^2 adj	0 .04320691			0.04271724			

Table 2. *Panel Regression Results*

Once again, we choose to present all the econometric results that came up by using all the different econometric methods. In this case fixed effects (fe) model it was prosed in the case of equation (18) and the pooled ordinary least squares (pols) method was the most appropriate in the case of equation (17). What is our main concern here is to find some evidence about the relation of investment and green capacity utilization. According to the proposed results (table 2), we see that when the growth rate of gross fixed capital formation is used, the term that describes green capacity utilization weighted by green capital share (x), (CUg_x), is positive but not significant. On the other hand (table 3), when the logarithm of gross fixed capital formation of non-financial corporations over gross fixed value added of non-financial corporations as investment indicator, this term appears to be positive again and this time appears to be significant (0,05<P<0,10). Those econometric results gives us some evidence to claim that a rising 'green' capacity utilization accompanied with a rising green capital share (x) is a positive driving force of investment. However, the fact that the econometric results of this approach does not stay the same among the different econometric methods that we have used gives us the feedback that our hypothesis must be checked again with more data from more years. Additionally, as the econometric analysis reveals we have strong evidence about the positive effect of profit share in investment in both cases. Finally, we also tried to investigate the possibility of whether the character of the economy as 'brown' or 'green' capital dominated by introducing the dummy variable D2 affects our model. As it appears in the results the introduction of the dummy variable does not affects our model and does not appear to have any significance.

Dependent Variable: Investment					
estimation method	fe	re	gmm	pols	pols
	log_accu2	log_accu2	log_accu2	log_accu2	log_accu2
const	2.045272*** (0.0835157)	2.066324*** (0.0785241)	0.8271968*** (0.0788054)	2.084945*** (0.0913552)	2.084077*** (0.0910088)
pr_sh	0.4542484*** (0.1865056)	0.4148191*** (0.1705184)	0.2687468*** (0.0782154)	0.4659976*** (0.1716508)	0.4644368*** (0.171133)
CUb_x	0.1528503*** (0.0453738)	0.1363503*** (0.0375611)	0.0641216*** (0.023963)	0.0676717 0.0431016	0.067999 (0.0432502)
CUg_x	-0.0332953 (0.1303491)	-0.0003738 (0.1139855)	-0.0620365 (0.0626784)	0.1657984* (0.0946918)	0.1686198** (0.0917628)
gr_GCF2 L1.			0.5814514*** (0.0362584)		
D2					0.0110197 (0.0581255)
obs	592	592	542	592	
Countries	28				
R^2				0.75	0.7589
R^2 adj					

Table 3. *Panel Regression Results*

Conclusion

In this paper we attempt to investigate the relation of investment and growth by using capacity utilization as a function of green capital share. The simple version of Bhaduri-Marglin model (1990) was used in order to test our hypothesis about the indirect positive effect of green capital on investment. Hence, investment, in terms of capital accumulation, is considered a function of profit share and capacity utilization. In order to approach our hypothesis we used a weighted function of capacity utilization by green capital share, taking into account the 'green' and 'brown' capacity utilization. The calculation of the capacity utilization proposed is a combination of economic concepts, as capacity utilization by definition is expressing the strength of effective demand in the economy, but also engineering data as the most obvious way of incorporating the separation of 'green' and 'brown' capital which is the cornerstone of this paper. We used data of the 28 countries that are members of the European Union. The first empirical results seem that are validating our hypothesis; the indirect effect of 'green' capital in favorable for investment. However, there is plenty of research that must be done in this direction. The incorporation of the market factor in the estimation of capacity utilization, and more specifically the energy market prices trend in consumption, and the market prices of the resources, will provide us better evidence about the relationship of 'green' capital with investment and growth.

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APPENDIX

1. Description of variables

Variable		Mean	Std. Dev.	Min	Max	Observations
log_accu2	overall	2.318485	0.113831	1.478783	2.686564	N = 644
	between		0.086577	2.168429	2.481009	n = 28
	within		0.07562	1.483869	2.580274	T = 23
gr_GCF2	overall	3.892914	11.32083	-75.9581	68.92799	N = 632
	between		2.477103	0.565445	9.457837	n = 28
	within		11.05504	-78.9219	65.96418	T-bar = 22.5714
pr_sh	overall	0.439787	0.078194	0.2234	0.7285	N = 616
	between		0.07067	0.319552	0.56223	n = 28
	within		0.038956	0.270069	0.606056	T-bar = 22
CU_x	overall	0.659572	0.259492	0.0932	1.368565	N = 603
	between		0.240619	0.120939	1.177633	n = 28
	within		0.103612	0.038481	1.203085	T-bar = 21.5357
CUb_x	overall	0.529742	0.318791	0	1.280663	N = 616
	between		0.300562	0.002349	1.129305	n = 28
	within		0.128114	-0.24563	1.224083	T = 22
CUg_x	overall	0.148558	0.11646	0.000224	0.578704	N = 620
	between		0.105188	0.013799	0.384216	n = 28
	within		0.054887	-0.00378	0.634179	T = 22.1429
D2	overall	0.791667	0.406419	0	1	N=672
	between		0.341716	0	1	n=28
	within		0.228931	-0.16667	1.75	T=24

2. tests

2.1

multicollinearity test		
Variable	VIF	1/VIF
CU_x	1	0.999231
pr_sh	1	0.999231
Mean VIF	1	

multicollinearity test		
Variable	VIF	1/VIF
Ug_x	1.63	0.61453
Ub_x	1.6	0.625656
pr_sh	1.02	0.976146
Mean VIF	1.42	

2.2

	log_accu2	gr_gcf2
Breusch and Pagan Lagrangian multiplier test for random effects	log_accu2[id,t] = Xb + u[id] + e[id,t]	gr_GCF2[id,t] = Xb + u[id] + e[id,t]
	Test: Var(u) = 0	Test: Var(u) = 0
	chibar2(01) = 1958.87	chibar2(01) = 0.00
	Prob > chibar2 = 0.0000	Prob > chibar2 = 1.0000
	We should not use pooled method	We should use pooled method
Wooldridge test for autocorrelation in panel data	H0: no first-order autocorrelation	H0: no first-order autocorrelation
	F(1, 27) = 155.614	F(1, 27) = 34.128
	Prob > F =0.0000	Prob > F = 0.0000
	There is no autocorrelation	There is no autocorrelation
Modified Wald test for groupwise heteroskedasticity in fixed effect regression model	H0: sigma(i)^2 = sigma^2 for all i	H0: sigma(i)^2 = sigma^2 for all i
	Chi2 (28) = 4202.86	Chi2 (28) = 2921.18
	Prob>chi2 = 0.0000	Prob>chi2 = 0.0000
	There is no heteroskedasticity	There is no heteroskedasticity
Hausman test	Ho: difference in coefficients not systematic	Ho: difference in coefficients not systematic
	chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 8.13	chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)=18.85
	Prob>chi2 = 0.0172	Prob>chi2 = 0.0001
	Fixed effects model should be preferred	Fixed effects model should be preferred

3. Table of covariance

obs=600	log_accu2	gr_GCF2	CU_x	CUb_x	CUg_x	D2
log_accu2	1					
gr_GCF2	0.4102	1				
CU_x	0.0514	0.0324	1			
CUb_x	0.0274	0.0525	0.9442	1		
CUg_x	0.0442	-0.0736	-0.3216	-0.6155	1	
D2	-0.1121	0.0123	0.5326	0.6277	-0.5302	1