ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

SCHOOL OF ECONOMIC SCIENCES

DEPARTMENT OF ECONOMICS

ENVIRONMENTAL RESOURCES AND ECONOMIC GROWTH

KOKKINIS D. IOANNIS

Dissertation submitted
in partial fulfilment of the necessary prerequisites
for the acquisition of the MSc Degree

Athens
January, 2018

Signatures

Supervisor: ECONOMIDES GEORGE, AUEB GREECE
Examiner 1: PHILIPPOPOULOS APOSTOLIS, AUEB GREECE
Examiner 1: VASSILATOS VAGGELIS, AUEB GREECE

Abstract

This dissertation has to do with a research in one of the most important aspects not only in economics, but in our whole life, the environmental care and more specific, environmental resources and pollution. This topic of interest is widely discussed through the years of economic science, and although in models we seem to have found solutions to the problems that pollutionary actions cause, in real life is difficult to form them. The study consists mainly endogenous macroeconomic models which mainly cope with pollution. Most of the models we use have the economic theory which lies behind, the intuition and finally the results. This study tries to see what problems arise when growth is affected endogenously and what relationship do those problems have with pollution and resources. Also, we try to find what the relationship between environmental regulation and economic growth is and how sustainable is the economic growth with different levels of pollution. These different levels are decisions of the policy makers. We also include a very interesting and intuitive case study of one of the most industrial country of the world. Finally, we try to have some results and some implications for policy makers in the end of each topic so that this research may help not only from theoretical prospect but also in real life.

I would like to thank Professor Economides George for his cooperation. Without his helpful advice, this thesis would have been much more difficult. I would also like to thank my friends, especially Panos, Nikos, George and Myrto who made the master's year easier for me through their true friendship. Finally I would like to thank my family for the support they give me all these years. Without them, nothing would be feasible.

Table of contents

1. Introduction

How environmental policy affects economic growth is a controversial issue. Industrialists typically argue that environmental policy hurts growth by raising production costs. Environmentalists, in contrast, maintain that environmental policy is needed in order to ensure that growth is sustainable. Environmental quality acts both as a public consumption good and a public capital good. In particular, as a consumption good, the environment yields environmental amenities. As a capital good, it enhances the productivity of man-made inputs into production. We can see that there is a tradeoff between long-run growth and short-run growth. In what follows there is a historical analysis about how differed through the ages the meaning of "economic growth".

Since classical economists, understanding the differences between countries has been a central issue. As Robert Lucas said (1988), "Once one starts to think about economic growth, it is hard to think about something else". However, although too much attention has been given to such things, not much has been given to the relationship between environment and economic growth. Researches have shown that it is necessary for economists to take into account the environmental pollution when they cope with economic growth.

Growth theory has passed through many stages. At first, Rampesy (1928) wrote about the maximization of the utility function of the household. Then, Solow and Swan (1956) imposed a simple model with steady saving rates, in which they assumed that technical changes where exogenously set. The model imposes that the technological growth is set by the researcher and it is based on econometric analysis. This model shows that without technological growth, there cannot be economic growth. A year after that, an econometric research showed that the growth of productivity has to do with the growth of technology, known as "Solow's residual". Then, Cass (1956) and Coopman (1956) used Rampey's analysis by setting again the saving rates endogenously but the technological growth was exogenous. What follows differs from the above, in the matter that growth rates can now be affected by policies. This is because in the 1980's, technological changes where endogenized. At 1990, L.E. Jones and Manuelli reconsidered the true meaning of the human capital and the natural capital. The accumulation of natural capital follows the same rules as the human capital and in that way economic growth is applicable without the technology being set exogenously.

In this framework, the environmental pollution is being introduced as a joint product and as a source of disutility in the optimal growth paths of endogenous models. Most of the economies face problems such as land degradation, water scarcity and pollution, air pollution, inadequate urban environmental infrastructure, contamination of the rural environment, increasing frequency and intensity of environmental accidents, loss of biodiversity and global climate change. In the following sections there are being given answers to questions such as:

1) Is the environmental protection compatible with economic growth?
2) Is it possible to sustain growth in the long run without accumulation of pollution?
3) How are the levels, the paths or the growth rates of the variables as capital, income, consumption or environmental pollution affected if we take into account the environment?
4) What are the deviations between market outcomes and social optimum?

Overall, the volume is an attempt to examine the role of environmental regulation as a means for solving existing problems and creating better futures not only rapidly developing economies but in the whole world.

In models where the technical change is exogenous, introducing environmental concerns into the social planner's utility function would not change the steady-state rate of variables like income, consumption, capital because the rate is determined exogenously. In these models, producers cannot take into account the negative externality of pollution. The main result is that as long the economy grows, the pollution will accumulate in the environment. This leads the productivity of physical capital to go to zero in the long-run.

In our study, we will deal with endogenous growth models. In these models, capital can be not only physical capital but also human capital. Technological progress here is not exogenous, but part of Research and Development (R&D). Under the concept of endogenous growth, growth rates are affected by government and they can remain greater than zero if productivity of capital does not reach to zero in the long run or production of knowledge is characterized by increasing returns.

The main concern here is how environment affects growth in such models. So one may ask: is economic growth compatible with environmental protection? What is the impact of environmental policy on growth rates? In what follows, we will try to answer to these questions. We will start with AK models with increasing returns, then we will continue with two sector model and with model with product variety. We will proceed with the methodology followed in the paper of Anastasios Xepapadeas "Economic Growth and the Environment". After that, we will analyse some empirical results and much attention will be given to a very interesting case study under the framework of Porter Hypothesis. In what follows, we will see a Growth Accounting and Environment model. Finally, we analyze a model with given environmental policy.

2. <u>Endogenous technological growth and climate change</u>

Embodying technological changes in studies about climate change is one of the key factors in order to analyze such policies. However, the evaluation of exogenously set technological changes is widely prevalent method. The endogenously set assumption can lead to wrong results for policies that face the climate change. There are new models about the policy of the climate change and natural resources which use the aggregate production function or costs of the aggregate economy with inputs of capital and labor. These theories are based on endogenous growth theories and in particular in the papers of (Romer 1990), (Kiley 1999), (Aghion and Howitt 1997) και (Acemoglu 1998, 2002).

The hydrocarbons like petrol, natural gas and carbon are probably the most used natural resources in order for mankind to produce energy. These resources tend to lessen and because of that, their price goes up. This results in this: the prices of any activity having to do with these resources i.e. agriculture, transportations, will go up. This leads us to the need to model the exhaustible energy resources.

2.1 AK models and models with increasing return.

The aggregate production function is y=Ak, where k denotes the broad sense to include human capital and A>0 is the level of technology.
We can assume pollution to follow the following formula: $P'=\varphi k-mP$, where P denotes the pollution levels and P' is the derivative with respect to time. $\varphi>0$ is the emission coefficient and m is the exponential pollution decay.

The social planner's problem is $\max\int_{-0}^{\infty} e^{-pt}\ \ U(c,P)dt$ subject to $k'=Ak-c-\delta k$ and $P'=\varphi k-mP$.
If we take the first order conditions with respect to c(t), we end up with the Euler equation:
$c'/c=1/\eta[A+A\lambda\varphi/U_c-\rho-\delta+P'U_cP/U_c]$.
The result we end up from this equation is that if $\lambda=0$ and $U_cP=0$, that is if pollution is not taken into account, then we end up to the classical result in AK models: consumption, capital and output have the same growth rates $\gamma=1/\eta(A-\rho-\delta)$ in the long-run.

As Michel and Rotillon in 1995 showed, if we mind for pollution, sustained long-run growth is not optimal. However, we can achieve positive long-run growth if we introduce abatement. If we manage to allocate the capital in two types, the constraints of the social planner's problem are
$k'=Aky-c-\delta k$
$P'=\varphi ky-\psi k\alpha-mP$
$k=ky+ka$

If $\psi/\varphi>(\rho+\delta)/(A-\delta-\rho)$ then unlimited growth without pollution accumulation is possible no matter what the utility function is.
In 1997, Xepapadeas introduced a model with two types of capital: one for output production named productive capital and one for pollution abatement named abatement capital. In that way, the new constraints of the social welfare maximization are:
$k'_j=k_j\kappa_j(I_j/k_j)$, j=a,y
$P'=\varphi(k_a,K_a,K_y)f(k_y,K_y)-mP$
$f(k_y,K_y)=c-I_y-I_a$

We assume that the numbers of firms is normalized to one. K_y denotes the aggregate capital and K_a denotes the pollution abatement. I_y and I_a denote the investment on each sector respectively. φ is the unit emission coefficient. Xepapadeas showed that when φ is fixed, permanent growth is not optimal. Permanent growth without pollution accumulation can be achieved if increasing returns to pollution abatement reduce the unit emission coefficient towards zero. The way the model is proposed allows us to talk about environmental traps, i.e. countries with low aggregate capital which have environmental concerns can be trapped in low growth region.

Mohtadi (1996) proposed that improvements in environmental quality increase productivity of aggregate production function when these improvements are done through reducing pollution. He introduces a new social planner's problem:
$\max\int_{0}^{\infty} e^{-\rho t}U(c,E)dt$,subject to $k'=A(E)k-c$, where UE>0 ,Ek(k)<0 with respect to c(t).
A(E) is the effects of environmental quality on productivity. It is shown that a socially-optimal balanced path exists with consumption and capital growing at the same rate.

2.1.1 Result

Studying these models, we can identify three externalities: knowledge spillovers in production, pollution abatement and environmental pollution. The above can be corrected by using subsidies for investment in production and abatement to correct underinvestment of competitive markets in two sectors. Also, emission taxes could be used to correct the environmental pollution.

2.2 Two Sector Models

In these models a process of development of technical knowledge is considered. This developments makes the production less pollutionary and in addition to that, it uses renewable resources more efficiently. In these models, the one sector produces the final good. The other sector introduces the pollution reduction knowledge which is a public good. Output is produced through the following production function: $y=f(E,k_y,Z_y)$. E denotes the environmental capital. k_y denotes the man-made capital used in production. Z_y is the effective input of the harvested environmental capital interpreted as pollution.

The knowledge, h, follows the following equation: $h'=H=H(k_h,Z_h)$. kh is the man-made capital. Z_h is the pollution input in the technology. The total effective level of pollution is $Z=Z_y+Z_h$. The pollution of the economy, P, is Z=hP, so $Z_y=\alpha hP$ and $Z_h=(1-\alpha)hP$.

Man-made capital follows: k'=y-c, where k=ky+kh. Environmental stoch has a renewable resource characteristic and follows: E'=R(E,P).

We can get the social optimum by maximizing:

$\max\int_0^\infty e^{-\rho t}U(c,E)dt$, subject to the constraint defined above, with respect to the following variables: $k_y(t)$, $k_h(t)$,$Z_y(t)$,$Z_h(t)$.

Solving the problem we can derive sustainable optimal balanced growth. At this point, consumption knowledge and man-made capital grow at a positive rate, whereas flow of pollution and stock of environmental capital remain constant. We need tax on pollution so sustain the social optimum. Knowledge is a public good, so government should invest on it.

We end up that optimal size of government's budget tends to increase with environmental concerns.

2.3 Models with Product Variety

As Aghion and Howitt (1998) introduced, the environmental concerns are introduced in the growth models in which profit maximizing firms innovate by introducing new varieties of goods. Following their model, aggregate production function can be written as $y=k^\alpha(BL)^{1-\alpha}z$, where $0<\alpha<1$ and z is between the closed interval [0,1]. B denotes the stock of intellectual capital and z is pollution intensity. Intellectual capital follows the formula: $B'=\sigma Bl$. Here, σ is a positive parameter related

to the innovation process. l denotes the labor used in the research. L+l=1 holds. Output is produced according to the following formula: $y=k^{a}[B(1-l)]^{1-\alpha}z$. Manufactured capital accumulates according to k'=y-c.
Environmental quality follows: E'=-P-mE, where E(t) is between the closed interval $[E^{min},0]$.
The flow of pollution is defined as $P=yz^{\zeta}$, ζ>0. m here is the environmental regeneration rate. The social planner's problem is to maximize $\int_0^{\infty} e^{-\rho t}U(c,E)dt$ subject to B'=σBl, k'=y-c, and
E'=-P-mE, with respect to c, z, l.

When the elasticity of marginal utility of consumption exceeds the unity and σ>ρ then unlimited growth is possible along the optimal path, as proven in the paper. Intuitively, the result we end up is that output, consumption and knowledge grow without bound while pollution decreases and environmental quality improves.

2.3.1 Result

Grimmand in 1999 determined some policy instrument that could implement the above socially-optimal path. As before, we can identify three kind of distortions, so we need 3 instruments to fix them. The first distortion is the spillovers from knowledge. In order to correct it, we can introduce subsidies. The second distortion is the monopoly in intermediate goods. Again, the instrument we can introduce here is the subsidies. The last distortion is the spillovers from pollution. We can correct it by introducing permits for environmental pollution. As we move in the optimal path, number of permits decrease. Growth is affected by environmental policy. This is happens because by decreasing the number of permits, the value of patents is reduced, so the marginal cost of Research and Development is reduced.

Elbasha and Roe (1996) introduced imperfect competition in growth model with international trade considerations. The economy has to goods that can be traded, Y and Q.
Each good has its own production function given by :
$Y=A_y(K_y)^{\wedge}\alpha_1(L_y)^{\wedge}\alpha_2(D_y)^{\wedge}\alpha_3$, $Q=A_q(K_q)^{\wedge}\beta_1(L_q)^{\wedge}\beta_2(D_q)^{\wedge}\beta_3$ $\sum_{i=1}^{3} ai = \sum_{i=1}^{3} \beta i = 1$,
where K_i denotes capital inputs and and L_i denotes labor inputs. i stands for y,z.

D_i is an index of differentiated inputs defined as $D_i=(\int_0^{M(t)} Xi(j)^{\delta} dj)^{1/\delta}$, i=y,z, δ>0.
M(t) is the number of differentiated inputs available at time t. X(t)is the amount of differentiated input j.
The production function $X(j)=A_x[K_x(j)]^{\eta}[L_x(j)]^{1-\eta}$, 0<η<1, j belonging in the closed interval [0,M], is the production function which shows that each type of input j can be produced once a license is obtained from Research and development sector of the economy. K_x is the labor input in the production of differentiated goods. L_x is the labor input in the production of differentiated products. The research and development sector, in order to increase the number of brands, produces new blueprints. This is done by using capital, labor and knowledge capital. We remind here that knowledge capital is a public good and its formula is: $M'=A_m(K_m)\theta(L_m)^{1-\theta}$ where 0<θ<1. M here is assumed to be the number of brands proportional to the knowledge capital. In this model, all markets are assumed to be competitive, with the exception of the differentiated input market. In this market, producers sell their product in an

imperfectly competitive market.

In what we have described so far, we can see that environmental quality can be either a flow variable related to the production of the two consumption goods or it can be seen as a stock variable related to the ise of the differentiated intermediate inputs. In the first case, environmental quality is defined as $P=(\int_0^{M(t)} Xi(j)^{\varepsilon} dj)^{1/\varepsilon}$ where ε is greater than zero. We will not deal with the mathematical solution in this part of this research, but the model can be solved for the market equilibrium and the social optimum. After solving it, we can compare the two solutions we get. The results show that if the elasticity of the intertemporal substitution of consumption is less than one, then environmental concerns increase growth. But happens if the elasticity is greater than one? We see that what happens is exactly the opposite, i.e. environmental concerns decrease growth. However, the effects of trade on the environment and welfare depend mainly on price elasticities, the terms of trade effects on growth and pollution intensities. Numerical simulations show that trade improves welfare but might worsen environmental quality.

3. <u>Empirical evidence</u>

As we saw above, there can exist different relationships between growth and environment. It is possible that pollution will grow as income grows if the negative externality of pollution is not taken into account. On the other side of the coin, environmental concerns might decelerate growth if productivity of capital in production and pollution abatement declines towards zero, as capital accumulates. However, it is possible for an economy to succeed in sustaining both economic growth and stable levels pf pollution. This can happen if there exist non-diminishing returns in output production or abatement processes. So we see again that environmental policy affects not only economic growth but also the pollution levels.

Under this framework, it would be interesting if we could analyze some empirical evidence show to see what is the “real” relationship between economic growth and pollution. There are going to be three different approaches between this relationship.

3.1 <u>The environmental Kuznets Curve (EKC)</u>

The relationship between growth and environment is an often-studied topic across many countries experiencing the consequences of rapid economic growth. The reason is that it is a common occurrence for economic growth to be initially associated with resource and environmental degradation, resulting in a need for increased environmental management. This need for management is prompted by an increased emphasis on environmental regulation, which in turn is stimulated by income growth. Looking across developed countries, it is straightforward to observe that this induced manner of environmental regulation has occurred in many places previously. The charting of this relationship between growth and environmental management is often referred to as the “Environmental Kuznets Curve” (EKC), where the basic variables of economic income are associated with environmental quality. In many already-developed countries and for several types of environmental emissions, it can be seen that the EKC takes the form of an inverted-U, demonstrating that increased growth induces environmental degradation in the initial phase and then environmental regulation subsequently. The results show that there exists an inverted-U shape relationship as hypothesized by the EKC model between per capita income and per capita emissions (or discharges) in the cases of waste gas from fuel burning and wastewater. It is important to emphasize at distinguishing waste gas due to production from waste gas due to fuel burning, as the per capita emission of the former is showing no signs of letting up. Identifying the stricter air pollution policy on emissions from fuel burning than from production as one of the possible causes of this trend. In general, it is to be anticipated that economic growth will result in increased environmental degradation, at least initially. The crucial need is to have a well -focused governmental response to increased degradation in the form of targeted environmental regulation that reduces the growth-generated problems. Governments need to respond to these problems in a systematic manner, and further efforts at regulation, technological change and institutional reform will continue to bring about significant changes to the environmental impacts of development.

The main idea behind the EKC is that there exists an inverted U relationship between ambient levels of pollution and GDP per capita. In 1990 it was introduced that there exists a break between growth and pollution. This break was told to be associated more with local pollutants than with global pollutants for countries that belonged in Organization for Economic Co-operation and Development (OECD). This link however was not to be broken for countries with lower income. In 1992 it was found that emissions where growing faster in low income countries that in higher income countries and thus there was an upward trend in industrial emissions relative to both GDP and manufacturing output. This research had the following result: dirty industries should move to low-income countries. Arrow (1995) pointed out that the process of economic development from agrarian economies to polluting, industrialized economies and then to cleaner service economies suggests output growth-pollution growth decoupling.

After some estimations of empirical relationships between environmental variables and development variables, there has been found that a de-linking exists between the researched. In general, economic growth may not cause harm to the environment. Studies have shown that there exists an inverted U relationship between ambient environmental quality and emissions and per capita GDP for certain types of pollutants. There is a turning point, where emissions decline despite economic growth may not cause harm to the environment. Grossman and Krueger (1995) by performing econometric operations showed that the turning point we mentioned above is GDP per capita $8000. Their analysis however did not end there: They ended up that for countries with income above $10,000 , the hypothesis that further economic growth will be associated with environmental degradation can be rejected at 5% significance level. These results started a new research which had two parts: The first is a theoretical foundation in which models take place. The second is a more theoretical explanation of the Environmental Kunznets Curve, having to do with verification of the results, probable improvements or extensions.

3.2 Theoretical foundation

At this point, mathematical models will be skipped and we will move straight to the results of the model. After a technology parameterization applied to the model, we end up that the inverted U shaped pollution relationship is consistent in two ways: First, in case many agents exists in the market and secondly in the social planner's problem. Using an optimal growth model with flow pollution and abatement expenditure, Selden and Song (1995) showed that there can exists EKC.
There exists a different approach, in which there are derived V-shaped curves. In these models, we assume that pollution and income increase up to a certain point. After this point is passed, pollution is reduced. In 1994, John and Pecchenino suggested an overlapping generation model. That model included both low income and high environmental quality economies. These economies is assumed not to have pollution abatement. The result they ended up is that when environmental quality deteriorates with growth, the economy moves to positive abatement. This leads to an improvement in the environment in the growth as environment improves. We end up having an inverted V-shaped relationship. In 2001 Jones and Manuelli proposed a model different from the others which has to do with environmental policy. Environmental policy is decided by majority voting and can take two different forms: The first is emission taxes and the second is "minimum standards" in technology. The model works like this: We assume that in low income countries, per capita emission taxes are zero. The above leads to the result that when income increases, taxes are positive and there exists an inverted V-shaped curve. When minimum standards are chosen, the pollution-income relationship is monotonic and converges to a limiting pollution level.

3.3 Empirical results

Economists and mainly econometricians have tried over the years to find more ideas about the inverted U-shaped EKC and expand their ideas. To do so, they use models like Ordinary least Squares (OLS), panel data, Tobit models and so on. The variables they use, aside from GDP per capita, are mainly lagged values, microeconomic or macroeconomic policy variable, trade variables etc. The result they ended up is that the relationship we are studying (pollution-income) is less affected than previously thought in changes in data. This happens because of the lag-structure of the GDP per capita and inclusion of additional country specific covariates.

4. The relationship between economic growth and environmental regulation

Economic growth is often seen to create environmental degradation initially, and the response then is to undertake environmental management as a "clean-up" activity. In these early phases of development, the main role of environmental regulation is reactive: it deals with the problems of environmental quality after they have been generated by economic growth. This might be termed the phase of reactive environmental regulation.

The second phase of the growth and regulation relationship is less reactive but still not forward-looking. This phase focuses on the role of regulation in resource allocation. All economic growth must be spent on different forms of productive and consumptive activities. When there is no regulation in place, it is possible for some forms of activities (i.e. some types of private production activities) to appropriate all of society's resources which necessarily results in misallocation of resources, and which in turn tends to generate a demand for the creation of mechanisms that will enable the reallocation of resources toward other activities. For example, the appropriation of a river's water (quantity or quality) by some private industry might be sufficient to deny a wide range of other private and public uses (e.g. drinking, fishing, cleaning, swimming and recreation). There is little chance that the routing of resources simply toward those able to appropriate them first (and foremost) is going to put in place the socially correct balance of usage. The role of regulation, in this instance, is to ensure that there is some mechanism available for balancing the allocation of resources among the various uses. Therefore, the second phase of economic growth and environmental regulation emphasizes resource allocation and the role of regulation to create the essential mechanisms for achieving a balanced allocation of resources across all of their potential uses in society. Finally, the most interesting phase of the relationship between economic growth and environmental regulation is the final phase, when governments begin to respond proactively to both processes.

In the proactive phase, the government views economic growth and environmental regulation as a paired process and involving the management of the path of technological change so that both growth and environment are optimized. In this phase, the government comes to recognize that technological change can contribute to both the process of economic growth and the avoidance of environmental degradation, and so policymaking becomes focused on creating incentives for guiding specific forms of technological change. For example, many developed countries have adopted policies that provide incentives for the creation of energy-saving technologies by means of labeling, which reduces the amount of information required to ascertain the aggregate benefits of a given technology, thus rendering investments in energy-saving technologies more easily rewarded. Even more proactive is Denmark's investments in wind turbine technologies, based on the fundamental belief that long-run energy prices would reward such investments. In these cases, environmental regulation functions as a form of industrial policy leader and allows the regulator to place the state's industries at the forefront of change. This has been done most explicitly in Japan when it attempted to acquire patent-based advantages and privileges with respect to environmental frontier technologies such that patents acquired by it on specific environmental technologies (e.g. advances in automotive emissions and energy-saving technologies) have enabled it to acquire a share of the societal benefits or be a beneficiary whenever any other country adopts the environmental policies necessitating those technologies, as in those in automotive production. The relationship between economic growth and environmental regulation has an interesting series of phases through the process of development. Initially, economic growth is often antithetical to environmental quality, and the role of regulation is reactive ("clean-up"). Later, the role of regulation becomes more contemporary, when the mechanisms to balance the allocation of resources are established. Finally, the role of regulation becomes proactive when the regulator itself becomes the guiding force of the economy toward the direction of combined economic and environment growth and development. A long-term review of economic growth and environmental quality needs to see the movement of regulation through these phases of management, from reactive to proactive. The pathway toward a brighter future requires that the PRC's environmental regulation becomes increasingly effective, and even active, over the coming decades.

4.1 Growth, competitiveness and Environmental Regulation.

After what we have discussed, it is easy to say that if one wants better quality in the environment, all they have to do is to transfer production from dirtier activities to cleaner activities. I addition, there is something else that can make the environmental quality better and this is environmental regulations. In what follows, we will discuss how environmental regulations can affect environmental quality.
Econometricians in 1990 used an intertemporal general equilibrium model and performed stimulations with and without environmental regulation. What they ended up is that regulations associated with investment in pollution control equipment, motor vehicle emissions and operating costs in pollution abatements resulted in a 19.1% drop in growth of GDP for the period 1973-1985.

Next we will discuss the relationship between environmental regulation and competitiveness. It is shown that the cost of environmental regulation slows productivity growth and impedes competitiveness in the international markets. However, Porter suggested that firms under strict environmental regulation are successful. The main idea as we have already mentioned is that environmental regulation provides firms with an incentive to innovate. This can lead to an increase in a firm's productivity and in the long-run, it may outweigh the short term costs of regulation. Porter not only suggested this hypothesis, but also supported it through a series of case studies. He reached to the conclusion that firm's competitiveness can increase and this increase can overcome the short-run costs of the regulation itself. This idea however cannot be supported without a set of assumptions regarding X-efficiency or strategic trade models.

4.2 Porter hypothesis

Many economists believe that environmental regulations increase production costs and as a result, these regulations reduce the productivity and the competitiveness of the firms. As Palmer mentions (1995), there is a trade-off between productivity and environmental protection. The Porter Hypothesis (PH) has met with great success in political debate, especially in the United States, because it contradicts the idea that environmental protection is always detrimental to economic growth. PH challenges a long-held paradigm in economics that presumes that, as profit-maximizing entities, firms are already using their resources in the most efficient way to achieve maximum profits, and that regulations merely restrict firms' options, inevitably leading to suboptimum profits. Porter and van der Linde went on to dismiss the traditional paradigm, contending that its founding premise – that all companies are making the best choices and operating at maximum efficiency – is unrealistically optimistic. This is especially true of environmental issues, they argued, since many companies are relatively inexperienced in dealing with novel environmental problems. Rather, productivity is constantly in flux, and firms are continually innovating to survive, using incomplete and asymmetric information to select the best technological opportunities to pursue among a continually shifting array of options. This is further complicated by the fact that the incentives of individual decision makers, corporate departments, and the corporation itself are difficult to align, and organizational inertia and control issues often prevent firms from pursuing the optimal path. They noticed that more stringent and flexible environmental policies are beneficial to the economy because they stimulate innovation that results in improvements in productivity. Porter said that firms may try to follow environmental regulations by reducing emissions, however the environmental regulations increase the cost. This leads firms to invest in innovation to find more efficient ways of responding to environmental regulations. An increase or decrease in productivity depends on whether the benefits from innovation are greater or less that the cost of compliance.

The PH has been invoked to persuade the business community to accept environmental regulations, as it may benefit from them in addition to other stakeholders. In a nutshell, well-designed environmental regulations might lead to a Pareto improvement or "win– win" situation in some cases, by not only protecting the environment, but also enhancing profits and competitiveness through the improvement of the products or their production process or through enhancement of product quality. Indeed, the hypothesis rests on the idea that firms often ignore profitable opportunities. Porter gave answer to a crucial question: Why is the impact of environmental regulation on productivity ambiguous? Well, if regulation is not stringent enough to trigger the innovation process, firms may end up pursuing end-of-pipe measures that might ultimately decrease their productivity. Assume that tighter environmental regulation triggers the innovation process and provides firms with benefits greater that the cost of compliance. This, in overall, improves the productivity. In cases where firms must take all or part of the responsibility for related environmental damage, environmental productivity is the appropriate measure. In other words, why would regulation actually be needed for firms to adopt profit-increasing innovations? In fact, Porter directly questions the view that firms are profit-maximizing entities: "The possibility that regulation might act as a spur to innovation arises because the world does not fit the Panglossian belief that firms always make optimal choices." As discussed below, firms might not appear to be making optimal choices for many reasons, such as imperfect information or organizational or market failures. Moreover, even if systematically profitable business opportunities are missed ("lowhanging fruits"), the next question is, how could environmental regulations change that reality? Are regulators in a better position than managers to find these profitable business opportunities? Porter argues that environmental regulation may help firms identify inefficient uses of costly resources. They may also produce and disseminate new information (e.g., best-practice technologies) and help overcome organizational inertia. There is much confusion in the literature about what the Porter Hypothesis actually says. As we note above, it does not say that all regulation leads to innovation—only that well-designed regulations do. This is consistent with the growing trend toward performance-based and/or market-based environmental regulations. Second, it does not state that this innovation necessarily offsets the cost of regulation—that is, it does not claim that regulation is always a free lunch. Instead, it does make the claim that in many instances, these innovations will more than offset the cost of regulation—in other words, there may be a free lunch in many cases.

Previous authors have disaggregated the PH into its component parts in order to test the theory and evidence. First, properly designed environmental regulation may spur innovation. This has often been called the “weak” version of the PH, because it does not tell us whether that innovation is good or bad for firms. Of course, the notion that regulation might spur technological innovation is not a new idea in economics and would not itself have brought about such controversy. The second part is the “strong” version of PH. Under the strong PH, the shock of new (well designed) environmental regulation induces firms to come up with new ways to comply with the regulation, encouraging innovation that increases business performance and competitiveness so much that it fully or more than fully offsets the costs of complying with the regulations. Jaffe and Palmer suggest that the strong PH implies that environmental regulation is a free lunch, in that regulation induces innovation whose benefits (to the firm) exceed its costs. Note, however, that the PH never goes so far as to suggest that environmental regulation will always lead to either innovation or increased competitiveness, but the authors say that it is probable. Note here that “weak” PH, unlike the strong PH, it is not specified whether the innovation is socially beneficial or not, only that innovation occurs. Finally, in what has been called the “narrow” version of the PH, it is noted that flexible regulatory policies give firms greater incentives to innovate and thus are better than prescriptive forms of regulation. Indeed, Porter challenges regulators to examine the likely impacts of their actions and choose regulatory mechanisms that will foster innovation and competitiveness, particularly economic instruments. Regulations that are flexible, stringent, and with minimal uncertainty about their application spur firms to innovate more than those that lack these attributes. For instance, regulations that apply to a performance standard and are always enforced the same way are much more effective at stimulating innovation than regulations that prescribe specific technologies or processes and are likely to become obsolete and replaced by new regulations in the future. Thus, the PH is as much a normative prescription for regulatory policy as it is a positive assessment of current policy.

The PH has been criticized for being incompatible with the assumption of profit maximizing firms. Porter and van der Linde do not specify all the characteristics that would be expected of “properly crafted environmental regulation” but note that stringency and flexibility are both key elements of such policies. For this reason, some authors have noted that the PH assumes policies that are performance-based, market-based and more similar to modern policies like cap and trade regimes or pollution pricing than to command-and-control regulations Porter Hypothesis does not indicate that environmental regulation will benefit all regulated firms. In fact, it is expected that the poorest performers in a regulated industry would eventually exit. Firms that fail to overcome organizational problems to innovate and comply with regulations should be penalized, and should not continue to operate if their efficiency and environmental performance falls significantly below industry standards. This will in turn free-up capital and human resources that can be put to more productive use by a competitor or new entrant to the industry. A regular rate of firm entry and exit is important to maintaining innovation in industries. It has also been criticized about distracting attention from the cost-benefit analysis of environmental policy.

4.3 Case study

Porter dealt with the Japanese industries. In 1950-1960, Japan had a high growth. However, due to many reasons, they lacked of environmental quality and had severe environmental problems. The problem was that big that in 1967, Japan's law system made a new law called "pollution diet". This law was actually a set of 14 different environmental regulations under which they tried to fight pollution. Environmental performance was good from 2000-2008. Studies have shown that CO_2 has tended to fluctuate with gross domestic product, whereas sulfur oxides have followed a downward trend, in spite of economic growth. Nitrogen oxides and waste have also shown a decoupling trend since the early 2000s. Japan is quite active in meeting environmental regulation standards, which accounted the 14% of certifications under ISO 14001. ISO 14001 is a family of standards related to environmental management that exists to help organizations minimize how their operations negatively affect environment (i.e., cause adverse changes to air, water, or land), comply with applicable laws, regulations, and other environmentally oriented requirements and also continually improve in the above. These facts have led to the consensus that Japanese firms are successful in decoupling environmental degradation and economic growth. Porter tested the productivity of various industries over the same period and took some various contexts into account when he made the comparisons. He studied firms like auto-mobile, food and electronics industries, as these are the most pollution-intensive industries.

4.3.1 Methodology and data

In this stage we will use the model described by Adisak Charmthanakom and Kazuhiro Ueta.
This study uses a two stage methodology. First, we calculate efficiency by using the data envelopment analysis (DEA) method and then we calculate productivity growth. DEA model is a nonparametric approach to estimating the efficiency score of a firm and uses linear programming (LP) methods to construct a piecewise frontier over the sample decision-making units. Efficiency score is calculated as a function of distance from the constructed frontier. In the second stage we conduct a regression model for productivity growth by environmental regulation stringency and other firm specific variables.

4.3.2 Productivity Growth Without Undesirable Output

The output oriented DEA model is: $Max_{\alpha,\lambda}$ α subject to $X\lambda <= \chi_i$ and $Y\lambda >= ay_i$ and $\lambda >= 0$.
X ις α K x N input matrix, Y is an M x N output matrix, α is a scalar, and λ is an N x 1 vector of constants. X_i and y_i are the input and output of firm i respectively. When we use linear programming to solve the DEA model, α is the efficiency score of firm i. Additionally, this DEA model can be defined as the following output in distance function: D0(x,y)=min{δ: (y/δ)ϵP(x)} where P(x) is the output set. The M index is employed to calculate productivity growth, using the following equation : $M_t^{t+1}=[D_0^t(x^{t+1,}y^{t+1})]^2 / [D_0^t(x^{t,}y^t)] \times D_0^{t+1}(x^{t,}y^t)]$. Here, t=1, T is the time period. The first term on the right-hand side is the output distance function when P(x) is the output set

in period t, and the second term is the output distance function when P(x) is the output set in period t+1.

4.3.3 Productivity growth with undesirable output

We cannot disregard the fact that in the real world, economic activity has an effect on the environment. To generate more accurate information on production emits pollution, environmental performance productivity is a more appropriate measure of productivity than traditional productivity. This is more common in cases where firms can bear some or most of the costs of the environmental damage. Firms that are able to expand output and reduce pollution simultaneously should be credited for both when calculating productivity. This study considers environmental performance, such as CO_2 emissions and biochemical oxygen demand, in productivity calculations. Pollution is referred to as an undesirable output. Our model assumes undesirable output, denoted my b, which is weakly disposable, such that:

if $(y,b)\ \epsilon P(x)$ and $\theta \epsilon [0,1]$ then $(\theta y,\theta b) \epsilon P(x)$.

This shows us that in order to get the good output, you have to get the undesirable output. We can also reduce undesirable output in tandem with an accompanying decrease in good output, while good output and input are maintained according to the strongly disposable DEA model.

4.3.4 Testing the impact of environmental regulation on productivity.

To test the impact of environmental regulation on productivity we apply an econometric model. Assume we used regression analysis. By using a productivity index calculated by DEA as a dependent variable, it is possible to end up with autocorrelation problems. Econometricians in 2007 tried to solve this problem by proposing a double-bootstrap method. Finally one year later Nakano and Managi applied the generalized method of moments (GMM). The estimated equation is:

$Growth_{it}=c+\alpha_1 Growth_{it-1}+\beta_1 ER_{it}+\beta_2 ER_{it-1}+\beta_3 K_{it}+\beta_4 inputprice_{it}+\varepsilon_{it}\ ,\ \varepsilon_{it}=\eta_i + v_{it}$

ε_{it} denotes the error term with consists of individual effect η_i and the disturbance term v_{it}. Productivity growth is denoted by $Growth_{it}$. As we see from the estimated equation, a firm's previous year performance may affect current-year performance. Intuitively, assume a firm had high growth rate last year. Probably, it is difficult to maintain that same high growth in the following year. $Growth_{it-1}$ is the lagged productivity growth. We see that the lagged dependent variable correlates with the error term. To solve this problem, we use the first-difference model to remove individual effect η_i and the dependent variable before t-2 is used as an instrumental variable in system GMM. In the same manner, productivity growth might affect capital K_{it}. We end up having endogeneity problems. We can solve this problem by using all lagged values of K_{it} as instrumental variables. The GMM model will give us consistency but may not give us unbiasedness. To estimate system GMM this study uses Dynamic Panel Data (DPD).

Productivity growth is regressed on one-year-lagged productivity growth $Growth_{it-1}$, environmental regulation stringency (ER_t) and its lagged value (ER_{t-1}), size of plant and input price. It is obvious that environmental regulation stringency is an important variable in order to determine the relationship between productivity growth and environmental regulation. We can also use variables like number of firm inspections. Wen environmental regulation is more stringer, we can expect that firms will address regulations by increasing their environmental preservation cost per production cost. This study uses environmental preservation cost per production cost as a proxy for environmental regulation stringency.

The lagged value of environmental regulation is an important dependent variable in the model. More stringent environmental policies will necessarily lead to innovation that ultimately reduces inefficiencies. This eventualy will reduce the cost. One year lagged value of environmental regulation (ER_{t-1}) is included in the econometric model. This is so, in order to determine the relationship between productivity growth and environmental regulation. ER_t and ER_{t-1} can either be positive or negative. This depends on the productivity growth. What matters here is that the effect of ER_{t-1} should be greater than the effect of ER_t. For that reason, the coefficient of ER_{t-1} must be positive if the innovation process takes time. On the other hand, the coefficient of ER_t may be negative if the account of compliance costs incurred in the current period and therefore there is no time for firms to adapt to the regulation. Correlation between size of plant and productivity growth must be a positive number. This is because it is easy to understand that larger plants should be more productive than smaller plants. In the same manner, input price should relate positively to productivity growth. Again, from our theory, when input price increases, firms tend to use less input to produce the same amount of output.

4.3.5. Environmental regulation in Japan

Environmental regulation in Japan emphasizes performance standards and negotiated agreements. The firsts are highly used in any discussion of environmental issue. Most important of these discussions are issues which deal with air pollution, solid waste, water pollution and climate change. Another characteristic is the negotiated or voluntary agreements. Municipalities and facilities argue and negotiate about newly established facilities. An important factor is that many municipalities have the ability to set more stringent standards that their national-level counterparts do.

OECD in 2010 showed that performance standards and negotiated agreements can lure businesses which want to invest in “green” technology. However, do these approaches provide sufficient incentive to improve environmental performance? And if this holds, do they encourage new technologies in the favored direction? From 1967 till 2007Japan has passed over 14 environmental regulations which helped to answer the above questions to the positive direction.

Studying a single industry will surely give us crucial results, but these result may be biased. In order to get better results, this study turn its interest in three different industries which own three different technologies. The industries selected to participate in this study are industries of automobile, food and electronics. These industries are among the most pollutant in Japan and also have environmental regulations.

In order to calculate the productivity growth, the study uses the following variables: output, input and undesirable output. Output is the deflated output. Input is the labor and the plant capital. Undesirable output is the CO_2, waste water discharge, toxic chemicals and solid waste. For all the above, there has been computed the mean and the standard deviation.

4.3.6 Results

1) Estimates of productivity growth

When undesirable output is included in the ML calculation, the relation is:
ML=f(Growth$_{it-1}$,ER$_t$,ER$_{t-1}$,plant size, input price index).
When we exclude the undesirable output in the M calculation, the relation is:
M=f(Growth$_{it-1}$,ER$_t$,ER$_{t-1}$,plant size, input price index).
Autocorrelation problems are dealt by using GMM system as recommended by Nakano and Managi in 2008.

2) Automobile industry

The models use as dependent variables the ML growth (%) and the M growth (%). The independent variables are the environmental preservation cost per production cost (%), plant capital and input price index. For all variables there has been computed the mean and the standard deviation.
When we regress the M mode, current period environmental regulation stringency has a significant and negative effect on productivity. However, in the ML model, the coefficient of ER$_{t-1}$ turns out to be significantly greater than that of ER$_t$, and the overall impact of environmental regulation is positive. Environmental regulation in the same time period has a negative effect on productivity growth because there has not been sufficient time for firms to adapt to the regulation. Nevertheless, after some time has passed, firms can adapt to the earlier environmental regulation and increase their environmental productivity growth.

3) Food industry

After running regressions, no conclusion can be drawn regarding the relationship between productivity growth and environmental regulation. This is because neither the coefficient for ER$_t$ nor that for ER$_{t-1}$ is significant. In the M and ML models, the sings of ER$_t$ and ER$_{t-1}$ are as expected but again they are not significant.

4) Electronics industry

As in the food industry, after running regressions, no results could be dragged out regarding the relationship between productivity growth and environmental regulation because the sings of ER$_t$ and ER$_{t-1}$ are not significant.

4.3.7. Conclusion of case study

This study explores the relationship between productivity growth and environmental regulation. Although there is a cost that firms must bear, we see that when environmental regulation is more stringent, environmental performance increases. As we said, there is a cost that firms must bear. But in the long term, this cost can be reduced and as a result, product value will increase. This has to do with the fact that when environmental regulation is more stringent, firms have an incentive to improve their production and products to meet environmental requirements.
We also saw that environmental productivity regulations differs between different industries. There is a trade-off between environment and economic performance in the case of automobile industry. When we added the one year lagged variable of environmental regulation, we saw there is a positive relationship between

environmental regulation stringency and environmental productivity. Firms can offset the compliance costs of regulation with benefits stemming from innovation, and by decreasing emission in subsequent years. So Porter hypothesis is correct for the automobile industry. In the case of food industry, we did not find positive results between productivity growth and environmental regulation. At the same time, we did not find any negative relationship between the compliance costs and the benefits of innovation. Therefore we concluded that in food industry, environmental regulation does nto stimulate productivity growth but it also does not impede economic performance. The same holds for electronics industry.

Overall, this study tries to make us understand the environmental regulation and the productivity growth. These two parameters where visible to three different industries. Models where created which have both current-period environmental regulation stringency and one-year lagged environmental regulation stringency. In the study there is also being tested the Porter hypothesis using environmental productivity. This enabled us to support with stronger results the hypothesis than in the traditional model. Policymakers should take into account environmental productivity in their decision-making processes. Finally, it would be interesting if we could also test by using not only one year lagged variables, but more periods ago. Also it would be interesting to see what happens in other fields of industry, not only the three we tested.

4.3.8 Implications for policy makers

• While there remains debate regarding how much innovation is induced by environmental regulations, and whether firms are net beneficiaries of this innovation, there is evidence that environmental regulations generally do induce innovation in the regulated firms and industries. It is important to identify and attempt to measure this induced innovation in order to gain a complete picture of the overall private costs and benefits of environmental regulation.

• There is early evidence that the more flexible market tools – when sufficiently stringent – are more likely to induce a greater level of innovation. As there are still many jurisdictions without a price on emissions, and even more which do not put a price on other forms of environmental externalities, policy-makers would be wise to consider flexible, stringent policies and regulations where appropriate.

• Further assessments of the private sector benefits of regulation would be useful in order to better understand the conditions under which firms benefit from environmental regulation and the firm-level qualities that determine which firms will benefit. While firm-level analysis can be difficult to undertake, given proprietary and confidential data, it could be a particularly insightful type of analysis – particularly if done ex-ante, with good pre-policy baseline data available. In addition, as newer policies incorporating market-based instruments are adopted, there is opportunity to expand the knowledge-base for the Narrow Porter Hypothesis.

5. Growth Accounting and the Environment

As Solow proposed in his growth model, growth is a result of manufactured capital K, labor L and technology A. By growth accounting we can split growth into two components: The first is associated with growth of observed factor inputs. The second one is a residual which reflects technological progress.

The production function is Y=F(K,AL) where AL is the effective labor.
The rate of technological progress is $g=F_L LA'/YA=Y'/Y - F_K KK'/YK - F_L LL'/YL$. A' denotes the derivative of technology with respect to time. Respectively, K' denotes the derivative of capital with respect to time and L' denotes the derivative of labor with respect to time.
In a competitive economy, factors are paid their marginal products, i.e. $F_K=w$ and $F_L=r$. Thus, the total factor of productivity is defined as: $\hat{g}=Y'/Y - s_K K'/K - s_L L'/L$.
Here, s_K and s_L are the respective factor shares.
Assume now that the aggregate production function without pollution augmenting technical change is Y=F(K,AL,Z). If we differentiate, we get that:
$g_Z=F_L LA'/YA=Y'/Y-s_K K'/K - sLL'/L - s_Z Z'/Z$

Assume in the model that there is a social optimum which is obtained by an optimal tax. This tax is time dependent and is defined as $T(t)=-\varphi\lambda(t)/U_C(c,P)$. All variables are evaluated at the optimal path. $\varphi\lambda(t)$ is the social damage from increasing output by one unit. $U_C(c,P)$ is the additional utility of the extra consumption which is realized by the output increase.
Under the emission tax, a firm solves the following maximization problem:
$\max\pi=f(k)-(r+\delta)k-\tau[\varphi(k)]$ with respect to k. The first order conditions show that: $f'(k)[1-\varphi\lambda(t)/U_C(c,P)]=r+\delta$, where f'(k) is the derivative of the production function with respect to k.

We borrow from the Rampsey-Cass-Koopmans model with environmental pollution the Euler condition $c'/c=1/\eta[r-\rho+U_{cP}P'/U_c]$ or $\eta=-U_{cc}c/U_c$. If we plug first order condition in the Euler equation we get the formula with which we defined the optimal emission tax. The social planner therefore can attain social optimum levels of pollution and output. As we expect, the equilibrium levels of output pollution and stock of capital will be lower than those if we had unregulated competitive economy.
Before going back in the Solow's model, we have to jump into a model with non-linear pollution accumulation with optimal emission choice. In this model, after defining the social planner's problem and the constraints of the problem, we end up to a current value Hamiltonian function. By maximizing this Hamiltonian, we get that when the value of marginal product of emissions equals the shadow cost of the pollutant, emissions are chosen optimally in the short. This can be written in the formula, which we get if we proceed to the mathematical solution of the model, $qf_Z=-\lambda$.
So now we can return to the Solow's analysis. After the results we got from the above, we can now write that $\hat{g}_Z=(Y'/Y)-s_K(K'/K)-s_L(L'/L)-s_Z(Z'/Z)$, where s_T is the share of optimal environmental taxes in total output.

The way we $\hat{g}$ is represented shows two things. The first is that the two conventional factors are paid by their marginal products. The second one is that environment is being damaged by using one more unit of emissions to produce output. This extra damage is equal to $-\lambda/q$, where λ denotes the shadow value of one more unit of pollutant accumulation. q denotes the marginal utility we get from the production causing the pollutant accumulation.
Now, suppose that environmental policy is not optimal, i.e. $0<\check{T}<T$, then the total

factor of productivity is measured by: $\breve{g}_Z = Y'/Y - \check{s}_K(K'/K) - \check{s}_L(L'/L) - \check{s}_Z(Z'/Z)$. Here, $\breve{g}_Z$ is the share of environmental taxes actually paid in total output.
If I subtract $\hat{g}_Z$ from $\breve{g}_Z$ we get that: $\hat{g}_Z - \breve{g}_Z = -(s_K - \check{s}_K)(K'/K) - (s_L - \check{s}_L)(L'/L) - (s_Z - \check{s}_Z)(Z'/Z)$, where $0 <= \check{s}_Z < s_Z$. Recall the assumption we made: environmental policy is not optimal. This last equation shows that when environmental policy is suboptimal, the estimated total factor of productivity deviates from the true total factor of productivity. Xepapadeas notices that if we regress the estimated residual $\breve{g}_Z$ on the growth rates of capital, labor and emissions, the true residual $\hat{g}_Z$ would be the intercept of this regression and the coefficients of the input growth rates would indicate the deviations of the optimal shares form the actual share.

5.1 Results

The last section of our discussion depicts some empirical evidence that have to do with growth and environment, but also tries to find a relationship between crucial matters and to answer to questions like: how feasible is the sustained growth in terms of environmental concern? What is the impact of environmental protection with respect to crucial economic variables?

To answer to the questions above, we took advantage of the models of modern growth theory that allowed us to proceed to these answers. The main messages we can derive are the following:

1). As we saw, sustained growth is not optimal when emissions per unit of output and resources devoted to the pollution are constant. When the number of emissions is constant, then sustained growth will increase the accumulation. In addition to that, incremental damages from the environmental pollution will be higher that the benefits from the growth. So we see again that economic growth is not compatible with environmental pollution under this framework. In the models we analyzed we saw this clearly. Environmental concerns affect the levels of certain key variables, but not their growth rate. Their growth rate is exogenously set. We end up that optimal levels of steady state are reduced, but steady state and pollution grow exogenously. If we fix the number of emissions, pollution follows the same exogenous rate which is not optimal. Pollution accumulation stops if economy stops growing.

2). It is possible to have constant pollution while at the same time economy grows. For some specification of technology and preferences, economy can grow at an exogenous rate. This can happen in Rampsey models. In these models, emission is taken into account as an input in the production function. This optimal choice of emissions could be regarded in this context as reflecting optimal pollution abatement.

3).The process of growth-environment depends basically on the productivity of abatement in the environmental sector. This can happen if the economy devotes resources to pollution abatement and development of clean technologies with reduced unit emission coefficient.

4).Non-pollutionary growth can be obtained in the Solow model. In order to get it, we need the marginal productivity of capital to be bounded an the unit emission coefficient to tend to zero as capital keeps accumulating.

6. Model with given environmental policy

The model assumes a representative household, a representative firm and the government. Households buy goods, work and they save capital. Their utility is raised through private consumption and through the natural resources reserves. The firms produce the goods using AK type linear technology. During the production levels, firms pollute the environment. Households and firms think that environment as public good. This economic policy taxes the pollution. This part studies the competitive equilibrium with given the environmental policy, for any environmental policy which is consistent with the structure of the economy. We assume infinite time horizon, continuous time and perfect foresight.
In order to proceed to our results, we will use the model that is being described in the paper of Miaouli-Philippopoulos-Economides.

6.1 Defining the problem

Households

The representative household maximizes its intertemporal utility function (1). c denotes the private consumption, N is the natural resources reserve and ρ>0 is the discount rate. This utility function is increasing and concave and it satisfies the Inada conditions. We also assume that $\int_{-0}^{\infty} u(c,N)e^{-pt} \quad U(c,P)dt$ is a logarithmic function, so u(c, N)= logc + vlogN (2), where v>0 denotes the quality of the environment compared to the private consumption.
Household, as we said, save capital. Firms borrow capital k from households and they get the return rate r. They also offer inelasticaly one unit of labor and as a result, they get wage denoted by w. They also have profits denoted by Π, Π>=0. Thus their budget constraint is
ḱ+c=rk+w+Π (3), where ḱ denotes the determinant of k with respect to time. We take initial capital k(o) as given.
The household acts competitively, taking prices and the quality of environment, N, as given. The choice variables are c and k. If we take the first order conditions, we end up with the following results: ḱ+c=rk+w+Π (3) and ć=(r-ρ)c (4). (4) is the known Euler condition.

Firms

Output and capital are linearly depended an AK type model, so the production function is y=Ak (5), where A is a positive parameter. This is an endogenous growth model. We assume that there exists θ which is the tax rate, 0<θ<1. The profits of the representative firm are Π=(1-θ)y-rk-w (6). The firm acts competitively and takes prices and tax policy as given. The choice variable here is capital. If we differentiate with respect to capital, the first order condition we get is r= (1-θ)A. If we see carefully

(5), (6) and (7), we end up that $\Pi=0$, $w=y-rk=0$, something that we expected since we are in AK type model.

6.2 Competitive equilibrium with given tax pollution

In this stage we introduce the pollution to the model, p. p is assumed to be a sub-product of the final output y. We assume that $y=p$. From (5) we get that $p=y=Ak$ (8). Also using that $w=\Pi=0$, (7), (4) and (3), we get that $\dot{c}=[A(1-\theta)-\rho]c$ (9a) and $\dot{k}=A(1-\theta)k-c$ (9b) which are the steady states of consumption and savings in the competitive equilibrium.
We define natural resources, N, to be expressed by the following equation $\dot{N}=\delta N-p+\theta y$ (10a), where δ positive is the renewaling rate of natural resources. We see that N gets less as pollution, p, grows and they grow as the environmental policy grows. The sum θy is what finances the environmental policy. We assume N (o) as given. Using (8) in (10a) we get that $\dot{N}=\delta N-(1-\theta)A\kappa$ (10b).
We end up that (9a), (9b) and (10) describe the competitive equilibrium when the environmental policy is taxing the pollution. In what follows, we will describe the second best policy, which will endogenize the choice of taxation θ.

6.3 Optimum tax pollution and economic growth

In this section, government will try to internalize the externalities by choosing endogenously θ, the tax pollution. The revenues from taxation will finance the anti-pollution policy.
We assume that he have a benevolent government which acts like a Stackelberg leader. Government chooses the paths of c, k, N, θ in order to optimize (1) and (2) subject to the constraints (9a) (9b) and (10b). The current value Hamiltonian is :
$H=\log c + v\log N + \lambda c[A(1-\theta)-\rho] + \gamma[A(1-\theta)\kappa-c] + \mu[\delta N-(1-\theta)A\kappa]$ (11), where λ,γ,μ are the multipliers of each constraint. If we take the first order conditions of our Hamiltonian with respect to θ, c, λ,κ,γ,N,μ we get that :
$(\lambda c+\gamma\kappa)=\mu\kappa$ (12α)
$\lambda'=\rho\lambda-(1/c)-\lambda[A(1-\theta)-\rho]+\gamma$ (12b)
$\dot{c}=c[A(1-\theta)-\rho]$ (12c)
$\gamma'=\rho\gamma-A\gamma(1-\theta)+A\mu(1-\theta)$ (12d)
$\dot{k}=A(1-\theta)k-c$ (12e)
$\mu'=\rho\mu-(v/N)-\delta\mu$ (12f)
$\dot{N}=\delta N-(1-\theta)Ak$ (12g)
We also need the transvesality condition $[A(1-\theta)-\rho]+\delta<\rho$ (12h)

Following the Benhabib and Farmer method in such dynamic problems, we will make some substitutions in order to proceed to the solution. Define $z=c/k$, $\psi=\mu\kappa$, $\varphi=vN$. We end up:
$z'=(z-\rho)z$ (13a)
$\psi'=[A(1-\theta)-z+\rho-(v/\varphi)-\delta]\psi$ (13b)

$\varphi' = \varphi\rho - v - (1-\theta)A\psi$ (13c)
$[z + (v/\varphi) + \delta]\psi = 1$ (13d)

6.4 <u>Long-run steady state</u>

In this section we will study the long-run properties of (13a)-(13d). As we know, at steady state variables do not change with respect to time, so $z' = \psi' = \theta' = \varphi' = 0$. This leads to the result that capital and natural resources can grow with the same steady rate. This is a known characteristic of AK endogenous models. As a result, we have a sustainable balanced growth path. **The reverse relationship between economic growth and quality of the environment is not a general result**.

6.5 <u>Solution to the long-run steady state</u>

Define the long-run values of $(z, \varphi, \theta, \psi)$ as $(\tilde{\eta}, \tilde{\iota}, \tilde{\upsilon}, \tilde{\omega})$.

$z' = (z-\rho)z = 0$, then $\tilde{\eta} = \rho$ (14a)
$\psi' = [A(1-\theta) - z + \rho - (v/\varphi) - \delta]\psi = 0$ then $\tilde{\iota} = v/[A(1-\theta) - \delta]$ (14b)

$\varphi' = \varphi\rho - v - (1-\theta)A\psi = 0$ then $\tilde{\omega} = \{v[\rho + \delta - A(1-\theta)]\}/\{(1-\tilde{\upsilon})A[A(1-\theta) - \delta]\}$ (14c)

From (14a)-(14c) and (13d) I get: $v[\rho + A(1-\tilde{\upsilon})][\rho + \delta - A(1-\tilde{\upsilon})] = A(1-\tilde{\upsilon})[A(1-\tilde{\upsilon}) - \delta]$ (14d)
We want to solve (14d) with respect to $\tilde{\upsilon}$, where $0 <= \tilde{\upsilon} <= 1$. After we find the solution, we check if it is a well-defined one, under the assumptions we have used so far. So, we need the economy to grow without destroying the natural environment, and natural resources to be strictly positive, i.e. $\mu > 0$. Finally, we need the transvesality condition we imposed in (12h) to hold.

In the paper we study, it is proven that $A > \rho + \delta$ (15a), $\rho > 2\delta$ (15b), $2v\delta > \rho - \delta$ (15c) and the well-defined long-run tax on pollution $\tilde{\upsilon}$ will be between $0 < 1 - (\rho+\delta)/A < \tilde{\upsilon} < 1 - \rho/A < 1$ (16).
This tax pollution is unique and well defined in the long-run. Capital, consumption and natural resources grow at a steady rate and that rate is the same for all of them. Thus, we end up with a sustainable balanced growth path.

6.6. <u>Properties of dynamic long-run steady-state</u>

If we differentiate (14d), we end up to the following results:
1)When the natural resources are renewable(δ is high) then the need to impose taxation is less.
2) When agents care more about environment (v is high) then environmental policy is more aliked. This requires low taxation which lead to higher growth and higher tax revenues.
3) The more agents care about the environment (the less is ρ), the higher is the tax so the less becomes the growth. The intuition behind this is that the less is ρ, the long-run growth rate grows because of $[A(1-\tilde{\upsilon}) - \rho]$. So we need a higher $\tilde{\upsilon}$ to slow down the growth and ensure that the utility is bounded.
4) When private capital is productive (A is high), the economy can choose higher taxation and less growth.

6.7 Results of economic policy and predictions for the future.

6.7.1. Results

This paper suggested a dynamic endogenous growth model with optimally chosen tax pollution. This methodology can be useful in models which use second-best economic policy. The main result is that the most efficient way to make the quality of the environment better is to make the economy grow. This leads to higher taxation and more economic resources. These resources finance environmental control programs. We can easily understand that only the big and advanced economies are able to finance such social welfare programs. We end up that the higher the economic growth, the higher the quality of the environment.

One can see that two things of concentration arise: the need for international cooperation and the development of new technologies.

Environment is an international good, in the sense that its quality in one country affect its quality in another country. This makes us think that international cooperation can internalize these externalities and lead to better results. However, the environment has the characteristics of an international public good and problems like free-riding arise. This leads to inconsistent environmental policy and low quality of the environment.

But free-riding is not the only problem in international cooperation. There is a large number of underdeveloped countries. These countries are very poor and lack of environmental quality. This means that there must be found motivation so that rich economies finance environmental maintaining programs. This is important not only for morality reasons, but also for the efficient distribution of resources. In the long-run, rich countries will be positively affected if they help poor countries in that ways.

In what follows, the main affair is the development of new technologies. In order to invest in programs that care about the environment and new eco-friendly technology, there must be a cooperation between private and public sector. At first place, the whole project will be based on public investment. This means that we will have short-run costs, like reducing the current consumption, something that may not be so pleasant for someone who cares a lot about the present and less for the future. It is well known that policy failures lead to economic policies with only short-term benefits. If this happens, then what is being “hurt” is the economic policy, the tax revenues and finally the provision of social goods, thus the protection of the environment. We end up that technology development must have mechanisms that, either endogenous motivation or exogenous by economic policy, will lead to decisions in order to achieve long-run goals.

Finally, we end up with two basic results. The first is that without economic growth and economic resources there cannot be a better environment. The second is that if economic policy makers want to have good long-term results, they must take into account the incentives and the strategic interaction of different economic agents.

6.7.2. Predictions

1). As Portney (2000) denoted, the marketable emission permits is going to grow, being a part of economic and environmental policy.
2). Again as Portney (2000) denoted, firms will be obliged to report systematically the pollution they cause at air, water and land.
These two measures can solve free-riding problems and also give a better meaning to the rights of property of natural resources.
3). Economic policy will be more and more in the hands of local authorities and international federal governments that national governments (Portney 2000). In this way, the international externalities and interactions between countries will be better handled.
4). Sachs (1999) proposed that there is going to be an international tax on the production of carbon dioxide. The revenues from this tax are going to finance eco-friendly programs in underdeveloped countries.
5). Renewable energy is going to be more competitive due to the technological growth.
6). Pressure is expected to put on from international organizations so that problems like free-riding are eliminated.

7. Transitional impact of environmental policy

7.1 Structure of the economy

Each consumer maximizes his utility by taking into account not only the consumption but also environmental amenities W=$\int_0^{\infty} e^{-\theta t} U\big(c(t), N(t)\big)dt$, (1.1) where U(c,N)=$[\sigma_c/(1-\sigma_c)](cN^{\varphi})^{1-1/\sigma}$. N as we said is the quality of the environment, like cleanliness of the air, of sea etc. Regeneration process allows the environment to be modeled as renewable resource N'= E (N, P) (1.2), where N' is the derivative of N with respect to time. However, the first derivative of the natural growth is negative with respect to N. This is because the larger the stock of natural capital and environmental quality, the more difficult it is to regenerate the complete stock. During production, environmental quality is being deteriorated because it requires inputs that pollute the environment directly or indirectly. This factor is called pollution and is denoted by P. The environment itself can sustain a certain level of pollution because it can regenerate itself. So If the pollution levels are small so that the regeneration of the environment is in higher rate, the growth process and the environmental quality rise over time. $\underline{N}(P)$ denotes the long run equilibrium point of environmental quality. The quality of the environment enhances the productivity of man-made inputs by providing non-extractive services. This is denoted in the following formulas: $Y=A_Y(N)F(K_Y,Z_Y)=C+K'$ (1.3) and $H=A_H(N)G(K_H,Z_H)=h'$ (1.4) , where A_Y and A_H are productivity factors which depend positively on N. Bovenberg, Lans, Smulders and Sjak call the equation (1.3) Y-sector and (1.4) H-sector. Such an example could be the effect of air quality on mental health. The environment acts as a non-rival good: not only it provides amenities to each household, but at the same time it boosts productivity in both sectors. So when it enhances the productivity of man-made inputs it is a public capital good and when it is an environmental amenity, it acts like a public consumption good.

Production requires rival production factors like private capital K and also rival inputs extracted from nature, which are measured in efficiency units (Z). No production level is feasible without using pollution. However, there can be pollution-saving techniques. In particular, we denote the stock of pollution-saving technical knowledge by h and the flow of polluting inputs by P, so we can represent the extractive use of the environment in efficiency units by $Z=hP$.

There are three types of assets that economy can invest in. It can accumulate more natural capital N by reducing pollution P. Also there can be more private capital investment (K') if we devote resources to it**.** Finally, there can be developed additional saving pollution technologies ($\dot{h}$). Natural capital is not man-made. However, the last two sectors are. Capital (K) and consumption goods are produced by the Y-sector and the pollution saving techniques by the Research and Development (R&D) which is the H-sector.

We also assume that knowledge is not a rival good, so one idea can be applied by various firms at the same time. Non-rivalry gives rise to externalities. In particular, pollution-saving technical knowledge is a public good, which should be provided by a public agency. Moreover, since N is a non-rival good, producers fail to take into account the adverse effects of pollution on the ecological system. Finally, the economy generates excessive pollution unless the government intervenes. We assume that the government charges a price for pollution by selling pollution permits.

The producers maximize their output by optimally selecting capital and pollution. If we take the price of output from Y-sector as numeraire, we can obtain the following equation: $hA_Y\partial F/\partial Z_Y = \tau_{p.}$ (1.9). The intuition behind this equation is that the marginal return of pollution inputs P equals the price of pollution permit τ_p. Also, we can get $A_Y\partial F/\partial K_Y=r$ (1.10) and the intuition behind it is that marginal return of capital K equals the rate of return in capital markets r. Arbitrage in the capital market and the market for pollution permits ensures that capital and pollution earn the same return in bothe sectors. This is denoted by the following formulas: $A_Y\partial F/\partial K_Y=q_h\partial A_H\partial G/\partial K_H$ (1.7) and $A_Y\partial F/\partial Z_Y= q_h\partial A_H\partial G/\partial K_H$ (1.8).

Consumers maximize their utility that the return of an additional unit of postponed consumption equals the marginal utility of current consumption, $\tilde{u}-U'_c/U_c=r$(1.11).

The government chooses optimally a number of pollution permits. In order to find the optimal number of permits, government solves $\tau_p =- E_p q_N$ (1.13). These permits are auctioned off by an environmental agency and the revenues are spend in the research and development. This auction is made by an environmental agent, who is taking the number of permits that government gives as given and solves $A_H\partial G/\partial Z_H P+q'_h/q_h=r$ (1.12).

7.2 Requirements for balanced growth

The economy can grow in the long run under some conditions. The rate of growth depends on the preferences, technology and environmental policy. We end up that the long run growth this is endogenous.
Using Bovenberg and Smulders (1993) conditions, we assume that the economy grows. After empirical studies and mathematical applications using the elasticity of intertemporal substitution σ_c and the substitution elasticities between environmental amenities and consumption of produced goods, they ended up that **no production can exists without pollution**. On a balanced growth path, the consumption of produced goods, σ_c, grow at a common positive growth rate (g>0). This is the Rampsey rule, $g=\sigma_c(r-\theta)$, where r is the return of investment and θ is the pure rate of time preference. So it easy to see that when $r>\theta$, then the growth rate is high. This is feasible because production has constant returns with respect to the reproducible factors of production. Under this balanced growth path framework, we assume that natural capital (N) and the pollution levels (P) are constant. Thus, prices of both pollution permits τ_p and pollution saving technologies q_N increase at the growth rate g. The price of each environmental permit and environmental quality makes g higher.

7.3 Conventional and green concepts of income

To address economic growth we need to aggregate the two-sector structure of the model. The first, conventional, procedure aggregates man-made production, assets and income. The second, "green" procedure accounts for the accumulation of natural capital and imputed income from environmental amenities.

7.3.1. Conventional aggregation

We denote M with man-made assets and J with aggregate output. Also denote q_M and q_J the price deflators in terms of consumption goods. Then the aggregate values of man-made assets and national product are:
$q_M M=K+q_h h$ (2)
$q_j j=Y+q_h H=K'+C+q_h H$ (3)
$Y+q_h h=rK+\tau_p P$ (4)
(3) denotes that national product amounts to the aggregate output produced by the two production sectors.
Aggregate consumption (C), national income and man-made income wealth after mathematical applications are related in the following two equations:
$C/q_M M=r-g$ (5)
$q_J J/q_M M=r$ (6)

Consumer's income consists of the return on holding of private capital K and the revenues collected by the environmental agency. It is proven that the revenues of the pollution permits coincide with the return on the stock of pollution saving technological knowledge.
The following equations characterize the importance of the public environmental agency relative to aggregate variables:
$K_H/K=[(1-\alpha)\beta g]/[\alpha r+(\beta-\alpha)g]$ (7)

$Z_H/Z=(1-\beta)g/r=1-v$ (8)
(7) and (8) show us that a higher growth rate boosts the proportion of aggregate rival inputs K and Z that are devoted to the environmental R&D sector. Higher growth shifts economic activity away from the Y-sector towards the H-sector. So economy is not producing consumption goods but only investment goods. It is easy to understand that when Y-sector is more and more pollution-intense, the more valuable pollution-saving technologies become. So a larger share of economy-wide capital is devoted to the environmental R&D sector.

We can also obtain the following equation:
$(\tau_p P-q_h H)/\tau_p P=(r-g)/r$ (9)
(9) denotes that $\tau_p P$, is the permits times the price, is the collected revenue from the pollution permits sales. By investing in pollution-saving technology, the productivity of pollution inputs increase, raising the price of pollution technology.

Share of pollution-saving knowledge (h) in the aggregate value of man-made assets denoted by ω, and the share of national product generated in the environmental H-sector can be imposed in the two equations:
$q_h h/q_M M=\tau_p P/q_J J=[(1-\alpha)r]/[r+(\beta-\alpha)g]=\omega$ (10)
$q_h H/q_J J==[(1-\alpha)g]/[r+(\beta-\alpha)g]=\omega g/r$ (11)

The intuition behind (10) is that the production share of pollution equals the asset share of pollution-saving knowledge capital. As we saw before, Y-sector is pollution intensive. The production share of pollution in the Y-sector 1-α exceeds the corresponding aggregate share ω. This is more visible if the rate of growth is large compared o the rate of return. In that case, investment is important compared to consumption and hence the capital intensive H-sector becomes more important compared to the pollution intensive Y-sector, which also produces consumer goods. If we could compare (10) and (11) we can see that the share of environmental knowledge in man-made assets $q_h h/q_M M$ exceeds the output share of the environmental R&D sector $q_h H/q_J J$. This happens because consumption goods are only produced in the Y-sector.

7.4 “Green” concepts of income and wealth

Consumption of proceeded goods and investment in man-made capital are measured by the conventional income. However, the investments in natural capital and the imputed income form consumption are both ignored. To solve this problem, an alternative green concept is used whose formula is:
$q_Q Q=q_J J+U_N N/U_C+q_N N'=(C+K')+q_h H+U_N N/U_C+q_N N'$ (12)
$U_N N/U_C$ denotes the green income supplements and is the income which is associated with consumption of environmental amenities. $q_N N'$ denotes the investment in environmental quality. A new equation can be extracted, $\varphi= U_N N/ U_C c$ (13) which is the imputed income from the environmental amenities which is related to physical consumption through the parameter of the utility function. In the long-run, conventional income substantially understates green income if environmental amenities are important. This is given by the following equations:
$q_J J/q_Q Q=r/[\varphi(r-g) +r]$ (14)
$C/q_Q Q=r-g/ [\varphi(r-g) +r]$ (15)

Following the same procedure, we can find a green measure of wealth. This kind of measure will incorporate both man-made and natural assets denoted by $q_M M+ q_N N$.

So the steady state value of natural capital related to the man-made capital is:
$q_N N / q_M M = [\varphi(r-g)+\alpha_N r]/r-g+\delta$ (16) , where $\alpha_N = Y\alpha_Y / q_J J + q_h H \alpha_H / q_J J$.
Nominator in (16) is the contribution of an additional unit of natural capital to environmental amenities and production. The intuition behind this is that environmental quality provides utility as an amenity. Thus, natural capital is valuable relative to man-made capital if the consumption to man-made capital ratio (r-g) is large and if environmental quality plays an important role in utility. α_N is the elasticity if total factor productivity in the economy with respect to environmental quality. It captures the importance of environmental quality as a public good. It is the sum of corresponding elasticities of Y-sector and H-sector and weighted by the respective income shares of the two sectors. Finally, the more powerful the environmental quality is in enhancing productivity (large α_N), the more important natural capital is, compared to the man-made capital.

7.6 <u>Environmental policy</u>

in that case, a shock is going to apply its effects in the equilibrium. This shock is an environmental policy reform aimed to internalize pollution externalities.

7.6.1. <u>The sub-optimality of initial equilibrium</u>

In the initial balanced growth path, we assume there exists excessive pollution, which means that government is allowed to sell many pollution permits. So it is easy to see that now the level of pollution is exogenously set by government, something that violates the optimal condition for choosing the optimal number of pollution permits and now $\tau_p < -E_p q_N$ (18). If we plug (6), (10) and call $\delta = -E_p$ then we can write that:
$\Delta = [\delta q_N N / \omega r q_M M] - 1/\varepsilon > 0$ (19), where $\varepsilon = E_p P / E_N N$ (20).
Δ is the gap between social costs of pollution and social benefits of non-pollution. The intuition behind (19) is that if ε, which is the elasticity of environmental quality with respect to the level of pollution, is large, the benefits of better environmental quality will outweigh the costs of low level pollution and the implicit pollution subsidy is likely to be large. If the benefits from additional environmental capital are large compared to benefits of a higher level of pollution, then we will have welfare distortions due to excessive pollution.
An analytical solution is able to be obtained by linearizing the model around initial balanced growth path but we will not deal with it.

7.6.2 <u>Comparative dynamics</u>

What is being discussed in this section is the economic intuition of some economic variables. The model distinguishes between two cases. First, the environment is a public consumption good so that the environmental benefits accrue entirely in the form of environmental amenities so that $\alpha_Y=\alpha_H=\alpha_N=0$. The second case is when the environment is a public capital good and thus benefits take the form of only beneficial productivity effects so $\varphi=0$.

7.6.3 The quality of the environment

As the levels of pollution go down, it is easy to see that natural capital levels go up. This is given by the following equation: $\tilde{N}(t)=(1-e^{-\delta t})\tilde{N}(\infty)$ (24). The long-run effect on the quality of the environment is given by: $\tilde{N}(\infty) = -\varepsilon P = -E_p P\tilde{P}/E_N N$ (25).
So, the larger the positive impact of lower pollution ($-E_P P$ is large), the smaller are the diminishing returns in natural growth processes ($-E_N$ is small), the more effective a lower pollution flow becomes in enhancing long-run environmental quality.
$\delta=-E_N$ is the rate that natural capital approaches to the steady state. The speed of convergence of environmental quality to its steady state is a function of the sensitivity of natural growth and absorption capacity to the environmental quality.

7.6.4. Welfare

After some mathematical implications, welfare effect is given by:
$\tilde{W}0)=(r/r-g)\omega\tilde{P}+(r/r-g)\eta\alpha_N\tilde{N}(\infty)+\eta\varphi\tilde{N}(\infty)$ (26), where $\eta=\delta/r-g-\delta$ (27).
If we could break the terms of (26) , we could see that the first term represents the costs of investing in the environment. This is the “crowding out effect”: production is crowded out by the additional investment in natural capital in the form of a lower pollution flow. The second and third term represent the benefits of investing in the environment. More analytically, the second term stands for the benefits of a cleaner environment as a public good. It is the positive income effects due to favorable productivity effects associated with a larger stock of natural capital. The third term represents the benefits of environment as a public consumption good. It measures the increase in permanent imputed income from environmental amenities.
If we plug (25) in (26), we find that: $[\tilde{W}(0)=\omega r\Delta\tilde{N}(\infty)]/(r-g)$ (28).
This shows us that total welfare increases if and only if the initial flow of pollution exceedsits socially optimal level. The gain in welfare change is proportional to the initial distortionary subsidy to pollution defined by Δ.
We can decompose welfare in two components. The first is the discounted consumption, called “blue welfare”. The second is discounted environmental amenities called “green” welfare. Note that with an initial distortionary subsidy on pollution, overall welfare improves. However, blue welfare may fall. In that case society faces a trade-off between blue and green welfare. It reaps a double dividend if $\eta\alpha_N\varepsilon>\omega$ (29). This conditions states that the beneficial productivity effects of a lrger stock of natural capital should exceed the crowding out effects of investing in natural capital. For this to hold, ω which is the input share of pollution in production should be small. Also α_N which is the productivity effects of environmental quality should be large. In addition ε, which is the sensitivity of environmental quality to a change in pollution, should be large. Finally, long-run effects should approach rapidly and should not be discounted heavily, so η must be large enough.
If we take the case that environment is a pure capital good, green welfare is absent. In that case, overall welfare consists only of blue welfare. When $\alpha_N=0$,

productivity effects are zero. As blue welfare declines, a tighter environmental policy yields to an improvement in green welfare.

7.6.5 Green income

In the short run, both stocks of man-made assets and natural assets are fixed. Because of less extractive use of the environment, real national income declines. This is stated in the flowing equation: $\tilde{J}(0) = \omega\tilde{P}$ (30). The lower flow of pollution involves an investment in natural capital. The green income involves investments in natural capital and is a better indicator of welfare. The initial impact of green income is proportional to the welfare effect and this is seen in the formula: $\tilde{Q}(0) = \widetilde{W}(0)(r-g)/[\varphi(r-g)+r]$ (31). So we see that green income concept is a gain in income. We see that the social benefits of investing in natural capital are higher than the social costs. Thus, the non-extractive use is more beneficial than the extractive use of it.

7.6.5 Consumption

Consumption is an aggregate variable and in order to study its behavior we have not only to check the rate of convergence δ we discussed above, but also to distinguish between short term and long term growth.

In the long run, consumption grows at the same rate with man-made assets and income. The intuition here is that if productivity effects are important, and pollution plays only a minor role in production, long-run growth rises. if environment is a pure consumption good then growth declines. However, if environment is a pure capital good, we see that long run improves. This is the reason why we must distinguish between consumption-good and capital-good features of environment.

In the case of short-run, again there is a distinction between pure capital good and pure consumption good. In the first case, the rate of return declines due to the adverse productivity impact of a lower flow of polluting inputs. When the environment is a pure consumption good, the growth depends on two factors. The first one is the intratemporal substitution between material consumption and environmental amenities. This means that when the environmental quality is rising, the consumption of material my decline if consumers desire to maintain a constant stream of utility over time. The second factor is the intertemporal substitution. This means that the physical rate of return on saving enables households to consume more produced consumption goods in future, while the rise in environmental quality allows consumers to benefit from a higher marginal utility on consumption of produced commodities. Households find it more attractive to move their consumption of commodities forward. They do so because they anticipate higher future quality of the environment. Generally, intertemporal substitution is more difficult than intratemporal substitution.

7.6.6 Income and savings

Income is a jump variable. The intuition behind the maths is that the economy adjusts its asset portfolio away from man-made towards natural assets. This happens because in anticipation pf future productivity and amenity gains, households consume more. Thus, they reduce savings in man-made assets. Large welfare gains as a result of improved environmental quality widen the contrast between reduced growth of man-made assets in the short run and increased growth of these assets in the long run. We can also say that saving is hurt by the consumption boom.

7.6.7 Resource allocation: the size of the public sector

One may ask: How can production structure change? Well, as we have talked about, we have related to two sectors: Y-sector and H-sector. We said that Y-sector is the consumption-goods or private capital-goods sector which produce pollution. H-sector denotes the R&D sector of the knowledge sector which develops the pollution-saving technology. Production structure can change by a tighter environmental policy. We will see two indicators for the relative size og the environmental R&D sector. This sector can also be viewed as the public sector because it is financed by public means. The first indicator is the income share of the environmental R&D sector which we denote as $q_h H/q_J J$. The second indicator is the share of pollution allocated to the R&D sector which is denoted as $Z_H/Z=1-v$. Those variables are related to the effective knowledge-capital ratio and the price of pollution-saving technologies, q_h, in the following way:

$\tilde{v}=(1-v)[\tilde{P}-(\tilde{K}-\tilde{h})+\sigma_K(\tilde{A}_Y-\tilde{A}_H-\tilde{q}_h)/(\beta-\alpha)]/(v-U)$ and

$\tilde{q}_h H/q_J J=(1-\omega g/r)\{-\tilde{v}/(1-v)+[1-(\beta\sigma_H-\alpha\sigma_Y)/(\beta-\alpha)](\tilde{q}_h+\tilde{A}_H-\tilde{A}_Y)\}$

The price of knowledge is constant if productivity shocks are symmetric. If in addition the substitution elasticities in both sectors are equal ($\sigma_u=\sigma_H=\sigma_Y$), then the above two equations can be written as:

$-\tilde{v}/(1-v)=[1/(v-u)][\tilde{K}-\tilde{h}-(1-\sigma_K+\beta-\alpha)\tilde{P}/(1-\alpha+\beta)]$ (47) and

$\tilde{q}_h H/q_J J==(1-\omega g/r))\{(\tilde{K}-\tilde{h})/(v-u)+[(1-\sigma_u)(1/(v-u)-\beta+\alpha)+(\beta-\alpha)/(v-u)][-\tilde{P}/(1-\alpha-+\beta)]\}$ (48)

In the following sub-sections we use this two formulas and analyze the short-run and long run effects.

7.6.8. Short-run effects

The magnitude of the initial expansion of the public sector depends on the intrasectoral substitution elasticities between capital and effective pollution. The relative size of the public sector increases most in the short run if intrasectoral substitution is difficult. Intuitively, intrasectoral substitution of resources substitutes for intersectoral substitution. If the intrasectoral substitution elasticities do not exceed one, intrasectoral substitution towards capital is not strong enough to cause the capital-producing sector to expand. Intuitively, in that case, pollution-saving technologies rather than capital are a better substitute for pollution. Hence, resources move to the sector developing pollution saving technologies.

7.6.9 Long-run effects

If productivity effects are not symmetric, the development of the sectorial allocation of resources through time reflects the adjustment of the aggregate capital-knowledge ratio. If we substitute the long-run solutions for the capital-knowledge ratio and the price of knowledge, we find the following for the long-run impacts:

$$v\,\tilde{v}(\infty)/(1-v)=-\beta(1-\sigma_H)[(\alpha_Y-\alpha_H)\tilde{N}(\infty)-\tilde{P}]/(1-\alpha+\beta)-\tilde{r}(\infty)\,\theta/(r-\theta) \quad (48)$$

$$\tilde{q}_h H(\infty)/q_J J=(1-\omega g/r)\{[\alpha(1-\sigma_Y)+\beta(1-\omega)(1-\sigma_H)/v][(\alpha_Y-\alpha_H)\tilde{N}(\infty)-\tilde{P}]/(1-\alpha+\beta)+\tilde{r}(\infty)\,\theta/(r-\theta)v\} \quad (50)$$

Taking environment as consumption good, we see that resources start to return to the Y-sector. This happens because investments in R&D gradually expand the stock of pollution saving technologies and thus the economy-eide ratio of effective pollution to capital. The larger relative supply of effective pollution boosts the pollution-intensive sector, the Y-sector. R&D sector is harmed because of the absence of productivity effects. Recall that R&D is a pure investment sector. The intuition behind(49) and (50) is that in order to substitute for pollution, the economy invests mainly in pollution-saving technologies instead of either investing in private capital. Amenities affect the transition. They may cause resources to temporary move into consumption-goods sector and this boosts the income of Y-sector.

If we take environment as a capital good, we see that investments become more attractive in the new steady state. Thus, more resources are gone to the R&D sector and this boosts the income share of public sector. During the transition, income share of public sector may develop in a non-monotonic way. As the accumulation of pollution-saving technologies favors the pollution-intensive sector, share of resources allocated to R&D decline. Due to a consumption-smoothness, resources are pulled into the consumption-goods.

7.7 Results

By using endogenous growth model, this papers shows us than initially, more resources are devoted to developing pollution-saving technologies. As more pollution-saving knowledge becomes available, resources move towards the pollution-intensive consumption-goods sector. However, over time, the economy becomes less oriented towards consumption and more towards investment. A tighter environmental policy induces a change in the composition of the economy's asset portfolio away from man-made assets towards natural capital. Also the initial consumption boom contributes to lower capital accumulation because consumption goods are produced in a pollution-intensive (and thus capital extensive) fashion. When pollution is excessive in the initial steady state, we saw that the growth effects of a tighter environmental policy depends crucially on whether the environmental benefits accrue in the form of amenities or in the form of higher productivity of the production processes.

8. Conclusion

In what we have seen so far, both economic models can be used to help us understand not only how important is pollution for the disutility of each individual, but also the importance in the environment and renewable resources. One could say that extreme taxation could be the solution so that environment is no longer affected by the pollutionary technology that firms use. However economics tell us that the optimal policy is different under each situation.

We also examined the different relationships between economic growth and environment. The models showed that pollution will grow as income grows if the negative externality of pollution is not taken into account. On the other hand, environmental concerns might decelerate growth if productivity of capital in production and pollution abatement declines towards zero, as capital accumulates. However, it is possible for an economy to succeed in sustaining both economic growth and stable levels pf pollution. This can happen if there exist non-diminishing returns in output production or abatement processes. So we see again that environmental policy affects not only economic growth but also the pollution levels.

Much importance was given to the Porter hypothesis and how sustainable can economic growth be when we take into account the environmental concern. After analyzing PH, we imposed a very interesting case study of an industrial country, Japan. Note here that attention was not given to the numbers but to the methodology and the results. This was done in purpose: this methodology can be used in any country, in addition with the implications to the policy makers we suggested.

The next chapter had to do with a model with given economic policy. After solving this model, we could extract the optimal taxation that can be used for economic growth so that environmental care is not deteriorated. Then we discussed about the importance of noting that environment is an international good and problems like "free-riding" must not exist. This is important not only for poor countries but also for the rich ones. Finally we ended up that without economic growth and economic resources there cannot be a better environment.

Bibliography

Ambec S., Cohen M.A., Elgie S, Lanoie P. [2011], Can Environmental Regulation Enhance Innovation and Competitiveness?
Bovenberg L.A. and Smulders S.A. [1994], Transitional impact of environmental policy in an endogenous growth model, Journal of Public Economics.
Bovenberg L.A. and Smulders S.A. [1995], Environmental quality and pollution-augmenting technological change in a two-sector endogenous growth model, Journal of Public Economics.
Blundell, R. and Bond, S. [1998], Initial conditions and moment restrictions in dynamic panel data models.
Chalermthanakom A. and Ueta K. , Impact of Environmental Regulation on Productivity: Case Studies of Three Industries in Japan
Domazlicky, B.R. And Weber, W.L. (2004),Does environmental protection lead to slower productivity growth in the chemical industry? , Environmental and Resource Economics 28: pp. 301-324
Doornik, J.A., Arellano, M. And Bond, S. [2006], Panel data estimation using DPD for ox, Economics Discussion Paper, Nyffield College, Oxford University.
Economides G. and A. Philippopoulos, [2000], Pollution versus resource extraction: Do they matter for the dynamics of growth?
Jaffe, A.B. and Palmer, K. [1007], Environmental regulation and innovation: a panel data study, The Review of Economics and Statistics 79: pp.610-619.
Lanoie, P., Party, M. and Lajeunesse, R. [2005], Environmental regulation and productivity: testing the Porter hypothesis, Journal of Productivity Analysis 30: pp.121-128.
Milne C., [2015], Environmental Regulation and Innovation: Select Case Study Evidence of the Porter Hypothesis, Policy Brief.
Philippopoulos A. and G Economides [2000], Are Nash tax rates too low or too high?

Xepapadeas A. [2017] Economic Growth and Environment.