BETA
Bureau
d'économie
théorique
et appliquée

Documents de travail

« A FRAMEWORK FOR ANALYSING SUSTAINABILITY TRADE-OFFS. FOCUS AT COMPANY LEVEL»

Auteurs

Ioana Filipas, François Marmier, Nathalie Picard

Document de Travail n° 2024 – 04

Février 2024

Bureau d'Économie Théorique et Appliquée BETA

www.beta-economics.fr

@beta_economics

Contact :
jaoulgrammare@beta-cnrs.unistra.fr

Université de Strasbourg · cnrs · UNIVERSITÉ DE LORRAINE · INRAE · AgroParisTech

A FRAMEWORK FOR ANALYSING SUSTAINABILITY TRADE-OFFS. FOCUS AT COMPANY LEVEL

Ioana Filipas*, François Marmier**, Nathalie Picard*
*University of Strasbourg, BETA UMR CNRS 7522
67000 Strasbourg France (deniaud@unistra.fr; picardn@unistra.fr)
** University of Strasbourg, ICUBE UMR CNRS 7357
67000 Strasbourg, France (marmier@unistra.fr)

Abstract :
This paper begins with a historical synthesis of the concept of sustainability. This is followed by a multi-level classification of sustainability key performance indicators (KPIs). Following the analysis, a framework is proposed for integrating the three pillars of sustainability - economic, environmental and social responsibility - into the management of a company. It is based on economic, management and optimisation knowledge.
We have developed four different models with different objective functions that show the impact of companies' decisions related to resource management in their production and the introduction of taxes imposed by public authorities to promote one specific pillar of sustainable development. The simulations carried out on the basis of these models make it possible to analyse, in an original way, the impact of incentives designed to encourage firms to internalise their environmental, social and economic externalities.

Key words: sustainability, externalities, Triple Bottom Line

JEL Code: Q5 Environmental Ecomnomics ; Q51, Q58s

A FRAMEWORK FOR ANALYSING SUSTAINABILITY TRADE-OFFS. FOCUS AT COMPANY LEVEL

Ioana Filipas*, François Marmier**, Nathalie Picard*
*University of Strasbourg, BETA UMR CNRS 7522
67000 Strasbourg France (deniaud@unistra.fr; picardn@unistra.fr)
** University of Strasbourg, ICUBE UMR CNRS 7357
67000 Strasbourg, France (marmier@unistra.fr)

1. INTRODUCTION

In this paper, we take an interdisciplinary look at the concept of sustainability. In line with the aim of the book, this paper mobilises knowledge from different disciplines, in particular the three areas of expertise of the authors: industrial engineering, economics and management. In addition, the literature review presented later covers a wide range of fields: health, agriculture, energy, transport and logistics, biotechnology.
This paper begins with a historical synthesis of the concept of sustainability. This is followed by a multi-level classification of sustainability key performance indicators (KPIs). Following the analysis, a framework is proposed for integrating the three pillars of sustainability - economic, environmental and social responsibility - into the management of a company. It is based on economic, management and optimisation knowledge.
We have developed four different models with different objective functions that show the impact of companies' decisions related to resource management in their production and the introduction of taxes imposed by public authorities to promote one specific pillar of sustainable development. The simulations carried out on the basis of these models make it possible to analyse, in an original way, the impact of incentives designed to encourage firms to internalise their environmental, social and economic externalities.

2. STATE OF THE ART

In this section we give a brief history of the concept of sustainability and present the different approaches presented in the literature. The proposed literature review was obtained by searching the international databases SCOPUS, Research Gate, Google Scholar and ISI Web of Knowledge. The keywords used were: circular economy, sustainability indicators, sustainability models, externalities and incentives in sustainable development.
In the 18th century, the term 'sustainability' was unknown. However, Thomas Robert Malthus was already thinking about these very issues. In 1798, Malthus explained that future generations would suffer from famine, plague or pestilence because there would not be enough food for everyone, as the human population would grow much faster than it could feed itself (Malthus, Winch, et James 1992). He did not use the keyword sustainability, but he was clearly concerned about the concept of sustainability (Winter et al. 2018). However, his curve was not so good because he ignored future technological revolutions.
Later, the Club of Rome, a non-profit organization of intellectuals and business leaders founded in 1968, discussed global issues linked with resource depletion. They emphasized the "limits to

growth” in the report, published in 1972. Finally, their predictions turned out to be quite accurate.

Today, the term 'sustainability' is used in countless articles, each with a slightly different definition. The majority of authors quote Brundtland's definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). The Brundtland Report is often seen as the beginning of an era in which people began to care about sustainability. As mentioned above, we believe that the concept of sustainability was being analysed long before the famous Brundtland report was written. Brundtland's contemporary definition of sustainability is of great importance in the real environments and settings of a company. This includes a vigilant examination of potential changes in national and international laws and requirements.

One of the first authors to extend the concept of sustainability was Elkington (1997). He broadened the concept of sustainable business, which had mostly been limited to environmental issues. He therefore raises the question "Is it progress when a cannibal uses a fork?", while agreeing with and defending this view. The cannibals are used as a metaphor for companies in today's rapidly changing capitalist economies, where it seems normal for companies to devour their competitors. In addition, the fork can be seen as a metaphor for sustainable business and thus for moving into a new stage of corporate evolution. He argues that the goal of sustainable business is achieved when economic prosperity, environmental quality and social equity are achieved simultaneously. In order to achieve this goal, he states that a revolution in thinking is necessary and explains that one should think in seven dimensions. These dimensions are markets, values, transparency, life-cycle technology, partnership, time perspective and corporate governance. Elkington proposed a new accounting framework to measure corporate sustainability, called the Triple Bottom Line (TBL) of profit, environmental sustainability and social responsibility. The three inherent pillars of TBL (economic, environmental, social) are interrelated, interdependent and to some extent conflicting (Elkington 1997). The TBL dimensions are also commonly referred to as the three Ps: people, planet and profits. Slaper and Hall (2011) discussed the difficulties of calculating TBL and identified independent key performance indicators for each pillar. Simon (2019) demonstrated that the human mind cannot process and decompose all the information needed to optimise a system in the best possible way due to what he called “cognitive limitations”. For this reason, a balanced scorecard (Kaplan and Norton 2005) is seen as an essential requirement for managers to make decisions.

In 2015, the member states of the United Nations adopted the Sustainable Development Goals. The aim of this resolution is to achieve 17 goals by 2030 in order to end all forms of poverty, fight inequalities and combat climate change, while ensuring that no one is left behind (United Nations 2015).

Many experts believe that sustainability will become an increasingly important issue in the European Economic Area. In fact, France was the first country in the world to introduce a carbon reporting obligation for financial institutions (Gollier 2022). Since 2013, carriers are required to report the CO2 emissions generated by a shipment, allowing customers to choose the least polluting option.

Through the European Green Deal, Europe aims to achieve climate neutrality by 2050, taking into account the United Nations Sustainable Development Goals and the Circular Economy Strategy. The main objectives of the European Green Deal are 90% reduction in transport emissions; greenhouse gas reduction for 2030 compared to 1990: at least 50% and towards

55%; zero carbon steel production by 2030; promotion of a circular bio-economy (no restrictions and a regulatory framework will be developed for biodegradable and bio-based plastics; measures on single-use plastics will be applied). Research and innovation on clean energy will be supported, taking into account the circular economy strategy. In this line, Loizia et al. (2021) propose a Force-Pressure-State-Impact-Response approach to identify key environmental performance indicators.

Kollmuss and Agyeman (2002) define pro-environmental behaviour as "behaviour that consciously seeks to minimise the negative impact of one's actions on the natural and built world". Sustainability issues affect: individuals, who may be competing with their own economic survival or well-being; businesses, which are primarily concerned with their own profitability and survival; and public authorities and local, national or international institutions (including NGOs), which are responsible for informing businesses and individuals (awareness) and guiding them towards sustainable behaviour through policies, standards and regulations.

Finding the right incentives to induce firms and households to internalise their externalities is the key to effective policies. However, public authorities face coordination difficulties at different levels of decision-making, they may be influenced by lobbies, and electoral concerns may lead them to favour short-term objectives rather than long-term sustainability goals.

A company will typically be willing to invest in sustainability or green issues if there is a tangible return on the investment. This return can be in terms of production efficiency, image (increased demand) or other external pressures (Milne et Gray 2013). Lean management methodology, which initially focused only on the economic pillar, consists of a set of principles, tools and practices aimed at reducing waste - in the broadest sense - to a minimum (Winter, Deniaud et Caillaud 2014), including the 'reduce, reuse, recycle' concept. Later, the lean and green management method introduced the environmental and social pillar (Hariyani and Mishra 2022), and the circular economy proposes a further step in this direction (Geng et al. 2012; Martinho 2021).

From the point of view of public authorities, a series of international standards, starting with ISO 14001, provide guidelines for establishing or improving environmental management systems. Then, the ISO 26000 standard defines the main aspects of a corporate social responsibility (CSR) approach. CSR overlaps with social sustainability and addresses the well-being of people and society through the management of social resources (Govindan, Shaw and Majumdar 2021). A CSR approach means that the company not only adopts responsible practices, but also acts as a role model in this area. It shares its knowledge, experience and best practices with stakeholders to encourage continuous improvement and overall commitment to CSR. In the same vein, the ISO 45001 standard specifies requirements for an occupational health and safety (OH&S) management system.

Today, Environmental Management Systems (EMS) help companies to fully integrate an environmentally responsible strategy into their value chain. It promotes an economic and industrial model that is low in carbon, energy and renewable natural resources. The EMS covers the eco-design of products and services and the circular economy. It involves deep integration of standards such as ISO 26000, ISO 14001 and ISO 45001, proactive risk management, compliance with procedures and a quality approach focused on social and environmental impacts.

Each company has a business model that explains the interaction between the factors that create economic value. In general, the business model includes supply chain actors (suppliers, distributors and customers), but only from the perspective of the company. The ecosystem, which includes external actors with whom the organisation is interdependent, is usually not

considered in the business model analysis (Lecocq, Demil, et Warnier 2023). External actors can have a positive or negative impact without any monetary compensation. These impacts are called externalities. Lecocq, Demil, et Warnier (2013) argue that the management of externalities should be taken into account in a company's business model.
They identified eight policies to manage (or not) externalities and the potential consequences of these policies for the company's business model and its ecosystem.
Despite a deliberate willingness to include environmental concerns in economic calculations in order to internalise environmental externalities and to attract customers and improve corporate image, there is no consensus or universal method of evaluation. In addition, the existing methods usually de facto exclude the social pillar (Nakagawa 2022).
Global studies and generic approaches tend to define concepts related to sustainability. However, when we delve into the literature review, the contributions are often very focused on a single pillar and lack the necessary global overview.

3. MULTI-LEVELS ANALISIS OF SUSTAINABLE KPIs

Focusing on the key performance indicators (KPIs) used to assess sustainable development, Table 1 provides an overview of the papers studied. For each selected paper, we have classified the KPIs used under each of the pillars of sustainable development. We have also refined the research to highlight the level at which the KPIs are used. Three levels have been defined:

- micro level: the company level, noted C,
- mezzo level: mainly the external / extended supply chain level, noted SC,
- macro level: the public policy level, noted PP.

To improve sustainability, companies, public organisations and countries have taken action at all these levels.
In the same Table 1, we also indicate whether the contribution is theoretical (T) or applied (A) and the geographical area of the case study, if it is presented in the contribution considered.

TABLE 1: Sustainable KPIs multilevel classification

Reference	Environmental			Economic			Social			Contribution	Area
	C	SC	PP	C	SC	PP	C	SC	PP		
Eidelwein et al, 2018	x			x						Petrochemical	Brazil
Shad et al 2019	x			x						T	
Deniaud et al 2021	x									T	
Martínez et Poveda, 2022	x									T, micro enterprise	
Trianni et al, 2017	x		x	x			x			T/A Industry	Italy
Winter et al, 2018	x	x		x	x		x	x		T/A Logistic	Luxembourg
Seuring et Müller, 2008		x			x			x		T, review	
Hassini, 2012		x			x			x		T, review	
Saputri et al, 2020		x			x			x		T, review	World
Hariyani & Mishra, 2022		x			x			x		T, review	
Li & Cruz, 2022		x			x	x		x		T	
Nguyen-Van et al, 2021			x			x		x	x	T	
Pezzey et al, 2006						x				T/A	Scotland

Reference	Environmental			Economic			Social			Contribution	Area
	C	SC	PP	C	SC	PP	C	SC	PP		
Evans et al, 2009			x						x	Renewable Energy	
Geng et al 2012			x			x				T/A	China
Snapp et al, 2018			x			x			x	Agriculture	
Pauliuk, 2018			x			x			x	T	
Qureshi et al, 2019			x			x				T/A - Health	40 SSA countries
Fernandez et al 2019			x			x				A - Road	Portugal
De Walque, 2020									x	Health	
Valentin et al, 2000			x			x			x	Energy	Europe
Jumbri et al, 2020			x			x			x	T/A	140 countries
Euchi, 2021			x			x				Road Transport	Tunisia
Loizia et al 2021			x			x			x	T - review	
Woźniak et al, 2021			x			x			x	Biotechnology	Europe, Poland
Ciarrochi et al, 2022									x	A Social	Venezuela

The articles in Table 1 cover various sectors: health, agriculture, energy, transport and logistics, biotechnology. Their case studies may cover a single country or an entire continent. Some papers describe the state of the art at different points in time and at different levels. For example, Seuring et Müller (2008), Hassini, Surti, et Searcy (2012), Hariyani et Mishra (2022) examine the SCM level, and Loizia et al. (2021) take a broad view of public policy. Some papers focus on a single level, relating to one, two or three pillars. For example:

- At the company level (micro-level):

Martínez et Poveda (2022) describe the action plans of 120 microenterprises to improve environmental and sustainability performance.
Shad et al. (2019) explore a conceptual framework that examines the moderating effect of sustainability reporting practices on the relationship between enterprise risk management implementation and firm performance.
Based on the internalisation of externalities in the firm's performance reports, Eidelwein et al. (2018) present a methodology for preparing the economic and environmental performance statement.

- At the mezzo-level:

Using TBL, A. Winter et al. (2018) proposed a model to quantify the risks to support the design or redesign of a supply chain. The aim is to enable managers to make appropriate decisions in order to maintain the ability to meet customer requirements. Their tool allows a company to assess the sustainability performance of its customers' supply chain, regardless of the domain served by the specific customer.
Based on forty Scopus articles, Lsaputri, Hisjam et Sutopo (2020) conducted a review of sustainable metrics for sustainability measurement in the supply chain.
Deniaud, Marmier et Michalak (2021) proposed a customised methodology and tool to help managers design and pilot a transformation strategy towards digitalisation by prioritising the development axes, including the essential axis of sustainable supply chain. This contribution makes it possible to compare companies by sector of activity and typology in order to define

possible standards and, implicitly, to develop a "bench learning" approach. The tool allows the aggregation of all the assessments and automatically generates diagrams that allow the company to directly visualise its positioning in relation to the objectives of the supply chain. It can then build a strategy based on the company's indicators in relation to the supply chain objectives.
Li et Cruz (2022) analyse the impact of consumer willingness to pay, externality costs, production capacity, net present value discount rate, sustainability investments and supply chain network structure on economic, social and environmental sustainability.

- At the public policy level:

Nguyen-Van, Stenger et Tiet (2021) identify three social incentive factors for pro-environmental behaviour: social influence, network factors and trust.
Geng et al. (2012) find a lack of social indicators in the circular economy in China. Qureshi et al.(2019) show that particulate matter emission damages and high mass carbon emissions are largely associated with communicable diseases, which require sustainable health policies to limit the growth of particulate matter emissions in a panel of SSA countries. Fernandes et al. (2019) propose the design of eco-traffic management policies, taking into account environmental indicators that integrate transport-related externalities (traffic congestion, noise, greenhouse and nitrous oxide emissions, health impacts and costs associated with road crashes) and are adapted to local contexts of vulnerability. Euchi et Kallel (2021) develope a method to quantify congestion and CO2 emissions in road transport, in order to discuss some marginal and policy implications in sustainable road transport.
Some authors focus their work on a single pillar. For example, Pérez, et Rivas-Echeverría (2022) refer only to the social dimension of sustainable development and try to measure the living conditions of citizens (health, education, access to services, gender equality, security, poverty and population change). Pezzey et al. (2005) estimate two economic measures of the weak sustainability of an economy: the change in the augmented green net national product and the interest on augmented real savings. De Walque (2020) analyses the use of financial incentives (drug prohibition, taxation of alcohol and unhealthy foods, conditional cash transfers) to prevent unhealthy behaviours.

By studying these papers, we have also identified a number of barriers to progress in implementing sustainable development approaches. For example, Blake (1999) identifies three barriers to pro-environmental action: individuality (e.g. lack of interest), responsibility (e.g. lack of trust in institutions or government) and practicality (e.g. lack of time, money, information, facilities). They call for a more equitable distribution of responsibilities between different environmental actors: policy makers, institutions and individuals. Barriers are also identified by Kollmuss and Agyeman (2002). They distinguish between individual barriers (lack of knowledge, emotional blocking of new knowledge on environmental values, attitudes, lack of environmental awareness) and external barriers related to political, social and cultural factors or economic situation (e.g. lack of incentives and opportunities). Trianni, Cagno, et Neri (2017) identify barriers to the adoption of industrial sustainability measures. Some of these barriers are related to public policy: regulations (lack of incentives, legal requirements, bureaucracy and policy distortions), lack of external technical support and advice, market uncertainty. Other barriers are internal to companies: economic (hidden costs, risks, investments), management and organisational behaviour, worker behaviour, access to information, technology and services.

4. CONCEPTUAL FRAMEWORK AND MODELS

As we have seen in the precedents section, the literature tends to address only one pillar of sustainable development, or at best all three, but only at one level of the three: "company", "supply chain" and "public policy". Often the 'economic' pillar is the only found in the corporate strategy. Some companies integrate one of the aspects related to environmental awareness and others consider social and societal aspects.
However, to the best of our knowledge, there is no global model in the literature that allows for the consideration and integration of all possible sustainability incentives and their impact on the three pillars.
We aim to fill these gaps by developing in this section a set of models that cover different configurations of incentive integration across different strategies. In order not to lose sight of the fact that the integration of the three pillars is in itself a multi-dimensional decision problem, simulations are required for a good understanding of the implications. Each model helps to:

- explain why some companies choose to adopt sustainable behaviour and why others do not;
- analyse how they respond to public policies aimed at encouraging sustainable behaviour;
- analyse the combined effect of the use of public incentives and the choices made in the management of their activities;
- make better decisions to improve the company's results.

We propose a conceptual framework that integrates those models to understand the effect of the cumulative consideration of the three pillars proposed by Elkington (Elkington 1997).
The framework for sustainable management is proposed in Figure 1.

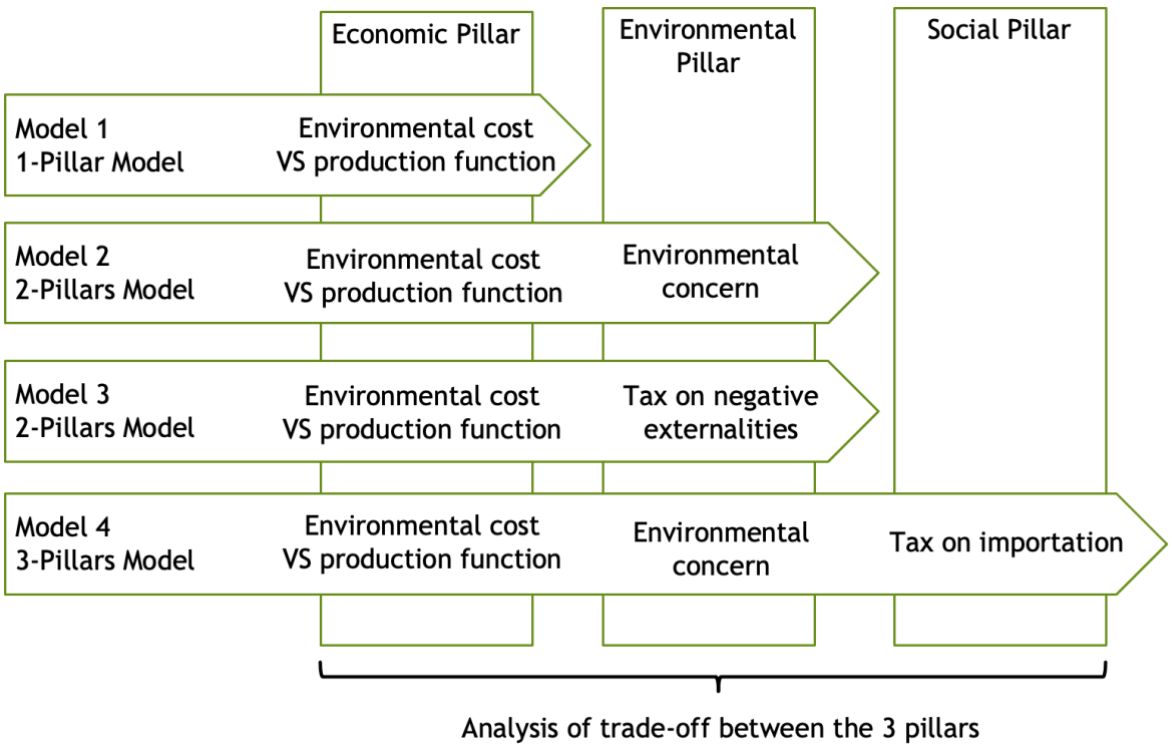

Figure 1. Framework for sustainable management

The proposed framework is divided into 3 steps:

1. Development of a basic model ignoring sustainable development aspects, in particular environmental and social aspects.
2. Integration of environmental (ecological and social) aspects into the model.
3. Integration of the intervention of the State, through two different public policies, into the model.

In the next section, we therefore propose four models that combine the three pillars and different public policies. We analyse the trade-offs between the different pillars of sustainable development. We also analyse the incentives that can lead companies to internalise their environmental, social and economic externalities.
To illustrate our ideas, we illustrate our models using the simple example of a laundry that can produce a unique service using a mix of two inputs: Organic and non-organic detergent. To keep the model as simple as possible, we do not explicitly model the other inputs such as labour, machines or clothes to be cleaned.
We then explore some generalisations to illustrate the trade-offs between the different pillars of sustainable development and the firm's responses to public policy.

Model 1: Focus on profit

The firm chooses to use a **quantity $X_1 \geq 0$** of Organic powder, sold at unit **price π_1** and a **quantity $X_2 \geq 0$** of non-Organic powder, sold at unit price π_2. The quantity of fabric which can be cleaned with these inputs is given by the **production function $f(X_1,X_2)$**, "sold" at **price p** per unit of fabric. Organic powder generates no externality, whereas non-Organic powder generates a **negative externality (environmental cost)**, **$g(X_2)$** depending on the quantity used.
We start with a basic model considering only economic pillar and relying on the following assumptions, which are intended to be both simple and realistic in the context.
Assumption 1*: $\pi_1 > \pi_2$: organic washing powder is more expensive than non-organic powder.*
Assumption 1 rules out trivial and unrealistic cases where only the organic powder would be used in the basic model with only economic pillar.
Assumption 2*: the two inputs are perfect substitutes, i.e. the quantity produced $f(X_1+X_2)$ only depends on the total quantity of inputs (X_1+X_2).*
Assumption 2 imposes some restriction and may not be fully realistic. It plays a non-negligible role to explain corner solutions (only one input is used). However, it greatly simplifies the computations, and the conclusions would not be fundamentally different without assumption 2.
Assumption 3*: production function f is increasing and concave: $f'(X_1+X_2)>0$ and $f''(X_1+X_2)<0$.*
The second part of Assumption 3 corresponds to decreasing returns to scale: the first kilogram of organic powder is more efficient than the second one. The first part of Assumption 3 simply means that the more washing powder you use, the cleaner your fabric.
Assumption 4*: Input 1 generates no externality, while input 2 generates a negative externality $g(X_2)$, with $g(0)=0$, $g'(X_2)<0$ and $g''(X_2)<0$.*
Assumption 4 means that the cost $-g(X_2)$ is increasing and convex, for the whole society.
Assumption 5*: For each input, the marginal productivity at origin is larger than the ratio of input to output price: $f'(0)>\pi_1/p$ and $f'(0)>\pi_2/p$.*

Assumption 5 means that, for each input, the marginal benefit is larger than the marginal cost for the first unit of washing powder used. This implies that, from a purely economic and selfish point of view, without taxation, at least some production would be worth with either input.
The **(financial) profit in the basic model Π1** is the value of production minus the cost of inputs:
$\Pi 1(X_1, X_2;\pi_1,\pi_2,p)=p\ f(X1+X2)-\pi_1 X1-\pi_2 X_2$
The solution of the basic model is that the firm uses only the non-sustainable input X_2. At the optimum, $X_2^*=f'^{-1}(\pi_2/p)$ is a decreasing function of π_2/p
The optimal quantity of non-organic powder 2, X_2^*, is a decreasing function of the ratio of input to output prices.

Model 2: Focus on sustainable concerns, without tax

We now focus on both economic and environmental pillars.
Model 2 considers the case of a more or less sustainable firm, to illustrate the trade-off between the economic pillar and the environmental pillar. Each Laundry is characterized by its **degree of environmental concern, σ**, which measures the weight attached to the environmental externality $g(X_2)$ in the **sustainable profit Π2** maximized by the Laundry. It corresponds to the value of the production minus the cost of inputs, plus a fraction, σ, of the negative externality generated by the non-sustainable input:
$\Pi_2(X_1, X_2;\pi_1,\pi_2,p,\sigma)= p\ f(X_1+X_2)-\pi_1 X_1-\pi_2 X_2+\sigma g(X_2)$
The least sustainable firms ($\sigma<\sigma_1$) use only the non-organic washing powder; its quantity, X_2 (orange curve) decreases with the degree of environmental concern, as well as the quantity produced (dash-doted black curve), the financial profit (dotted blue curve), the sustainable profit (solid blue curve) and the magnitude of externality (dashed red line). Thus, the effect of environmental concern is to decrease both production and pollution, enhancing the trade-off between economic and environmental pillars.
The most sustainable firms ($\sigma>\sigma_2$) use only the organic washing powder; its quantity, X_1 (green curve) does not depend on the degree of environmental concern, nor the quantity produced, the financial profit (dotted blue curve), the sustainable profit (solid blue curve) or the magnitude of externality (dashed red line). Thus, the degree of environmental concern has no effect on production nor on pollution, above some threshold, since the firm already does its best concerning the environmental pillar.
In-between, for a firm with an intermediate level of environmental concern ($\sigma_1<\sigma<\sigma_2$), the effect of increasing σ is to substitute more non-organic powder by organic powder, keeping constant the total quantity of input as well as production level, and decreasing both externality and financial and sustainable profit. For such intermediate firms, there is a trade-off between economic and environmental pillars (financial profit versus externality), but not for the rest of society, since total production is not affected by the degree of environmental concern.
Figure 2 represents the effect of the degree of environmental concern on the quantities of inputs and output, and on the financial and sustainable profit. Two thresholds for the degree of environmental concern, $\sigma_1<\sigma_2$, define three regimes, as discussed below.

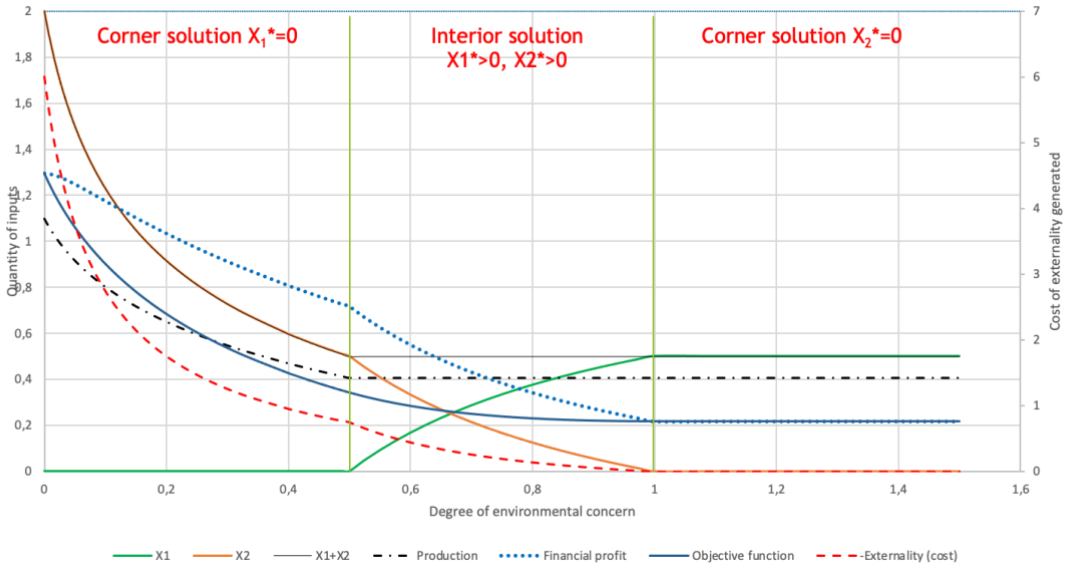

Figure 2: Effects of the degree of environmental concern

Model 3: Focus on environmental concern, with tax on externalities

We now introduce a tax rate, τ, on the negative externality. This tax rate may affect the firm's degree of environmental concern, which becomes σ'(σ,τ).

Assumption 6*: The change in the degree of environmental concern induced by the tax partially offsets this tax:* $\sigma \leq \tau+\sigma'(\sigma,\tau)\leq\tau+\sigma$, *i.e.* $\sigma-\tau \leq \sigma'(\sigma,\tau) \leq \sigma$.

Assumption 6 seems natural since σ measures how much the firm feels guilty for polluting. If the firm is taxed for polluting, it feels less guilty, hence $\sigma'(\sigma,\tau) \leq \sigma$. However, it would seem quite unrealistic that the firm would overreact to taxation. It seems more realistic that, even though taxation reduces the firm's degree of environmental concern, the firm still feels more concerned by the externality it generates when tax (economic concern) adds to (reduced) environmental concern, thus $\tau+\sigma'(\sigma,\tau) \geq \sigma$.

The firm now maximizes the sustainable and environmentally-taxed profit Π3:

$\Pi 3(X_1, X_2;\pi_1,\pi_2,p,\sigma,\tau)= p\, f(X_1+X_2)-\pi_1X_1-\pi_2X_2+(\tau+\sigma'(\sigma,\tau))g(X_2)$

All the results obtained with Model 2 directly apply to Model 3, simply replacing σ with $\tau+\sigma'(\sigma,\tau)$. The effect of taxation on the laundry behaviour is simply to increase its degree of environmental concern from σ to $\tau+\sigma'(\sigma,\tau) \geq \sigma$, i.e. to move it to the right on Figure 1. The effect of taxation thus depends on the firm's degree of environmental concern.

The least sustainable firms (such that $\tau+\sigma'(\sigma,\tau)<\sigma_1$) still only use the non-organic washing powder and decrease their production, their profit, as well as the magnitude of externality. Taxation meets its objective of reducing pollution, but this implies a cost on the activity and on the economic viability of the least sustainable firms. Some of these firms may go bankrupt if their sustainable and taxed profit becomes negative.

Taxation does not affect the most sustainable firms, which do not use the non-organic washing powder anyway (with or without tax).

In-between, taxation induces the firm such that $\sigma_1<\tau+\sigma'(\sigma,\tau)<\sigma 1$ to substitute more non-organic powder by organic powder, keeping their production constant, and decreasing both externality and profit. For such intermediate firms, there is a trade-off between economic and environmental pillars (financial profit versus externality), but not for the rest of society, since

total production is not affected by the degree of environmental concern. Except for the firms such that the sustainable and taxed profit becomes negative, leading to bankrupt.
Overall, Model 3 illustrate the fact that the trade-off between environmental and economic pillars concerns mainly the firms with the lowest degree of environmental concern.

Model 4: Focus on environmental concerns, with tax on importations

The previous sections were only concerned by the economic and environmental pillars. Indeed, Model 3 assumed that the sustainable firms and the State are concerned by the same externality, generated by the same input, X_2, and evaluated by the same function, $g(X_2)$. We now add the social pillar. Model 4 extends the analysis of Model 2 (we do not mix the two cases to keep the analysis as simple as possible) to the case where the state is concerned by a pillar (social concern) different from the one of sustainable firms (environmental concern).
To illustrate this case, we assume that the organic powder is produced abroad, whereas non-organic powder is produced locally. In order to enhance the social pillar, the state thus decides to tax non-organic powder (per unit of input used). The tax rate on input 1 thus adds to its market price, and the firm now maximizes the sustainable and socially-taxed profit Π4:
$\Pi 4(X_1, X_2;\pi_1,\pi_2,p,\sigma,\tau_1)= p\, f(X_1+X_2)-(\pi_1+\tau_1)X_1-\pi_2X_2+\sigma g(X_2)$.
The results of Model 2 extend to Model 4, replacing π_1 with $\pi_1+\tau_1$. The behaviour of the least sustainable firms is not affected by the tax on organic powder, since they do not use it. However, our model predicts that the tax on organic powder increases the threshold σ_1, implying that some firms who use the organic powder without tax stop using it with tax. Furthermore, the total quantity of input used and the quantity produced decrease with the tax rate, for the most sustainable firms ($\sigma>\sigma_1$).
Overall, Model 4 illustrates the trade-off between environmental and social pillars, for the firms with the largest degree of environmental concern, and also for intermediate levels. This very simple but illustrative example shows the mechanisms explaining how introducing a tax to favour employment may be detrimental to environment.

5. CONCLUSIONS & PERSPECTIVES

However, the literature review revealed that often only one pillar or one aspect of one of the pillars was considered. No global model was identified that allows the consideration and integration of sustainability incentives and their impact on the three pillars. To fill this gap, we developed a global framework for sustainable management, taking into account the level of environmental concern. The framework includes a set of models and simulations covering different configurations of incentive integration across different strategies. The framework can be used to assess and compare how different public policies affect business decisions differently depending on the level of sustainability concern. We have used a laundry example to illustrate the diversity of responses that can be expected to different sustainable development policies and the trade-offs between the three pillars.
In such a situation, public policies should consider the three pillars simultaneously and could be better optimised. Such optimisation is complex and deserves more analysis, both in terms of modelling and empirical application, including data collection. However, it is feasible and such scientific investment and dissemination to public decision-makers is necessary to promote the three pillars of sustainable development simultaneously.

In perspectives, we aim to develop a questionnaire to assess a company's level of performance on the various pillars of sustainable development. This will make it possible to carry out sectoral and longitudinal analyses.

Bibliography

Blake, James. 1999. “Overcoming the ‘Value-action Gap’ in Environmental Policy: Tensions between National Policy and Local Experience”. Local Environment 4 (3): 257-78.

Brundtland, Gro Harlem. 1987. “Our Common Future—Call for Action”. Environmental Conservation 14 (4): 291-94.

Ciarrochi, Josseny, Anna Gabriela Pérez, et Francklin Rivas-Echeverría. 2022. "Social Sustainability Measurement for Venezuela During 2007–2009“. Design, construction, maintenance 2, 42-47.

Deniaud, Ioana, François Marmier, et Jean-Louis Michalak. 2021. “4.0 Transition Methodology for Sustainable Supply Chain Management”. In IFIP APMS proceedings: Artificial Intelligence for Sustainable and Resilient Production Systems 5: 626-33, Springer.

De Walque, Damien. 2020. “The Use of Financial Incentives to Prevent Unhealthy Behaviors: A Review”. Social Science & Medicine 261: 113236.

Eidelwein, Fabrício, Dalila Cisco Collatto, Luis Henrique Rodrigues, Daniel Pacheco Lacerda, et Fabio Sartori Piran. 2018. “Internalization of Environmental Externalities: Development of a Method for Elaborating the Statement of Economic and Environmental Results”. Journal of Cleaner Production 170: 1316-27.

Elkington, John. 1997. Cannibals with Forks: Triple Bottom Line of 21st Century Business. Oxford, U.K.: Capstone Publishing Ltd.

Euchi, Jalel, et Ahmed Kallel. 2021. “Internalization of External Congestion and CO2emissions Costs Related to Road Transport: The Case of Tunisia”. Renewable and Sustainable Energy Reviews 142: 110858.

Fernandes, P., M. Vilaça, E. Macedo, C. Sampaio, B. Bahmankhah, J. M. Bandeira, C. Guarnaccia, et al. 2019. “Integrating Road Traffic Externalities through a Sustainability Indicator”. Science of The Total Environment 691: 483-98.

Geng, Yong, Jia Fu, Joseph Sarkis, et Bing Xue. 2012. “Towards a National Circular Economy Indicator System in China: An Evaluation and Critical Analysis”. Journal of Cleaner Production 23 (1): 216-24.

Gollier, Christian. 2022. Entre fin de mois et fin du monde.Economie de nos responsabilités envers l’humanité. Collège de France. Ed.Fayard.

Govindan, Kannan, Mahesh Shaw, and Abhijit Majumdar. 2021. “Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development”. Journal of cleaner production 279: 123075.

Hariyani, Dharmendra, et Sanjeev Mishra. 2022. “Drivers for the Adoption of Integrated Sustainable Green Lean Six Sigma Agile Manufacturing System (ISGLSAMS) and Research Directions”. Cleaner Engineering and Technology 7: 100449.

Hassini, Elkafi, Chirag Surti, et Cory Searcy. 2012. “A Literature Review and a Case Study of Sustainable Supply Chains with a Focus on Metrics”. International Journal of Production Economics 140 (1): 69-82.

Kaplan, Robert S., et David P. Norton. 2005. “The Balanced Scorecard: Measures That Drive Performance”. Harvard Business Review 83 (7).

Kollmuss, Anja, et Julian Agyeman. 2002. “Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to pro-Environmental Behavior?”. Environmental Education Research 8 (3): 239‑60.

Lecocq, Xavier, Benoît Demil, et Vanessa Warnier. 2023. “Moving business models forward for positive social, environmental and economic outcomes: Managing externalities (and internalities) for sustainability innovation”. Journal of Business Models 11.3: 117-132.

Li, Dong, et Jose M. Cruz. 2022. “Multiperiod Supply Chain Network Dynamics under Investment in Sustainability, Externality Cost, and Consumers’ Willingness to Pay”. International Journal of Production Economics 247: 108441.

Loizia, Pantelitsa, Irene Voukkali, Antonis A. Zorpas, Jose Navarro Pedreño, Georgia Chatziparaskeva, Vassilis J. Inglezakis, Ioannis Vardopoulos, et Maria Doula. 2021. “Measuring the Level of Environmental Performance in Insular Areas, through Key Performed Indicators, in the Framework of Waste Strategy Development”. Science of The Total Environment 753: 141974.

Lsaputri, V H, M Hisjam, et W Sutopo. 2020. “A Review on Sustainable Metrics for Sustainability Measurement in Supply Chain”. IOP Conference Series: Materials Science and Engineering 943 (1): 012056.

Malthus, T. R., Donald Winch, et Patricia James. 1992. Malthus: « An Essay on the Principle of Population ». Cambridge University Press.

Martínez, Clara I P., et Alexander C. Poveda. 2022. “Strategies to Improve Sustainability: An Analysis of 120 Microenterprises in an Emerging Economy”. Global Sustainability 5: e3.

Martinho, Vítor J. P. D. 2021. « Insights into Circular Economy Indicators: Emphasizing Dimensions of Sustainability ». Environmental and Sustainability Indicators 10: 100119.

Milne, Markus J. et Rob Gray. 2013. “W(h)Ither Ecology? The Triple Bottom Line, the Global Reporting Initiative, and Corporate Sustainability Reporting”. Journal of Business Ethics 118 (1): 13‑29.

Nakagawa, Maho. 2022. “Permanence in Economics, Social Preferences and Social Interactions - Application to Environmental Issues”. University of Strasbourg.

Nguyen-Van, Phu, Anne Stenger, et Tuyen Tiet. 2021. “Social Incentive Factors in Interventions Promoting Sustainable Behaviors: A Meta-Analysis ». Édité par Sergio A. Useche. PLOS ONE 16 (12): e0260932.

Martínez, , Clara I P., et Alexander C. Poveda. 2022. “Strategies to Improve Sustainability: An Analysis of 120 Microenterprises in an Emerging Economy”. Global Sustainability 5: e3.

Pezzey, John C. V., Nick Hanley, Karen Turner, et Dugald Tinch. 2005. “Augmented Sustainability Measures for Scotland”, 35.

Qureshi, Muhammad Imran, Shazia Qayyum, Abdelmohsen A. Nassani, Abdullah Mohammed Aldakhil, Muhammad Moinuddin Qazi Abro, et Khalid Zaman. 2019. “Management of Various Socio-Economic Factors under the United Nations Sustainable Development Agenda”. Resources Policy 64: 101515.

Seuring, Stefan, et Martin Müller. 2008. “From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management”. Journal of Cleaner Production 16 (15): 1699‑1710.

Shad, Muhammad Kashif, Fong-Woon Lai, Chuah Lai Fatt, Jiří Jaromír Klemeš, et Awais Bokhari. 2019. “Integrating Sustainability Reporting into Enterprise Risk Management and Its Relationship with Business Performance: A Conceptual Framework”. Journal of Cleaner Production 208: 415‑25.

Simon, Herbert A. 2019. The Sciences of the Artificial, reissue of the third edition with a new introduction by John Laird. MIT press.

Slaper, Timothy F., et Tanya J. Hall. 2011. “The triple bottom line: What is it and how does it work”. Indiana business review 86 (1): 4‑8.

Trianni, Andrea, Enrico Cagno, et Alessandra Neri. 2017. “Modelling Barriers to the Adoption of Industrial Sustainability Measures”. Journal of Cleaner Production 168: 1482‑1504.

United Nations. 2015. “Sustainable development goals: Communications materials“. Retrieved from https://www.un.org/sustainabledevelopment/news/communications-material/. (Accessed 12 December 2023).

Winter, Anne, Ioana Deniaud, François Marmier, et Emmanuel Caillaud. 2018. “A risk assessment model for supply chain design. Implementation at Kuehne + Nagel Luxembourg”. In GOL 2018: 4th IEEE International Conference on Logistics Operations Management, 1‑8.

Winter, Anne, Ioana Deniaud, et Emmanuel Caillaud. 2014. “Risk assessment of a sustainable supply chain. Case study at Kuehne+ Nagel Luxembourg”. In GOL 2014: 1rst IEEE International Conference on Logistics Operations Management, 118‑24.