Dietary changes for a better environment? A quali-quantitative policy assessment[1]

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Over the last fifteen years, meat production has gained attention as an emitter of GHGs. In view of a generalized reduction of anthropogenic emissions, several scholars have been debating on which measures to adopt in order to reduce meat consumption. This paper aims at contributing to this discussion with an integrated policy assessment. The strength of this novel approach is that it couples a quantitative with a qualitative analysis in a unified framework. Focusing on the EU, we evaluate two of the most debated policies (a tax measure and an information campaign), according to the attributes of the economic policy evaluation (effectiveness, efficiency, equity and feasibility). The quantitative analysis applies a dynamic model of the world economy with specific GHG emission flows. As we are aware of the limits of this type of analysis, we articulate its results with the findings of the qualitative analysis. We find that both policies score relatively well in terms of efficiency and equity, whereas their effects on emissions' reduction are below the one-percent threshold. While this result is in line with other findings in the literature, it seems to challenge the idea that meat consumption policies can have a potential in curbing GHG emissions.

Key words: meat production, GHG emissions, integrated policy assessment, qualitative analysis, CGE modelling

JEL codes: C68, D04, D58, H21, H23, Q18, Q58

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1 Introduction

Concerns about the environmental costs of meat production activities are quite recent (Ripple, 2014). Only two decades ago, for instance, Goodland (1997) blamed that there was "no agreement that diet matters for environmental sustainability in the agriculture sector" (Goodland, 1997, p. 189). His analysis however, already identified in the livestock sector the most harmful agricultural branch from an environmental point of view. Today, the environmental responsibility of the livestock sector is widely documented. The external impacts of meat production activities are manifold, and they include groundwater pollution, GHG emissions, soil degradation. As to GHG emissions, many studies provide estimates of the total amount of GHG emissions due to meat production, and figures are quite diverse. In terms of total emission burden, emissions from the livestock sector oscillate between a lower bound of 10%-12% (Friel et al. 2009) and an upper bound of 25%-30% (Wirsenius et al. 2011). According to a FAO's report, (Steinfeld et al. 2006) meat production is responsible for approximately 18% of total human emissions. For their role in climate change, GHG emissions are at the same time the main "bad" of the livestock sector and a promising channel of climate change reversal (Cook et al. 2013). For this reason, a reduction in GHG emissions arising from meat production sector is an urgent priority.

The logic behind any policy intervention in the meat sector strictly depends on the type of relationship between output quantities and emissions. In a "conservative" view, this relationship is given, and the only way to limit emissions is to reduce output. Theory suggests that policies may target either the supply side or the demand side. Mostly discussed policy initiatives include production taxes (on the supply side), consumption taxes and information campaigns (on the demand side). Information campaigns should increase consumers' awareness about the environmental effects of meat production, and induce them to modify their dietary habits. According to an alternative "less conservative" view, the relationship between emissions and output quantity can be indeed modified, and it is a policy target itself. In this perspective, policies to abate emissions target production techniques, with the aim of making them more efficient from an environmental point of view. In this case, lower emissions do not necessarily mean less production.

In the relevant literature, there is a wide consensus about the inefficiency of production taxes. Several authors, as for example Wirsenius et al. (2011) and Nordgren (2012) maintain that this type of measure would cause "high monitoring costs" (Nordgren 2012, 578). The measurement of methane and nitrous oxide from farms would have to be a continual process, by which measurements of significant samples of different animals would "need to be carried out regularly" (Nordgren 2012, 578)[2]. These authors, together with Eshel and Martin (2006)[3] and Ripple (2014) are convinced that a consumption tax should be indeed efficient in inducing an effective change in dietary habits. This view however is not unanimous. Randall (2014) for example, identifies two main weaknesses of a consumption tax. On the one side, he claims, the effectiveness of any consumption tax would be undermined by the low price elasticity of poultry meat, which has a lower carbon footprint than cattle or pig meat, but it not innocuous from this point of view. On the other side, he believes that the lack of awareness among the public about the environmental externalities of meat production would make a consumption tax hard to understand and thus hardly acceptable. The idea that information campaigns are a crucial element of any policy initiative in the area of meat consumption is one of the conclusions of Röös et al. (2014). However, while Röös et al. (2014) see information campaigns as an appropriate tool to increase effectiveness and acceptability of a consumption tax, Randall (2014) shares the "less conservative" view regarding the relationship between emissions and output and does believe that policies, which

[2] See also Edjabou and Smed (2013).
[3] See Frank (2007)

contribute to modify production techniques in order to render them environmentally more efficient, may be more effective.

The possibility of modifying the relationship between output quantity and emissions implies that the policy menu to reduce emissions in the livestock sector is wider. According to a FAO study (Gerber et al., 2013) it is possible to change the meat production process in order to make it more efficient from an environmental point of view. In this framework, there is wide scope for improvements in the feed quality and in animal health, for example. According to the report, it should be possible to achieve an emission reduction as high as 30%. The idea that the meat production process can be significantly improved is contained also in other previous studies, which highlight the weaknesses of the so-called intensive production system in comparison to the extensive one (e.g. Seidl, 2000). In the case of groundwater pollution due to manure deposits, Frank (2007) notes that, manure per se is not the problem, being rather its density. When applied in the correct amount, ruminants' manure is not a pollutant, but also it is useful as a fertilizer (on this point, see, for example, Ribaudo et al., 2003 and Hoag et al. 2004). Manure turns into a problem once production methods become intensive because in most cases manure is not managed in a sustainable way[4]. This example makes clear that internal (economic) efficiency and external (environmental and social) efficiency do not overlap in the case of meat production. As to the social inefficiency of large production settlements, the relevant literature has developed in various directions, and it includes for example a strand (e.g. Murbarak et al. 1999; Palmquist et al. 1997; Park et al. 1988), which studies how house prices falls with the point distance to the CAFOs (concentrated animal feeding operations). Wing and Wolf (2000) show that the rates of physical and mental illness are higher for people living near an intensive livestock operation.

The heterogeneity of views regarding which policy may actually succeed in reducing negative impacts on the environmental of meat value chain, suggests that further research is needed in this area. A major issue in the current debate relates to whether policies should be inspired by the "conservative" or by the "less conservative" view about the relationship between output and emissions. In other words, the question of whether to intervene on output quantities (e.g. Wirsenius et al., 2011; Nordgren, 2012; Ripple; 2014) or on production techniques (e.g. Gerber et al., 2013; Randall, 2014). Information campaigns, in fact play a mere ancillary role in both cases. From an effectiveness point of view, initiatives targeting production practices seem more promising than consumption taxes, as their potential in terms of emission reduction reaches 30% of total emissions according to Gerber et al. (2013) whereby a consumption tax would achieve a 12%-14% emission reduction (Wirsenius et al. 2011).

This paper contributes to this policy debate with a novel ex-ante policy assessment exercise, which relies on an *integrated* approach. This method couples qualitative and quantitative instruments in a single, unified framework of analysis. In this perspective, both types of instruments are necessary and they complement one another. The rationale for evaluating policies qualitatively and quantitatively lays in the nature of these two types of analyses. Ex-ante (model-based) quantitative analyses are necessarily stylized since they can capture only those aspects of reality, which can be objectively measured. Quantitative models for example face difficulties in accounting for differences in production techniques. The qualitative analysis, on the other side, can throw light on a larger number of issues, which the quantitative analysis is bound to neglect. The need for both types of analyses also follows from the multi-criteria methodology adopted in the spirit of Rossell (1993). According to this author, a policy may be scrutinized according four distinct criteria, namely effectiveness, efficiency, equity and political feasibility. These four attributes clearly reflect measurable and non-measurable aspects, which can be at best assessed through an integrated approach.

[4] The source of this issue is extreme specialization: nowadays livestock farmers only deal with animal breeding, and not with growing crops as well as it used to be the case.

Our policy assessment exercise focuses on policies, which assume the "conservative" view of the livestock sector. Our analysis focuses on the EU and its aim is twofold. On one hand, we are interested in comparing the two mostly debated strategies to reduce meat demand, i.e. a consumption tax and a targeted information campaign. On the other hand, we seek to elicit the full potential of this type of policies in comparison to those, which are based on the "less conservative" view of the meat production process. For this reason, we rely upon a intertemporal CGE model to quantify the effectiveness and the efficiency of both policies under analysis. The dynamic framework allows in fact accounting for the largest spectrum of re-allocation effects arising from exogenous policy changes. This means that the quantitative effects are larger in this framework than in any other static simulation setting. In addition, we assume particularly optimistic scenarios for both policies. In the case of the meat consumption tax, we specify it as a EU-wide harmonization of VAT rates on meat to the standard rate of 20%. For the quantitative evaluation of the effects of a hypothetical information campaign in the EU countries, we allow for the most optimistic scenario, in which EU consumers totally shift to a low-protein diet. However, in order to keep our analysis realistic, we assume that EU consumers decide to adopt the least meat-intensive diet at EU level, which is the one of Bulgarian consumers. In this respect, our approach differs from the one by Tukker et al. (2011) and Wolf et al. (2011) who set-up ideal low-protein diets, and assume that EU consumers adopt them.

Our quantitative findings indicate that the contribution of both policies in terms of reduced emissions is quite negligible. Over the entire simulation period (which spans from 2020 to 2050), the harmonization of VAT rates on meat brings about a reduction in CO_2 – equivalent emissions by 0.16% (at EU level) while in the case of a particularly effective information campaign this reduction would be approximately 0.27%. From an effectiveness point of view, both policies perform far worse than policies focusing on the production process (Gerber et al. 2013). Other major findings relate to the overall economic effects of these policies. In the case of the VAT rates' harmonization, the GDP effect is slightly negative in most EU countries whereas the opposite occurs in the case of information campaigns. This result is relevant for both the efficiency and the feasibility assessment. If we neglect the costs, arising from the implementation of each policy, a little but still positive GDP growth in the case of the information campaign can be interpreted as an efficiency improvement. Moreover, a policy with positive economic effect is in any case preferable to a policy, which requires material sacrifices. In general, our results show that information campaigns may be effective, efficient fair and feasible (see however the case of the Danish "fat tax" in Bødker et al., 2015) and thus preferable to market based measures on the demand side. However, the limited effect of both policies on total emissions despite the dynamic simulation framework and the optimistic assumptions behind the specification of both policies, prompt us to challenge the idea that emissions can be reduced by reducing output quantities. Moreover, the results reported by Gerber et al. (2013) seem to suggest that targeting production techniques is a much more effective strategy than acting on quantities. This would help reducing the environmental impact of meat production, and would simultaneously ensure improvements in on-site animal welfare.

This paper belongs to the literature concerned with the evaluation of policies aimed at changing consumers' dietary habits for environmental motives. Papers in this literature can be grouped according to four dimensions. The first relates to the type of policy under investigation, which can be a market-based measure, a regulatory policy, or an information campaign. The second dimension refers to the methods employed by the analysis (quantitative vs. qualitative) while the third dimension focuses on which attribute of the policy (effectiveness, efficiency, equity, political feasibility) is considered. The fourth dimension distinguishes whether the study is ex-ante or ex-post in nature. As to market-based policies, Wirsenius et al. (2011) and Nordgren (2012) quantitatively investigate the effectiveness of a meat consumption tax. Two papers, very similar to one another - Tukker et al. (2011)

and Wolf et al. (2011)- apply input-output analysis to show that the effectiveness of information campaigns inducing changes in diets are negligible. Edjabou and Smed (2013) study quantitatively effectiveness and efficiency of a consumption tax on 23 different types of food, and they find that this type of initiative is effective. Another contiguous and much more developed literature focuses on policies inducing dietary changes for health-related reasons (for a recent review of studies, which quantify the effectiveness of market-based policies, see Niebylski et al., 2015). An example of one ex-post estimation exercise is Nordström and Thunström (2011) who quantify the distributional effects of market-based measures, which aim at inducing healthier grain consumption in Sweden. Another ex-post qualitative assessment is Bødker et al., (2015) which thoroughly study the whole history of the "fat tax" in Denmark with particular attention to its political feasibility.

This paper contributes in two ways to the existing literature on economic policy assessment in the field of dietary change for environmental motives. We are not aware of papers, which quantify the effects of policies targeting meat demand by using intertemporal computable general equilibrium (CGE) models, nor are we aware of studies, which perform a multi-criteria integrated assessment of such policies. The intertemporal model we use, ICES[5], contains an environmental module that allows assessing the effects of a policy in terms of most important GHG emissions (CO_2, N_2O, CH_4). The coupling of the quantitative dynamic analysis and the qualitative one in a unified integrated assessment is a necessary strategy when performing a multi-criteria analysis. This methodologically novel approach allows giving particular robustness to the results.

In the next section, we provide a brief background analysis of the main types of environmental externality in the meat production sector. Section 3 reviews the ongoing debate on which policies have the highest potential to reduce these impacts, and it describes the details of the two policies under investigation in this paper. Section 4 is about the methods employed in the integrated policy assessment. In Section 5, we illustrate the main economic effects, which we can expect from the introduction of the two policies according to ICES. Section 6 is devoted to the results of the integrated policy assessment while Section 7 discusses them. Section 8 concludes.

2 The environmental costs of meat production

The livestock sector is responsible for a variety of environmental externalities. The main objective of this section is to provide some basic information about the most important ones.

A major source of concern is due to the GHG emissions. In the case of the livestock sector, these include nitrous oxide (N_2O), ammonia (NH_3) and methane which originate from manure deposits. Part of methane emissions are enteric. According to some studies, which adopt a (life-cycle assessment) LCA perspective, fertilizers used to produce animal feed should be also included.

According to some authors (e.g. Frank, 2007), a further type of externality derives from the inefficient use of land, which is allocated to pasture while it could be used to grow crops. However, Seidl (2000) refers to Wade et al. (1998) who observe that "lands grazed for livestock are largely economically untenable for row crops" (Seidl, 2000, p. 6).

[5] ICES is the acronym of Intertemporal Computable Equilibrium System, which is developed at Fondazione Eni Enrico Mattei. See http://www.icesmodel.feem.it/

Table 1 reports the main sources of environmental externality with the estimates in the existing literature.

Table 1 Main externality sources in the livestock sector (fraction over total anthropogenic emissions)

	Origin	EPA (2002)	Steinfeld et al. (2006)		
CH_4	enteric manure	22%			
CO_2	respiration		9%		
N_2O	manure				
NH_3	manure				

The type and intensity of externalities in the livestock sector strictly depend on the type of production technique. Seidl (2000) collects a number of studies, which show that many impacts would be lower if intensive techniques were replaced by extensive production methods. These would mean lower "purchased inputs (Ward et al., 1980; Pimentel and Pimentel, 1996), lower risk of environmental damage due to nutrient loading (e.g. Owens et al., 1983; Young et al., 1985; van der Molen et al., 1998), and greenhouse gas emissions (Jarvis and Pain, 1994) relative to intensively managed livestock" (Seidl, 2000, p. 6).

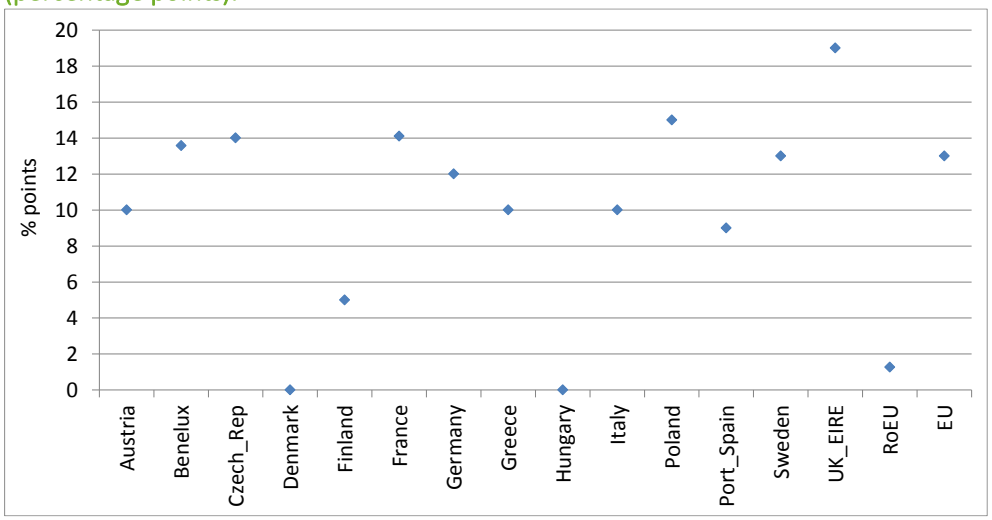
3 Policies to curb emissions in the livestock sector

We propose two policies, which willingly reflect the "conservative" view of the relationship between emissions and output quantities in the livestock sector. Our aim in fact is to assess how successful this type of policies could be in the case of the EU in order to compare them with the alternative strategy that is based on the "less-conservative" view.

The first policy is a market-based measure. In the spirit of the proponents of a consumption tax on meat, we assume a EU-wide harmonization of VAT rates on meat products. Since VAT rates on meat are quite low in most EU countries, the consequent increase in meat prices is substantial. The idea of adjusting an already existing tax seems preferable to the introduction of a new one for a variety of reasons, which mostly reflect efficiency and political acceptability issues.

Figure 1 summarizes the consequent change in meat VAT needed in each country.

Figure 1 Gap between current level of VAT on meat and current average VAT rate in EU countries (percentage points).

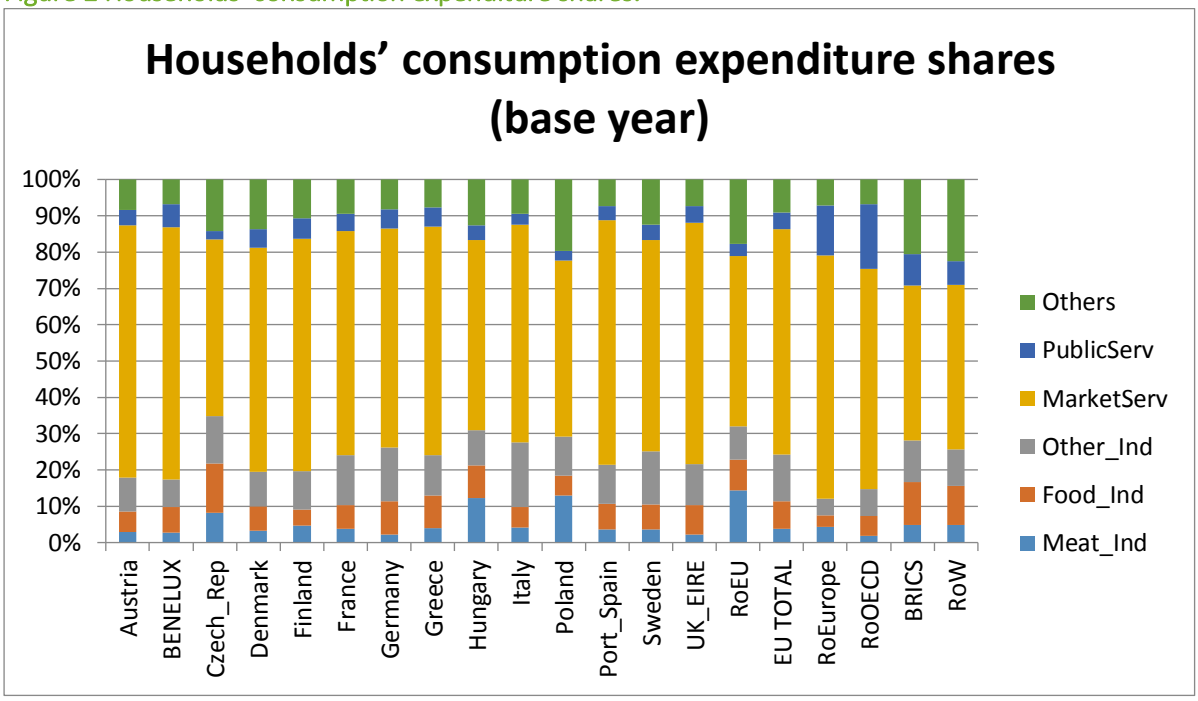


In no EU country, VAT rates on meat products fall while they remain unchanged only in Hungary and Denmark because they already equate the national average level and they only increase marginally in the rest of the EU (RoEU).

In our simulation exercise, the VAT harmonization policy targets one sector, i.e. MEAT INDUSTRY. VAT rates are increased on both final and intermediate sales. Following the chosen sectoral aggregation (see appendix), MEAT INDUSTRY does not include dairy products, which remain tax-exempt (note that in our sectoral aggregation, AGRICULTURE includes milk production).

A look at consumers' expenditure shares (See Figure 2) shows that our policy only affects households indirectly. In the base-year, in fact, the EU-average expenditure on MEAT INDUSTRY is 1.77% over total consumption spending while the expenditure shares on FOOD INDUSTRY and MARKET SERVICES (which includes the retail sector, indeed – see Appendix) are respectively 8.57% and 62.21%.

Figure 2 Households' consumption expenditure shares.



The second policy is an information campaign. This measure is an awareness campaign that aims to encourage and achieve a change towards diets with less meat. The basic idea is that the provision of information and advice to consumers will create awareness and foster behavioural change. Information should be in fact tailored to the audience, in terms of media used and contents. The campaign should take into account channels to induce the desired behavioural change while generic provision of information is not enough. It should be combined with other policies targeted at enhancing resource efficiency in the food sector.

A major issue regarding information campaigns is that the degree of uncertainty around their effects on the public is high (the literature, which seeks to quantify their effectiveness ex-post, is still in an initial stage). The results of the qualitative evaluation of information campaigns are contained in Section 6. For the sake of our quantitative exercise, here we just need to realize that such a policy can be either fully ineffective or fully effective, or it can have some intermediate degree of effectiveness. If it is fully ineffective, it brings about no quantitative effects (a part from the realization-related expenses), and the simulation exercise has no scope. However, there is wide consensus in the literature that information on agri-food markets is highly incomplete and asymmetric (e.g. Verbeke, 2005; Randall, 2014). According to some authors (e.g. Laestadius et al., 2013), this is also due to the "general lack of formal campaigns". Therefore, we are allowed to believe that the effect of information initiatives can be significantly positive indeed. Since we intend to compare our results with those obtained by Gerber et al. (2013), we allow for the most optimistic scenario in terms of effectiveness for an information campaign. In order to keep realism, we assume that our hypothetical information campaign induces consumers in all EU countries to adopt the same dietary habits as in Bulgaria, which features the least meat-intensive diet in the EU. The fact that consumers do not simply adopt a healthy but hypothetical diet gives this scenario full realism.

Note that this does not mean that this exercise is not highly stylized. Like every quantitative analysis, there are some aspects, which cannot be accommodated:

- It does not consider issues related to the quality of what is consumed; that is, meat and non-meat are undifferentiated aggregates (thus, for instance, poultry and beef are the same in this framework) .
- It does not quantify nor evaluate economically the potentially positive health effects induced by the dietary shift.
- It quantifies environmental effects only in terms of changes in GHG emissions and associated social gains.
- It abstracts from any consideration about the design, implementation strategies and costs of the information campaign.

With these qualifications in mind, it is assumed that, following the campaign, each EU country, while keeping unchanged the total per capita caloric intake of the reference scenario, redistributes it across meat and non-meat-based food, mimicking the least meat-intensive European country. This is Bulgaria whose average citizen gets today 21% of her/his calories from meat and 79% from other (non-meat) food[6]. It is assumed that the campaign starts in 2020 and slowly reaches its objectives in 2050.

Table 2 reports the reallocation between meat and non-meat food categories required in each country. The largest change in habits would affect Finland that is expected to reduce meat consumption by -39% and increase that of non-meat by 21%. The mildest change awaits Greece with a meat consumption reduction of the -21% and an increase in consumption of non-meat food products of the 3.5%.

Table 2 Dietary change fostered by the information campaign (%).

	Meat consumption	Non-meat food consumption
Austria	-27.24	11.16
BENELUX	-32.70	14.98
Czech_Rep	-20.45	7.41
Denmark	-34.88	16.77
Finland	-39.51	21.24
France	-34.55	16.50
Germany	-28.42	11.92
Greece	-11.20	3.50
Hungary	-29.57	12.69
Italy	-13.25	4.27
Poland	-17.44	6.01
Port_Spain	-18.42	6.45
Sweden	-31.44	14.02
UK_EIRE	-25.93	10.36
RoEU	-16.47	5.58

[6] Our computation based upon FAO Food Balance Sheets - http://faostat3.fao.org/download/FB/FBS/E

4 The integrated policy assessment

The policy assessment exercise, which this paper aims to perform, is based on a multi-criteria analysis (Rossell, 1993). This type of analysis investigates a policy from four points of view, namely effectiveness, efficiency, equity and political feasibility. Effectiveness is usually defined as the capability of a policy to achieve a given target (e.g. OECD, 1999 in Clinch et al., 2006) while efficiency contrasts the net benefits of reaching this target with the net costs of the policy implemented to reach it. Equity has to do with the heterogeneity of impacts that a policy has on different groups within the same category. Policy analysis usually focuses on three categories of actors, namely households, firms and sectors. A policy may in fact worsen income distribution among different groups of families. At the firms' level, small enterprises and large companies may be differently able to cope with the same set of rules with important consequences on their profitability. Different sectors, in turn, may unevenly be affected in terms of competitiveness as a consequence of the same policy. A comprehensive policy evaluation clearly requires reconciling various perspectives. Moreover, when a policy has a supra-national dimension, its effects may be different across countries, and this calls for careful attention. In a wider perspective, if a policy is implemented in a relatively large economy like the EU, this may also bring about several impacts on third countries. Political feasibility has to do with the level of difficulty associated with the introduction and the implementation of a policy, even when the policy is in principle fair, effective and efficient. In the relevant literature (e.g. Caraher and Cowburnb, 2015), there is agreement that an effective and efficient policy may be indeed difficult to implement. Although important for feasibility, equity is not always decisive in this case. Effectiveness and efficiency are necessary but simply not sufficient for successful implementation (on this point, see also Gago et al., 2013 in the area of energy policy).

This brief review of the four criteria shows their mixed quali-quantitative nature. Both effectiveness and efficiency are to a great extent measurable in our modelling framework. This does not mean, however that both attributes have some aspects, which can just discussed qualitatively. Equity can be quantified ex-ante, but this requires an appropriate modelling structure, which allows, for example for differences in households' income distribution. Equity among nations is easier to be quantified, as this requires country-specific results, which for example our model can produce. Feasibility is far less easy to quantify than the first three attributes, because it is mostly influenced by non-quantifiable factors, which have to do with institutional, social and even cultural aspects. In general, it strongly depends on the types of actors affected by the measure, by their ability to convey their own interests into the policy process and by the evolution of their interactions. Thus, it is quite difficult to predict how different groups will react to a specific policy proposal and how they will behave during the process leading to the final decision on it. Two types of studies can help shedding light on this issue. On one hand, there are "studies of behavioral responses to environmental taxes" (Clinch et al., 2006, p. 961) such as those reporting the results of the PETRAS project on policy options in the energy area (Energy Policy 34, 2006). On the other hand, there are studies analysing the process behind the introduction of a new policy and how this may be steered by various stakeholder groups (see for example Bødker et al., 2015 on the introduction of a fat tax in Denmark). Unfortunately, however, studies of both these types are very few and their strict connection with specific policy initiatives hampers in any case their generalization to other contexts.

The presence of both qualitative and quantitative aspects in each policy attribute justifies our integrated approach of analysis, which is able to take account merges the qualitative and the quantitative analysis. From a methodological point of view, these two types of analysis rely on different instruments, and they are autonomous from each other. In the rest of this section, we briefly describe the methods adopted for the two types of analysis.

4.1 Qualitative analysis

Due to its qualitative nature, our analysis strongly relies on the findings of the existing economic policy literature. The policy evaluation exercises performed by this type of literature are usually guided by four criteria, effectiveness, efficiency, equity and feasibility (Rossell, 1993). Our assessment of both policy measures is based on these criteria. Their application does not follow a standardized protocol as in the case of empirical or experimental studies. This does not exclude, however, that our evaluation exercise exhibits a clear systematic structure, which entails two main steps, summarized as follows. The first step is a thorough screening of the existing literature with the aid of scientific search engines (e.g. EBSCO®, Google Scholar® and Scopus®). For our exercise, both theoretical contributions (including review papers) and empirical studies are in principle relevant. Among the latter, we gave priority to those focusing on the EU and on its member States. As a rule, we considered papers published since 1995 and earlier seminal papers. The second step consists in analysing those findings, which helps shed light on the performance of the policy measures under investigation.

Clearly, we cannot be sure to have covered the universe of publications in the field of interest of this paper. However, we are quite confident to have covered the most relevant ones, among which we can count a number of comprehensive survey studies that add, indirectly, to the completeness of our coverage of the relevant literature. Thus, we are reasonably confident about the robustness of our findings. Note that the qualitative approach adopted makes the robustness of our conclusions less dependent from specific values and statistical relationship, and thus more robust in general terms. In order to keep this analysis as systematic as possible, we adopted the four criteria, which we briefly illustrated above in this section. The relative weights of these criteria mostly reflect the relevance placed upon them by the literature, which first looks at policy efficiency and effectiveness and less frequently to feasibility and equity.

4.2 Quantitative analysis

For our quantitative analysis, we rely upon the Intertemporal Computable Equilibrium System (ICES), a top-down recursive dynamic general equilibrium model based on the core structure of the GTAP-E model (Burniaux and Truong, 2002) and using the GTAP-8 database (Narayanan et al., 2012). It is solved recursively up to 2050.

The global economy is divided in 19 geographic entities: 11 single EU countries, three EU groups (Benelux, Portugal&Spain, UK&Eire), one residual EU bundle and four more non-EU aggregates. Each country/region is characterized by 20 representative industries. The model also features four primary factors of production (Table 3).

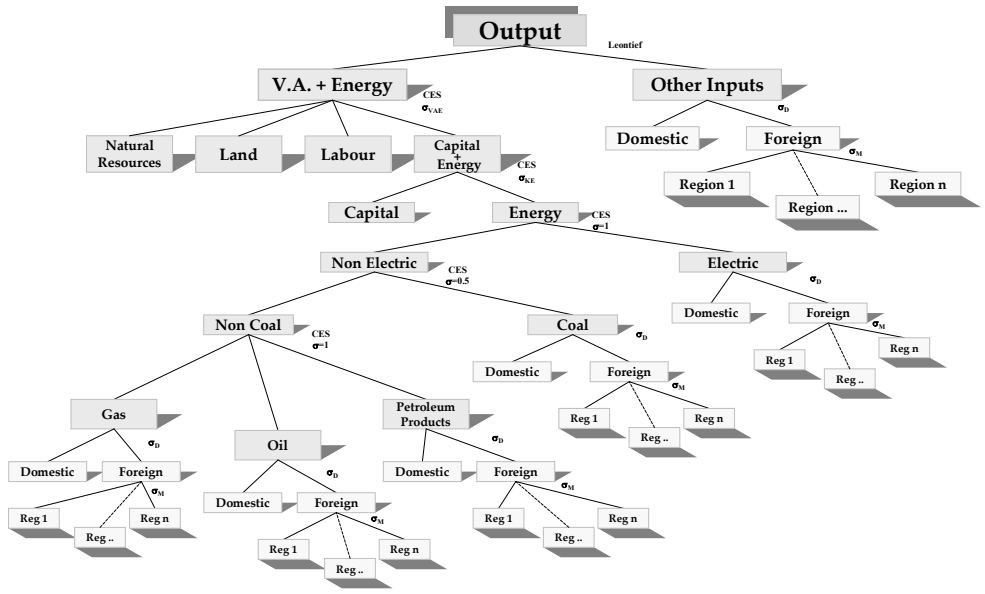
Table 3 ICES countries/regions, sectors and primary factors detail.

Countries/Regions	Sectors	Primary Factors
Austria	Agriculture	Land
BENELUX	Livestock	Labour
Czech Republic	Timber	Capital
Denmark	Fishing	Forest
Finland	Coal	Fish stock
France	Crude Oil	Energy Sources
Germany	Natural Gas	Mining/Metals
Greece	Oil Products	
Hungary	Electricity	
Italy	Mining	

Poland	Meat Industry
Portugal&Spain	Food Industry
Sweden	Chemical Industry
UK&EIRE	Iron&Steel
Rest of European Union	Non Ferrous Metals
Rest of Europe	Non Metallic Minerals
Rest of OECD	Construction Industry
BRICS (Brazil, Russia, India, China, South Africa)	Light Industry
Rest of the World	Market Services
	Public Services

Supply side[7]**:** Productive sectors are modelled in each country/region through a representative cost-minimizing firm, taking input prices as given. In turn, output prices are given by average production costs. Figure 3 illustrates the nested production function of each representative "firm" (an entity which here coincides with the concept of sector) within the model. Each node in the tree combines single or composite factors of production in a constant elasticity of substitution (CES) production function. All sectors use primary factors such as labour and capital-energy, and intermediate inputs. In some sectors (energy sources, extraction industries, timber and fishery) primary factors include natural resources (e.g. fossil fuels, raw metals, forest and fish), others (agriculture and livestock) use land. The nested production structure depicted in Figure 3 is the same across all sectors, and diversity in production processes as well as technologies are captured through sector-specific productivity and substitution elasticity parameters.

Figure 3 ICES nested production function.



At the top of Figure 3, production stems from the combination of intermediate inputs (QF) and a value added composite including all primary factors and energy (QVAEN). Perfect complementarity is

[7] In the mathematical description that follows, lower-case symbols in equations denote (linearized) variables expressed in percentage changes, while upper-case symbols represent variables in levels.

assumed between value added and intermediates. This implies the adoption a Leontief production function. For sector *i* in region *r* final supply (output) results from the following constrained production cost minimization problem for the producer:

$$\min PVAEN_{i,r}\, QVAEN_{i,r} + PF_{i,r}\, QF_{i,r} \tag{1}$$

$$s.t.\ Y_{i,r} = \min[QVAEN_{i,r}, QF_{i,r}\ ]$$

In (1) *PVAEN* and *PF* are prices of the related production factors.
The second nested-level in Figure 3 represents, on the left hand side, the value added plus energy composite (QVAEN). This composite stems from a CES function that combines four primary factors: land (QLAND), natural resources (QFE), labour (QFE) and the capital-energy bundle (QKE) using σ_{VAE} as elasticity of substitution.[8] Primary factor demand on its turn derives from the first order conditions of the following constrained cost minimization problem for the representative firm:

$$\min\ P_{i,r}^{Land} LAND_{i,r} + P_{i,r}^{NR} NR_{i,r} + P_{i,r}^{L} L_{i,r} + P_{i,r}^{KE} KE_{i,r} \tag{2}$$

$$s.t.\ QVAEN_{i,r,t} = \left(LAND_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} + NR_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} + L_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} + KE_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} \right)^{\frac{\sigma_{VAE}}{\sigma_{VAE}-1}}$$

On its turn, the KE bundle combines capital with a set of different energy inputs. This is peculiar to GTAP-E and ICES. In fact, energy inputs are not part of the intermediates, but are associated to capital in a specific composite. The energy bundle is modelled as an aggregate of electric and non-electric energy carriers. Non-electric commodities are produced in two levels, the first using Coal and Non-Coal commodities and then at the basic level the non-Coal input is a composite commodity that contains Natural Gas, Crude Oil and Petroleum Products.

The demand of production factors (as well as of consumption goods) can be met by either domestic or foreign commodities which are however not perfectly substitutable and regulated according to the 'Armington' assumption. In general, inputs grouped together are more easily substitutable among themselves than with other elements outside the nest. For example, the substitutability across imported goods is higher than that between imported and domestic goods. Analogously, composite energy inputs are more substitutable with capital than with other factors.

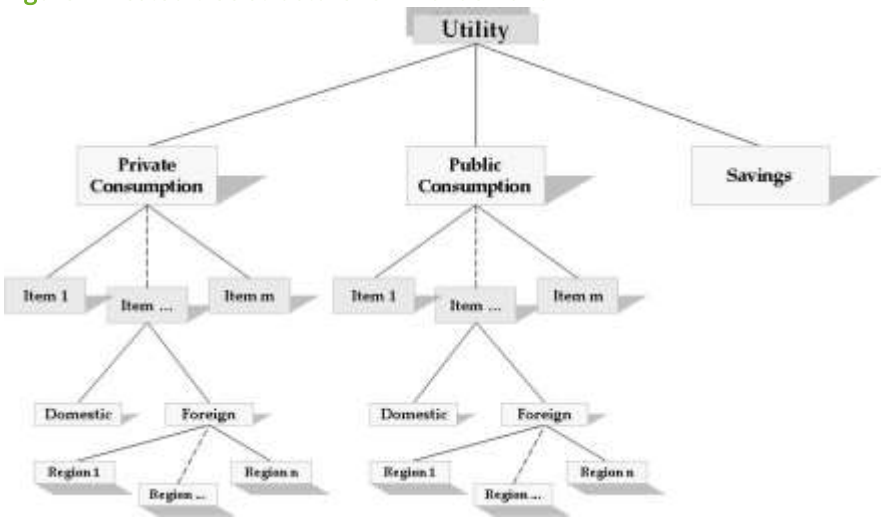
In ICES, two industries are treated in a special way and are not related to any country: international transport and international investment production. International transport is a world industry, which produces the transportation services associated with the movement of goods between origin and destination regions, thereby determining the cost margin between *fob* (free on board) and *cif* (cost, insurance and freight) prices. Transport services are produced by means of factors submitted by all countries, in variable proportions. In a similar way, a hypothetical world bank collects savings from all regions and allocates investments so as to achieve equality in the absolute change of current rates of return.

Demand Side: In each country/region, a representative utility maximizing household receives income, originated by the service value of national primary factors (natural resources, land, labour, and capital) that she owns and sells to the firms. Capital and labour are perfectly mobile domestically but immobile internationally (note however that investment is mobile, see below). Land and natural resources, on the other hand, are industry-specific. The regional income is used to finance three classes of

[8] The values for all elasticities used in ICES are drawn from the GTAP8 database.

expenditure: private consumption, public consumption and savings. These expenditure shares are generally fixed, which amounts to saying that the top-level utility function has a Cobb-Douglas specification. Also notice that savings generate utility and this can be interpreted as a reduced-form of intertemporal utility.

Figure 4 Nested tree structure for final demand.



Both private and public sector consumption are addressed to all commodities produced by each firm/sector. Public consumption is split into a series of alternative consumption commodities (item *1* to item *m* in Figure 4), again according to a Cobb-Douglas specification. However, almost all public expenditure is actually concentrated in the specific sector of Public Services, including education, defence and health.

Private consumption is analogously addressed towards alternative goods and services including energy commodities that can be produced domestically or imported. However, the functional specification used at this level is the Constant Difference in Elasticities (CDE) form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods.

Thus, the upper level represented in Figure 4, mathematically translates into a Cobb-Douglas utility constrained maximization problem:

$$max\ U = C \prod_i U_i^{B_i} \tag{3}$$

$$subject\ to\ \ X = \sum_i E_i(P_i, U_i)$$

Where U_i are the per capita utility from private consumption, per capita utility from government consumption, and per capita real savings; *C* is a scaling factor and B_i are distribution parameters. *X* describes the budget constraint which must meet the sum of three types of expenditures E_i. *P* is the expenditure-share-weighted index of commodity group price indices.

At the second level, per capita utility from private consumption is derived from the aggregation of per capita private consumption of individual commodities. This is done using the Hanoch's constant difference elasticity (CDE) demand system (Hanoch, 1975).

$$1 = \sum_i B_i \, U^{\Upsilon_i R_i} \left(\frac{P_i}{X}\right)^{\Upsilon_i} \tag{4}$$

where U denotes utility, P_i the price of commodity *i*, X the expenditure, B_i are distribution parameters, Υ_i substitution parameters, and R_i expansion parameters.
As can be noted by inspecting (4), the CDE in principle does not allow to define explicitly direct utility, expenditure or indirect utility functions. Accordingly, also explicit demand equations could not be defined. Fortunately, in a linearized equation system such as that used in GTAP, to do so it is sufficient to obtain the price and expenditure elasticities. Thus, taking (4) defining *U* implicitly as a function of *X* and P_i, first differentiate with respect to P_i. Then use Roy's identity[9] to obtain implicit functions for Q_i and finally differentiate it again to obtain price and expenditure elasticities. This, in linearized terms and expressed in per capita terms, leads to the following demand equation:

$$q_{Pi} - n \; = \; \sum_k EP_{ik} p_{pi} + \; EX_i \left(x_p - n\right) \tag{5}$$

where EP_{ik} and EX_p are price and expenditure elasticities of demand, *n* population.

Dynamics: inside the ICES model, dynamics are driven either by endogenous or exogenous sources. The endogenous source involves two components.

The first and most important is the capital accumulation processes governed by endogenous investment decisions while the second regards foreign debt evolution. ICES is a recursive dynamic model. This means it presents a sequence of static equilibria which are intertemporally connected by the process of capital accumulation. Capital growth is standard along exogenous growth theory models and follows:

$$Ke_r \; = \; I_r \; + \; (1 - \delta) \, Kb_r \tag{6}$$

where Ke_r is the 'end of period' capital stock, Kb_r is the 'beginning of period' capital stock, δ is capital depreciation and I_r is endogenous investment. Once the model is solved at a given step t, the value of Ke_r is stored in an external file and used as the "beginning of period" capital stock of the subsequent step *t+1*.

As with capital, at each simulation step the debt at the end of the period is stored in an external file and then recalled in the next simulation step as debt at the beginning of period.
Finally, debt is serviced at the world rate of return to capital, that is, regional income is increased or reduced by $R^W \cdot Db_r$. In terms of the Gempack code, this is shown as the variable 'DEBS$_r$'.

The second source of dynamics is exogenous and is defined by a set of assumptions concerning changes in some supply-side parameters and variables like those described in Gustavsson et al., 2013, Appendix) and namely future trends for population (EC, 2012), TFP (EC, 2102), as well as fossil fuels (Eurelectric, 2010 and IEA, 2011) and metals/materials use (EC, 2014).

In view of the structure of our model, the contribution of our quantitative analysis focuses on efficiency and effectiveness. With regard to the former, the model allows to quantify the effects of each policy on the volume of emissions, both year by year and cumulatively. We believe this is the main variable to consider when evaluating effectiveness quantitatively. Since, as noted in the literature (e.g. Randall, 2014 and Gallet 2010), elasticity is important to determine the reaction of consumers and hence the overall effect of a given measure, we propose a series of simulations to account for how the choice of elasticity can affect the result. As for efficiency, we compare the result in terms of GHG reduction with

[9] Roy's identity allows deriving the ordinary demands from the indirect utility function (Roy, 1947).

two variables computed by the model. One is the change in GDP, the other is the change in consumer utility.

5 Economic effects of policies

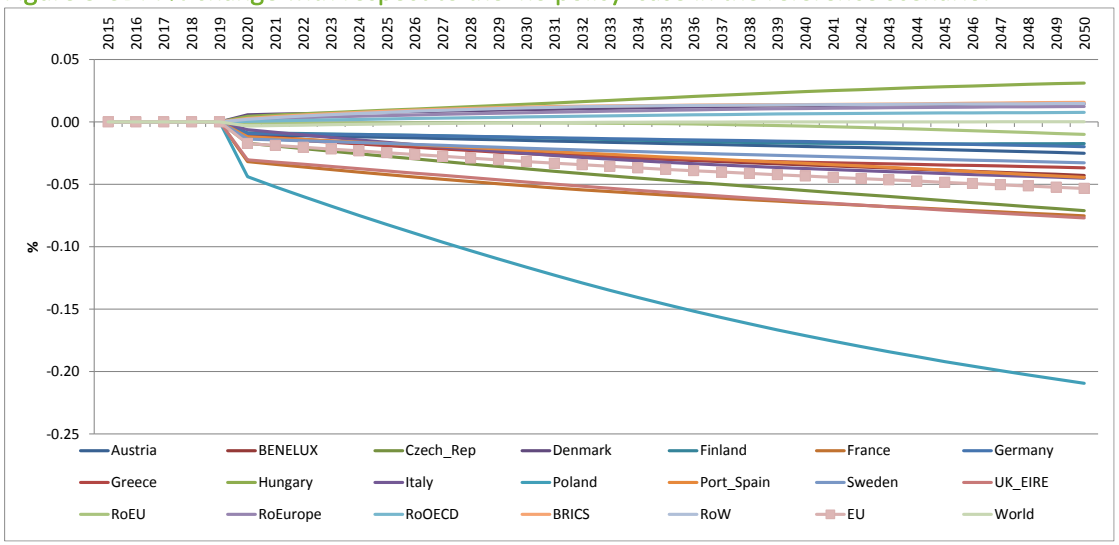
The economic effects, which the policies under evaluation bring about, are important for the assessment of each of the four criteria. Results regarding GDP and welfare changes for example, are necessary to quantify efficiency insofar this is measurable. These results also impinge political feasibility. The macroeconomic effects of a policy are often used by opponents if they are negative or by proponents of a policy if they are positive. It is intuitive that policies with sound economic consequences are easier to accept. For this reason, this section illustrates the main economic effects of the VAT harmonization policy and of information campaigns.

We consider results regarding national per-capita GDP for each EU country and for other country blocks. We further analyse output changes in the sectors, which are most affected by the policy, and we look at consumers welfare changes.

5.1 EU-wide harmonization of VAT rates on meat products

In terms of the impact on GDP of this this policy on GDP we notice the following. First, all effects are negligible, both for winners and losers. Poland is the only exception, with a still modest but noticeable -0.2%.

Figure 5 GDP: % change with respect to the 'no policy' case in the reference scenario.



Effects on the sectors directly targeted by the policy are not negligible (Figure 6).

This explains why at the EU level, production in the livestock and meat-industry sectors falls in 2020 by -3% and -6% respectively. A similar outcome characterizes all EU countries, including Hungary and Denmark.

This is plausible, as demand for meat products falls in all other EU countries following the increase in VAT and hence also the demand for exports from these two countries. Note that imports are charged at the same VAT rate as domestic production. Table 14 shows that in H, DK and RoEU the decline in production levels in the two Livestock and Meat Industry sectors is much lower than in other countries. The effects on the (non-meat) food industry are mixed. It expands, as expected, in the majority of EU countries with a maximum of 0.7% in Denmark, but it contracts in countries like UK and Ireland, France and Poland.

As to Denmark, the growth in the Food Industry is due to exports. In all other EU countries, less Meat Industry and more Food Industries are consumed, thus there is also a growing demand for Denmark.

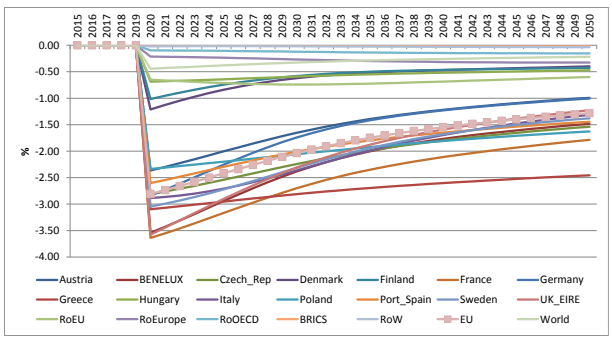
Indeed, the non-meat food industry also uses some intermediates from the meat industry and these, in becoming more costly, increase the production costs of food. In the long term, the shift towards non meat products benefits agricultural activity.

A glance at the overall sectoral production (Table 4) shows that the remaining sectors of the economy are negatively affected by the higher VAT, albeit with tiny impacts.

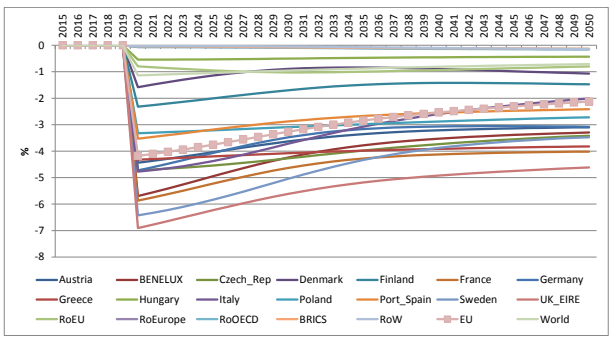
In any case, as in the case of chemicals for agricultural use, the policy is addressing sectors whose share of total value added is limited (Livestock and meat industry together account for 0.75% of value added in the EU). Accordingly, the final impact on overall economic activity summarized by GDP is small: a loss of -0.05% at the EU level in 2050 (Figure 5).

Significant differences can be highlighted at the country level. Poland is the worst-off country with a GDP loss of roughly -0.2% in 2050. This is due to the higher economic relevance in the national economy of the impacted sectors, and to their higher orientation to export compared to other EU countries. On the contrary, Denmark and Hungary, are slightly benefited by the policy. This indeed increases their international competitiveness as, in contrast to other EU countries, their production systems are not burdened by an increase in taxation consequent on implementation of the policy.

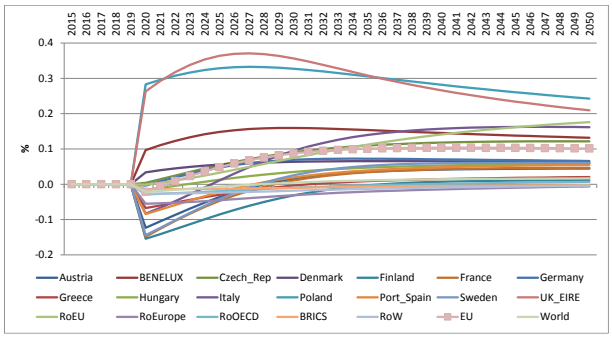
Figure 6 Output: % change with respect to 'no policy' in the reference scenario



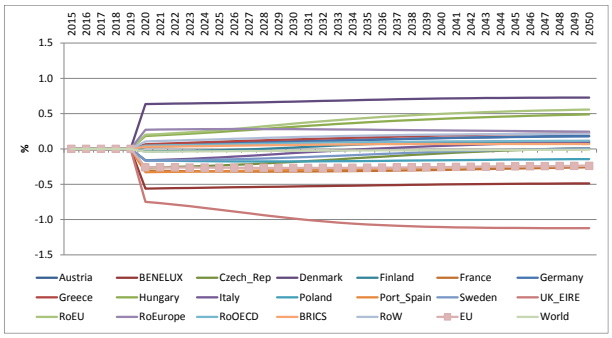
Livestock



Meat Industry



(Non-meat) Food Industry



Agriculture

Table 4 Sectoral output: % change with respect to the 'no policy' in 2050 in the reference scenario.

	Austria	BE NE LUX	CZ	DK	Finland	France	D	Greece	Hungary	Italy	Poland	Port & Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	0.044	0.134	0.122	0.063	0.011	0.046	0.067	0.020	0.058	0.162	0.249	0.054	0.060	0.219	0.171	-0.008	0.006	-0.003	-0.005
Livestock	-1.029	-1.530	-1.581	-0.412	-0.434	-1.841	-1.041	-2.482	-0.481	-1.374	-1.658	-1.480	-1.425	-1.286	-0.616	-0.327	-0.153	-0.012	-0.035
Timber	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.002	0.001	0.002	0.003	0.003	0.005	0.003	0.002	0.002	0.001
Fishing	-0.001	-0.004	-0.002	-0.003	0.000	-0.004	-0.002	-0.004	-0.002	-0.002	-0.006	-0.002	-0.002	-0.007	0.002	0.000	0.002	0.001	0.002
Coal	-0.001	0.001	-0.001	0.000	-0.001	-0.001	-0.001	0.000	0.000	-0.001	-0.003	0.002	0.000	0.001	0.003	0.000	0.000	0.000	0.000
Oil	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	-0.004	0.001	0.000	0.001	0.003	0.000	0.000	0.000	0.000
Gas	-0.004	0.004	0.071	0.006	0.016	0.094	-0.005	0.039	-0.029	0.053	-0.015	-0.005	0.010	0.007	0.024	0.001	0.007	0.004	0.005
Oil_Pcts	0.012	-0.020	-0.007	-0.001	-0.003	-0.032	0.012	0.028	0.002	0.018	-0.069	-0.025	-0.001	-0.005	-0.022	0.006	-0.003	0.000	0.008
Ely	-0.009	-0.022	-0.021	0.000	-0.045	-0.011	-0.008	0.004	0.013	-0.023	-0.136	-0.006	-0.011	-0.012	0.038	0.019	0.012	0.012	0.014
Other_Min	0.004	0.005	-0.008	0.022	-0.001	-0.006	0.006	-0.001	0.040	-0.002	-0.039	0.010	0.007	0.009	0.045	0.006	0.008	0.002	0.004
Meat_Ind	-3.111	-3.329	-3.465	-1.035	-1.459	-4.028	-3.066	-3.835	-0.434	-2.102	-2.747	-2.438	-3.522	-4.664	-0.826	-0.145	-0.153	-0.125	-0.133
Food_Ind	0.180	-0.490	0.002	0.727	0.084	-0.266	0.176	0.219	0.480	0.093	-0.146	-0.243	0.003	-1.122	0.550	0.248	0.115	0.070	0.214
Chem_Ind	-0.028	0.067	-0.028	0.081	-0.066	-0.012	-0.059	-0.066	0.040	-0.044	-0.226	0.041	-0.050	0.129	0.131	0.009	0.007	-0.009	0.018
Iron_Steel	-0.011	0.069	-0.017	0.065	-0.073	0.008	-0.025	-0.074	0.042	-0.034	-0.257	0.039	-0.007	0.112	0.128	0.021	0.021	0.000	0.025
Non_Fer_Met	0.059	0.081	0.022	0.140	-0.025	0.054	0.029	-0.033	0.081	-0.023	-0.244	0.082	0.044	0.158	0.140	0.086	0.025	-0.001	0.002
Non_Met_Min	-0.014	-0.017	-0.019	0.038	-0.026	-0.048	-0.012	-0.015	0.048	-0.034	-0.227	-0.014	-0.019	-0.045	0.074	0.021	0.019	0.010	0.006
Cons_Ind	-0.008	-0.037	-0.047	0.027	-0.009	-0.051	0.003	-0.008	0.046	-0.018	-0.196	-0.027	-0.019	-0.056	-0.009	0.021	0.015	0.019	0.016
Other_Ind	-0.084	0.063	-0.068	0.057	-0.157	-0.022	-0.020	-0.026	0.034	-0.010	-0.332	0.018	-0.095	0.084	0.081	0.006	0.011	0.012	-0.007
MarketServ	0.001	-0.018	-0.012	0.012	-0.001	-0.016	0.012	0.018	0.021	0.019	-0.183	0.003	0.001	0.008	0.017	0.011	0.005	0.021	0.022
PublicServ	0.057	0.050	0.137	-0.025	0.046	0.089	0.034	0.157	-0.020	0.106	0.370	0.077	0.068	0.097	-0.007	0.000	-0.002	0.005	0.005

Note: In red the sectors primarily affected

5.2 Information campaign to influence food behaviour towards changing diets.

By 2050 processed meat production in the EU declines by -8%, with a peak of roughly -17% in Hungary, Finland and Sweden. On average, the production contraction is thus somewhat smaller than the demand contraction. This is because EU meat producers export more outside the EU.

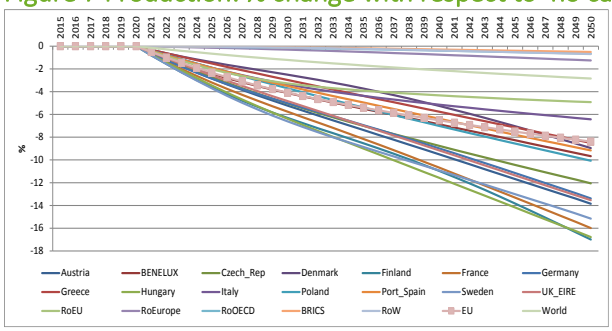
By contrast, non-meat food products experience an increase in production of around 3% at the EU level. This is again on average quite lower than the EU demand increase as the bulk of the latter is fulfilled by non-EU imports. This stresses the particular import dependence of non-meat food products in the EU and raises 1.9%.

Apparently, the recomposition of the sectoral activity toward non meat production induces small (+0.04% at the EU level in 2050), but generally positive effects on EU countries' GDP with Hungary as the best performer (+0.4%) (Figure 8).

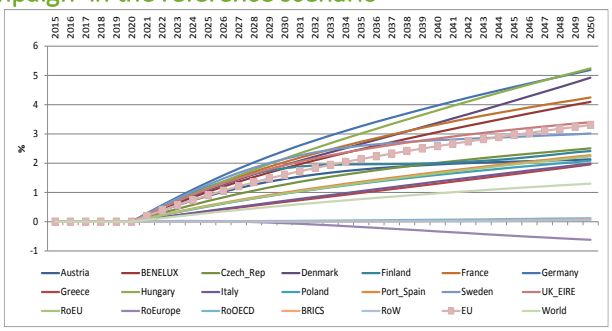
The improvement of GDP is mostly driven by a slight improvement of terms of trade consequent on the recomposition of household consumption bundle.

GHG emissions, that the model is able to quantify worldwide, thus tracking all the indirect effects triggered on non EU food (meat and non-meat) industry as well as on all the other economic sectors, decline (Figure 10). All over the 2020-2050 period the Mtons of CO_2 equivalent saved are 508.36. This amounts just to the 0.27% of the EU emissions of the period, however the social advantages should not be easily dismissed. For instance, according to the survey by Tol (2008) the social cost of one ton of carbon emitted ranges between 24 and 317 $. The campaign would thus be able to produce a social benefit of roughly 12 to 160 Bln $.

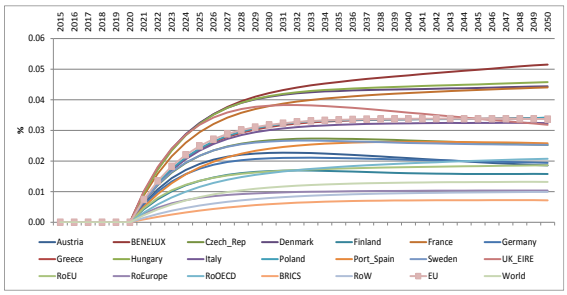
Figure 7 Production: % change with respect to 'no campaign' in the reference scenario



meat industry



food industry



fisheries: bottom

Figure 8 GDP: % change with respect to 'no campaign' in the reference scenario.

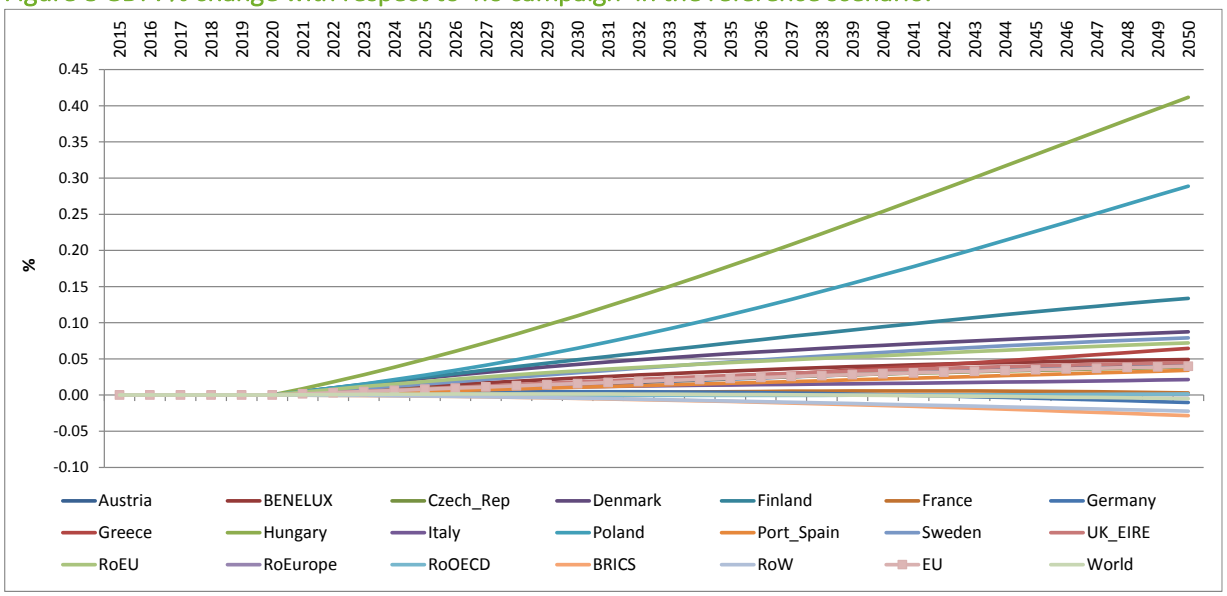


Table 5 Sectoral output: % change with respect to 'no campaign' in the reference scenario (2050).

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	0.54	0.64	0.71	0.82	0.63	0.54	0.67	0.27	1.29	0.84	1.18	0.48	0.61	1.15	1.17	0.12	0.10	0.07	0.09
Livestock	-4.33	-4.32	-6.14	-2.63	-4.14	-6.72	-4.26	-5.49	-6.74	-4.10	-6.34	-5.04	-6.25	-3.51	-3.38	-1.41	-0.56	-0.12	-0.27
Timber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.02	0.05	0.03	0.04	0.02	0.04	0.02	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.02	0.01	0.01
Coal	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	-0.10	0.02	-0.57	0.03	-0.33	-0.47	-0.09	0.09	0.52	0.15	0.44	0.07	0.07	-0.03	0.18	-0.02	-0.01	-0.01	-0.01
Oil_Pcts	-0.06	-0.17	-0.12	-0.13	-0.14	-0.13	-0.30	0.10	0.36	0.10	0.48	0.03	-0.10	-0.11	0.29	0.05	0.04	-0.02	-0.01
Ely	-0.04	0.04	0.02	-0.07	0.01	-0.13	0.02	0.01	0.29	0.04	0.07	-0.02	-0.03	0.03	0.26	-0.02	-0.01	-0.03	-0.01
Other_Min	0.01	0.01	0.03	0.04	0.05	0.01	0.04	-0.03	0.17	0.00	-0.07	-0.01	0.02	0.01	0.02	0.00	0.00	0.00	0.00
Meat_Ind	-13.86	-9.67	-12.06	-8.96	-16.99	-15.99	-13.39	-8.51	-16.78	-6.42	-10.07	-9.16	-15.16	-13.54	-4.92	-1.25	-0.65	-0.50	-0.69
Food_Ind	2.14	4.10	2.51	4.92	2.42	4.25	5.19	1.96	5.25	1.99	2.09	2.27	3.02	3.40	2.24	-0.62	0.12	0.08	0.06
Chem_Ind	-0.10	0.30	0.19	0.32	0.26	-0.06	0.21	-0.18	0.29	0.01	-0.44	-0.14	0.17	0.07	0.20	0.00	-0.03	0.03	-0.05
Iron_Steel	-0.05	0.25	0.08	0.51	0.27	-0.07	0.23	-0.27	0.11	-0.07	-0.78	-0.15	0.15	0.00	0.07	-0.03	-0.05	0.00	0.01
Non_Fer_Met	0.00	0.28	0.08	0.64	0.24	-0.06	0.29	-0.26	0.03	-0.05	-1.06	-0.16	0.16	0.04	0.09	-0.01	-0.07	0.01	0.00
Non_Met_Min	-0.02	0.10	0.09	0.19	0.17	0.00	0.05	0.01	0.36	0.02	-0.17	0.02	0.11	0.12	0.20	-0.01	0.00	-0.01	0.00
Cons_Ind	0.04	0.01	0.02	0.04	0.06	-0.01	-0.05	0.10	0.49	0.01	0.39	0.05	0.06	0.02	0.10	0.02	0.02	-0.04	-0.01
Other_Ind	-0.01	0.17	0.05	0.34	0.26	-0.12	0.08	-0.31	0.03	-0.09	-0.40	-0.10	0.13	-0.05	0.18	-0.06	-0.04	0.01	0.00
MarketServ	-0.12	-0.19	-0.13	-0.14	-0.19	-0.17	-0.26	0.03	0.44	0.06	0.32	-0.03	-0.09	-0.17	0.39	0.02	0.01	-0.08	-0.02
PublicServ	-0.05	-0.16	-0.11	-0.11	-0.11	-0.13	-0.23	0.16	0.44	0.07	0.21	0.05	-0.10	-0.11	0.18	0.04	0.02	0.01	0.01

Note: In red the sectors primarily affected

6 Results

This section illustrates the results of the integrated assessment of the two policies described in section 3. The analysis follows the methodology illustrated in section 4. In the first part, it discusses each criterion separately, while in the second part it reports on the outcome of the more general evaluation of each policy. For sake of exposition, the four criteria described in Section 4 will be treated separately throughout the whole section, although they are obviously interdependent.

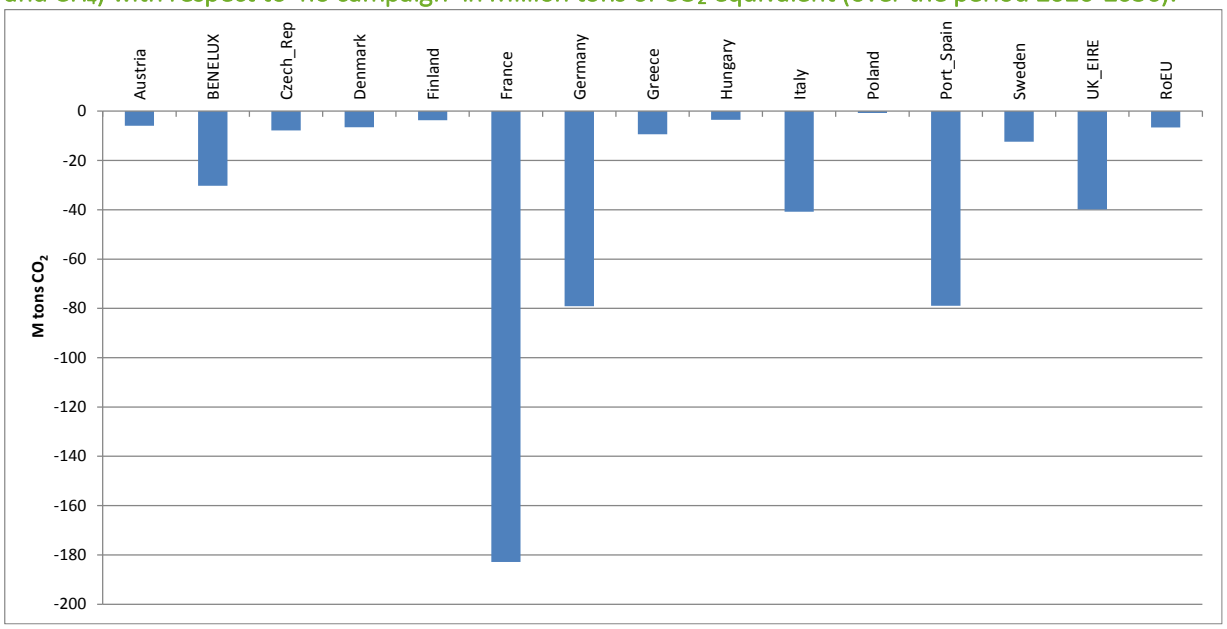
6.1 Effectiveness

The most significant variable that we observe to evaluate the effectiveness of both policies is the amount of GHG emissions.

Figure 9 and Figure 10 show xxxx

Figure 9 Environmental effectiveness of the VAT harmonization. Change of GHG emissions (CO_2, N_2O and CH_4) with respect to benchmark scenario in Million tons of CO_2 equivalent (over the period 2020-2050).

Figure 10 Environmental effectiveness of the information campaign. Change of GHG emissions (CO_2, N_2O and CH_4) with respect to 'no campaign' in Million tons of CO_2 equivalent (over the period 2020-2050).



From a qualitative point of view, the target of the meat tax should be at the root of the inefficiency to correct, as with any green tax. In this case this is the production of meat rather than its consumption, since the former is the really inefficient activity. However there is agreement in the literature around the idea that a tax on the output of the livestock sector is quite "virtually impossible in practice" (Wirsenius et al. 2011) mainly because of high monitoring costs (Nordgren 2012, 578). For this reason, taxing consumption appears to be more effective, also considering that consumption itself has become inefficient (thus it effectively would become a food tax).

The literature on food-related policies is large (Niebylski, M.L. et al., 2015, for example, find 1174 articles with 315 relevant papers) while the literature on green taxes on food consumption is much smaller. The first question regards the potential effectiveness of a meat tax in comparison to other instruments (typically: command-and-control measures and information campaigns). With regard to the food-related policy nature of this measure, command and control instruments are economically inefficient and have mainly been used in relation to cases where there is an acute threat to the life and health of citizens (Reich et al. 2011). Information campaigns have been widely used to improve general health, such as to decrease smoking or to increase consumption of fruits and vegetables. However, a large number of authors (e.g. Wirsenius et al., 2011; Nordgren, 2012 and more recently Ripple, 2014) believe that only a measure like a tax can lead to "strong sustainable consumption", namely "changes in consumption patterns and reductions in consumption levels in industrialized countries' (Fuchs and Lorek, 2005). This view is confirmed by various literature reviews, which substantially conclude that food taxes are effective in lowering the intake of unhealthy foods (Thow et al., 2010; Powell et al., 2010). If we consider the measure as a green tax aiming at reducing GHG emissions from food production, the information campaigns do not seem very effective according to Edjabou and Smed (2013) because the consumption of meat and dairy is deeply rooted in our culture (Olesen, 2010). This allows us to conclude that a price-based instrument seems the most appropriate to reduce GHG emissions from food consumption. Also other authors (e.g. Anders Nordgren, 2012 and Alcott, 2008) are convinced that without a measure like a meat tax too few people would make any significant change to their diets within a short space of time.

The market-based instrument however has a major weakness, as indicated by Olesen (2010) and Randall (2014). In general meat demand is quite inelastic and clearly more inelastic than other types of food which have already been targeted by similar policies (salty foodstuff, sugar-rich products…). Additionally, a meat tax can also have unintended effects (Carahera, M. & G. Cowburnb (2015) or even adverse substitution effects, i.e. that consumers substitute taxed foods with foods that are equally or even more unhealthy (Nnoaham et al. 2009; Mytton et al., 2007). Since this tax is not targeting dairy products there is a risk that taxing meat moves consumption to dairy products. With regard to elasticity, ruminant meat seems quite elastic (Gallet 2010) and has the largest contribution of greenhouse gases. An option could be to tax only ruminant meat while leaving unchanged the policy on non-ruminant meat.

In general, it seems that the effectiveness of the policy might be improved if it were coupled with adequate information campaigns. This reinforces the view that taxes need to be paralleled by subsidies and other interventions to encourage healthy eating (OECD, 2006). Notably, Nordström and Thunström (2009) show that subsidies in isolation increase the intake of healthy food but also the intake of nutrients that are often overconsumed (fat, saturated fat, sugar, added sugar, salt) due to a dominant (and unwanted) income effect.

As far as the information campaign is concerned, its effectiveness is very difficult to evaluate, as we said in Section 3.

In economic terms, our information is imperfect, incomplete, and asymmetric in most occasions, thus any measure that in principle can improve the information we have can lead to welfare improvements. If these information gaps entail a situation in which negative externalities are present, the case for improving the knowledge of the individuals involved is even stronger, because it can help understand the causes and the extent of the damage suffered and then deploy the correct remediation actions.

Tietenberg (1998) explores precisely this possible role of information in supplementing environmental policies. Tietenberg argues that the traditional justification for environmental policy due to the Coase Theorem, in which the marginal benefit for the polluter exceeds the marginal damage of the pollutee, can be augmented to allow for a role for information in that it can allow people at risk of being damaged or being damaged unknowingly (e.g. by increasing the chances of future diseases) to realise that they are at risk and to take steps to reduce their damage.

Tietenberg (1998) reviews the literature on the role of information disclosure in environmental policies up to the middle '90s, with a specific focus on the situations in which the general public has limited access to relevant information, but there is no particular asymmetry in the information held by the players. The papers reviewed are empirical studies mostly looking at specific environmental issues in the US, Canada and China. His main conclusions are (Tietenberg 1998: 14):

- The evidence in general suggests that disclosure strategies can ultimately motivate polluters to reduce emissions even in the absence of more traditional regulatory controls.
- "Disclosure strategies may have an efficiency role to play" besides responding to moral motives.
  Disclosure strategies may complement traditional strategies or substitute for them, depending upon the circumstances. In some case disclosure strategies may provide interim incentives to control pollution until such time as more traditional regulation can be established (such as in developing countries or in controlling air toxics in the United States).
- "More information in not always better. The amount and type of information conveyed is important. And the incentives faced by the victims of environmental damage in acting on the information are also important".
- "The literature also raises a cautionary note with respect to the distributional impacts of disclosure strategies. Can it be that in certain circumstances disclosure strategies benefit only the more educated victims? When actions taken by victims have a strong regional component (..), resources may be diverted from less educated (less vocal) regions and toward the more educated regions which complain more"

Verbeke (2005) takes a more specific look at the role of information in the agricultural sector. He argues that the availability of more information is no guarantee of better informed consumers and that "information is likely to be effective only when it addresses specific information needs, and can be processed and used by its target audience" (Verbeke 2005: 348). Moreover, "it cannot be taken for granted that a target audience will pay attention to information intended for it. First, it requires identification and thorough understanding of the target audience's needs, and second, appropriate management of the information provision so that it optimally addresses particular needs" (Verbeke 2005: 348).

Verbeke (2005) looks more into the details of the inability of standard microeconomic assumptions to account for the consumers' situation in the food market.

On one hand, he notes that information is particularly incomplete and asymmetric on this market: citing Caswell and Mojduszka (1996) he remarks "that rational decision-making, utility maximisation, systematic interpretation of information and optimal choice are hampered because information in agrifood markets is often imperfect, incomplete, inaccessible, asymmetrically distributed, non-standardised or costly to collect. Hence, potential market failures from information asymmetry arise because consumers face uncertainty regarding the true nature of product attributes, and as a result,

make choices that are not well aligned with their preferences (Teisl and Roe,1998). This risk of market failure holds particularly in situations where product differentiation is low and mainly based on so-called credence attributes (Akerlof, 1970; Darby and Karni, 1973; Blandford and Fulponi, 1999; Grunert et al., 2000). It means that situations prevail in which individuals cannot adequately assess product quality or safety, even after experiencing the good, thus facing uncertainty and having to trust the information provided. […] In other cases, relevant information may be imperfect, i.e. it may not exist or it may be contradictory, as in the early days of the BSE and dioxin crises where scientists and government held opposing views on the potential health risks" (Verbeke 2005: 350)

Moreover Verbeke points to another issue which consumers may have with information on this market: relevant information about food quality and safety may be publicly available but not easy to find, to process and to verify, and therefore it might be costly for a consumer to acquire it. "Rational consumers would not knowingly consume unsafe food, though in the absence of credible food quality and safety signals, consumers face uncertainty and incur specific information search costs (Hobbs, 2004)" (Verbeke 2005, p. 350). Verbeke reports that "McCluskey and Swinnen (2004) introduced the 'rationally ignorant consumer' hypothesis, indicating that it may be rational for consumers to be imperfectly informed in the specific case of food safety issues. The reason is that the price of information and/or the opportunity cost of processing information are too high compared with the marginal benefits from information, hence constraining information processing willpower" (Verbeke 2005, p. 351).

All in all, Verbeke's survey shows that "solving market inefficiencies due to information asymmetry can be effective only if consumers are willing to pay attention to the information and process it for subsequent use in their decision making. The latter depends largely on individual characteristics, which are often situated in the psychological domain" (Verbeke 2005 : 361)

Moreover, "it appears that strategies for reducing information asymmetry through the provision of vast amounts of information to consumers have a limited chance of success, simply because a lot of this information does not target a particular need. Hence, it risks not being attended to and processed by consumers. The particular challenge lies in identifying and effectively reaching market segments. In many cases this is feasible, though it may be problematic when variables such as involvement, personality, motivation or attitudes come into play. A generic approach, involving the provision of massive amounts of information to the general public, stands a real risk of information overload, leading to confusion and lack of interest among the majority of consumers. Hence, over-provision of information in an attempt to solve market inefficiencies caused by imperfect or asymmetrically distributed information may not yield the intended solution to market failures. The implications for information provision, e.g. through generic advertising or labelling, are that the recipient population needs to be well understood, segmented, identified and targeted." Verbeke concludes that "The assumption that market deficiencies as a result of information asymmetries can be solved simply through providing more and better information seems not to hold when dealing with food consumers facing quality and safety uncertainty. Instead, the management of information from agriculture and the food industry requires that the target population be identified and their specificities be well understood and taken into account so as to make information meaningful, useful and effective" (Verbeke 2005 : 361).

Verbeke's survey is quite exhaustive and covers a great deal of the issues related to the provision of information in the agrifood sector. Although it contains a section on the issues posed by the information provided directly by firms in this sectors through labelling and advertising, he fails to capture another reason why the provision of correct and unbiased information is important in this sector. This additional rational goes under the name of deep capture, and while it has a certain conspiracy theory flavour, it has indeed been studied and empirically confirmed in the case of the food

sector. Smith and Tesnadi (2013) argue that foods low in nutritional quality may dominate the market due to search costs and, the endogeneity of consumer beliefs. They claim to demonstrate the empirical relevance of the phenomenon—in which firms expend costly effort to influence consumer beliefs by looking at the case of obesity-inducing foods in the US.

Stigler (1971) wrote of the corrupting effect of political interference on industry regulation, a phenomenon now commonly referred to as "regulatory capture.". What Stigler failed to note, however, was that his logic—that an industry will attempt to influence powerful government institutions that affect its bottom line—applies equally to any institution that holds such power. This larger phenomenon, in which industry attempts to influence not only its regulator, but also (perhaps) politicians, celebrity spokespeople, the media, education, and even academic research—with the aim, ultimately, of influencing the broader public—has been dubbed "deep capture," and like Stigler's more limited theory, appears in many cases to have empirical validity (Hanson and Yosifon, 2003; Benforado et al., 2004; Yosifon, 2006). Viewed in the light of modern information theory, the problem of nutritional quality in manufactured foods is in essence an equilibrium selection problem, in which profitability is a function of consumer perceptions and beliefs about nutrition. It is interesting to consider the extent to which the "deep capture" phenomenon might be affecting these beliefs.

6.2 Efficiency

In terms of efficiency, OECD (2010)[10] argues that the combination of measures has a positive impact also on this aspect: this is because a combination of different measures increases the population coverage and can therefore exploit synergies between the different measures. It is also argued that a combination of measures may be more cost-effective than any standalone policy measure by itself. In view of the administrative costs of an increased VAT on meat, these seem to be quite low. Since this would not be a fully new tax but an increase in an existing one administrative control costs ought to be rather limited.

One problem with this policy is that all meat is treated in the same way. This, of course, is not true, as shown in section 2. The imposition of an equal tax by type of meat means not to reward those who produce extensively over those who produce intensively.

6.3 Equity

As to VAT, it is well known that changes in food prices usually create winners and losers, the latter often among the poor (Anderson et al., 2012). This is also claimed by Randall (2014) while Ripple et al. notes that, "social justice, equity and food access issues need to be carefully considered" (2014, 3). With regard to consequences on equity, the literature shows that there are two main aspects to consider, namely the economic equity and the health equity. The economic equity deals with the intensity of the impact of the tax on the income level of the different consumer groups. To be economically fair, the impact rate of the tax should be either the same for all groups or progressive. The health equity deals with the changes in the dietary habits of different consumer groups induced by the measure.

While the literature on effectiveness is huge, the same does not hold for the one on equity. The reason is intuitive: the investigation of equity aspects requires more complex models and larger amounts of

[10] OECD Health Ministerial Meeting, Paris (2010) 'Health Choices'.

data than in the case of a single representative consumer. Papers, which study equity issues, are for example Chouinard et al. (2007) and Smed et al. (2007). Most authors (see for example Nnoaham et al., 2009) find that these measures are regressive. Nordström and Thunström (2011) obtain quite the opposite result in the case of a simulation of a VAT reform and an excise tax reform in Sweden. According to the authors, none of the measures seems to have any negative effect on economic equity, as they are both progressive. As to health-related equity, the VAT reform has approximately the same effect on all groups (although this result does not emerge sharply from the literature), while the excise tax reform has a negative effect on the poorest. A study by the Danish Academy of Technical Sciences, 2007, reported in Bødker, M. et al. (2015) claims that it is unsure that food taxes have negative effects on health-related equity.

6.4 Feasibility

In the case of a food tax such as the one on meat, groups holding vested interest are the food industry and trade associations, consumers and public health advocates. The first two groups enjoy a strong influence on political decisions through their lobbying activity. Additionally, they use a wide range of instruments to prevent taxation being implemented (Carahera, M. & G. Cowburnb, 2015). Several studies show how the food industry uses tactics similar to those used by the tobacco industry to fight policies threatening their business (Wiist, 2010 and Brownell et al. 2009). The latter two are usually weak in tackling the issues of corporate power and providing evidence to maintain policy and political support. In this framework, academic research often seems to report long after the event (Carahera, M. & G. Cowburnb, 2015).

With regard to government ideology, it is quite well-known that policymaker's preferences show a bias towards agricultural protection (de Gorter and Swinnen, 2002). This means that a rise in the VAT on meat may see some opposition in government. In the case of the fat tax in Denmark, the inclusion of meat was discouraged as it was considered infeasible for food corporations (Bødker et al. 2015). Also milk was excluded by the policy in Denmark.

Some points for public acceptability are:

1. Given the first objective, the policy belongs to the category of food taxes. This relates to the issue of the justification for public intervention in food consumption (Smed, 2012)
2. Meat consumption is perceived as a measure of social and economic development (World Watch Institute 2003).
3. Mismatch between health objectives (including single person health and environmental health) and budget objectives

More generally,

1. For higher equity (and higher effectiveness as well) tax reductions on vegetables and other healthy food (e.g. fruit, as in Bødker et al. 2015) may be also included. This would also add to the issue of proving that an increase in the VAT on meat is not dictated by public budget needs but is a measure for healthier diets and living habits.

2. For higher effectiveness, it may be sensible to distinguish between the two types of meat (ruminant and non-ruminant) as they differ both for their environmental impact and for their role in human diet.

Lopez (2001) found that political contributions from agriculture are highly effective at generating subsidies. The analysis found contributions both from commodity groups (such as the beef industry) and from supporting industries (such as feed manufacturers) to have an impact. Lopez concludes that not only do these rent-seeking activities shift consumer surplus to producers, but also they cause a net loss to society from these agricultural activities.

7 Discussion

8 Conclusions

Frank, J. (2007): When used as a fertilizer at an appropriate level, livestock and poultry manure can provide valuable organic material and nutrients for crop and pasture growth (Ribaudo et al. 2003).

References

Gallet, C. (2010) “Meat Meets Meta: A Quantitative Review of the Price Elasticity of Meat.” American Journal of Agricultural Economics, 92: 258-272

Gerber, P. J. et al. (2013) Tackling Climate Change Through Livestock – A Global Assessment of Emissions and Mitigation. Rome: Food and Agriculture Organisation of the United Nations.

Hoag, D. L., Lacy, M. G. and Davis, J. (2004) ‘‘Pressures and Preferences Affecting Willingness to Apply Beef Manure on Crops in the Colorado High Plains,’’ Journal of Agricultural and Resource Economics 29(3): 461 – 480.

Lopez, R. A. (2001) ‘‘Campaign Contributions and Agricultural Subsidies,’’ Economics and Politics 13(3): 257 – 279.

Ribaudo, M., Gollehon, N., Aillery, M., Kaplan, J., Johansson, R., Agapoff, J., Christensen, L., Breneman, V. and Peters, M. (2003) ''Manure Management for Water Quality: Costs to Animal Feeding Operations of Applying Manure Nutrients to Land,'' United States Department of Agriculture, Economic Research Service, Agricultural Economic Report Number 824.

Rossell, C. Using multiple criteria to evaluate public policies. The case of school desegregation. Am. Politics Res. 1993, 21, 155–184

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., & de Haan, C. (2006). Livestock's long shadow - Environmental issues and options. Food and Agriculture Organization of the United Nations. ISBN 9251055718, 390 pp

Appendix

Commodity/Sector Aggregation

	ICES sectors	GTAP sectors
1	Agriculture	pdr wht gro v_f osd c_b pfb ocr rmk wol
2	Livestock	ctl oap
3	Timber	frs
4	Fishing	fsh
5	Coal	coa
6	Oil	oil
7	Gas	gas gdt
8	Oil_Pcts	NuclearFuel OthP_C
9	Ely	Nuclear Biomass Hydro Solar Wind OthEly
10	Other_Min	omn
11	Meat_Ind	cmt omt
12	Food_Ind	vol mil pcr sgr ofd b_t
13	Chem_Ind	crp
14	Iron_Steel	i_s
15	Non_Fer_Met	nfm
16	Non_Met_Min	nmm
17	Const_Ind	cns
18	Other_Ind	tex wap lea lum ppp fmp mvh otn ele ome omf
19	MarketServ	wtr Trd Tour otp wtp atp cmn ofi isr Tech Ros dwe
20	PublicServ	RD Edu Hpu Hpr Pub

1	AUSTRIA	aut
2	BENELUX	bel lux nld
3	CZECH REPUBLIC	cze

4	DENMARK	dnk
5	FINLAND	fin
6	FRANCE	fra
7	GERMANY	deu
8	GREECE	grc
9	HUNGARY	hun
10	ITALY	ita
11	POLAND	pol
12	PORandSP	prt esp
13	SWEDEN	swe
14	UKandEIRE	irl gbr
15	RoEU	cyp est lva ltu mlt svk svn bgr hrv rou
16	RoEurope	che nor xef alb xer
17	RoOECD	aus nzl jpn kor can usa mex chl isr tur
18	BRICS	chn ind bra rus zaf
19	RoW	xoc hkg mng twn xea khm idn lao mys phl sgp tha vnm xse bgd npl pak lka xsa xna arg bol col ecu pry per ury ven xsm cri gtm hnd nic pan slv xca xcb blr ukr xee kaz kgz xsu arm aze geo bhr irn kwt omn qat sau are xws egy mar tun xnf cmr civ gha nga sen xwf xcf xac eth ken mdg mwi mus moz tza uga zmb zwe xec bwa nam xsc xtw

GTAP sector listing

Nr.	Code	Description
1	pdr	Paddy Rice: rice, husked and unhusked
2	wht	Wheat: wheat and meslin
3	gro	Other Grains: maize (corn), barley, rye, oats, other cereals
4	v_f	Veg & Fruit: vegetables, fruitvegetables, fruit and nuts, potatoes, cassava, truffles,
5	osd	Oil Seeds: oil seeds and oleaginous fruit; soy beans, copra
6	c_b	Cane & Beet: sugar cane and sugar beet
7	pfb	Plant Fibres: cotton, flax, hemp, sisal and other raw vegetable materials used in textiles
8	ocr	Other Crops: live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds, beverage and spice crops, unmanufactured tobacco, cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets, plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes, sugar beet seed and seeds of forage plants, other raw vegetable materials
9	ctl	Cattle: cattle, sheep, goats, horses, asses, mules, and hinnies; and semen thereof
10	oap	Other Animal Products: swine, poultry and other live animals; eggs, in shell (fresh or cooked), natural

		honey, snails (fresh or preserved) except sea snails; frogs' legs, edible products of animal origin n.e.c., hides, skins and furskins, raw , insect waxes and spermaceti, whether or not refined or coloured
11	rmk	Raw milk
12	wol	Wool: wool, silk, and other raw animal materials used in textile
13	frs	Forestry: forestry, logging and related service activities
14	fsh	Fishing: hunting, trapping and game propagation including related service activities, fishing, fish farms; service activities incidental to fishing
15	coa	Coal: mining and agglomeration of hard coal, lignite and peat
16	oil	Oil: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	Gas: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	Other Mining: mining of metal ores, uranium, gems. other mining and quarrying
19	cmt	Cattle Meat: fresh or chilled meat and edible offal of cattle, sheep, goats, horses, asses, mules, and hinnies. raw fats or grease from any animal or bird.
20	omt	Other Meat: pig meat and offal. preserves and preparations of meat, meat offal or blood, flours, meals and pellets of meat or inedible meat offal; greaves
21	vol	Vegetable Oils: crude and refined oils of soya-bean, maize (corn),olive, sesame, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and canola, mustard, coconut palm, palm kernel, castor, tung jojoba, babassu and linseed, perhaps partly or wholly hydrogenated,inter-esterified, re-esterified or elaidinised. Also margarine and similar preparations, animal or vegetable waxes, fats and oils and their fractions, cotton linters, oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; degras and other residues resulting from the treatment of fatty substances or animal or vegetable waxes.
22	mil	Milk: dairy products
23	pcr	Processed Rice: rice, semi- or wholly milled
24	sgr	Sugar
25	ofd	Other Food: prepared and preserved fish or vegetables, fruit juices and vegetable juices, prepared and preserved fruit and nuts, all cereal flours, groats, meal and pellets of wheat, cereal groats, meal and pellets n.e.c., other cereal grain products (including corn flakes), other vegetable flours and meals, mixes and doughs for the preparation of bakers' wares, starches and starch products; sugars and sugar syrups n.e.c., preparations used in animal feeding, bakery products, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products, food products n.e.c.
26	b_t	Beverages and Tobacco products
27	tex	Textiles: textiles and man-made fibres
28	wap	Wearing Apparel: Clothing, dressing and dyeing of fur
29	lea	Leather: tanning and dressing of leather; luggage, handbags, saddlery, harness and footwear
30	lum	Lumber: wood and products of wood and cork, except furniture; articles of straw and plaiting materials
31	ppp	Paper & Paper Products: includes publishing, printing and reproduction of recorded media
32	p_c	Petroleum & Coke: coke oven products, refined petroleum products, processing of nuclear fuel
33	crp	Chemical Rubber Products: basic chemicals, other chemical products, rubber and plastics products
34	nmm	Non-Metallic Minerals: cement, plaster, lime, gravel, concrete
35	i_s	Iron & Steel: basic production and casting
36	nfm	Non-Ferrous Metals: production and casting of copper, aluminium, zinc, lead, gold, and silver
37	fmp	Fabricated Metal Products: Sheet metal products, but not machinery and equipment
38	mvh	Motor Motor vehicles and parts: cars, lorries, trailers and semi-trailers

39	otn	Other Transport Equipment: Manufacture of other transport equipment
40	ele	Electronic Equipment: office, accounting and computing machinery, radio, television and communication equipment and apparatus
41	ome	Other Machinery & Equipment: electrical machinery and apparatus n.e.c., medical, precision and optical instruments, watches and clocks
42	omf	Other Manufacturing: includes recycling
43	ely	Electricity: production, collection and distribution
44	gdt	Gas Distribution: distribution of gaseous fuels through mains; steam and hot water supply
45	wtr	Water: collection, purification and distribution
46	cns	Construction: building houses factories offices and roads
47	trd	Trade: all retail sales; wholesale trade and commission trade; hotels and restaurants; repairs of motor vehicles and personal and household goods; retail sale of automotive fuel
48	otp	Other Transport: road, rail ; pipelines, auxiliary transport activities; travel agencies
49	wtp	Water transport
50	atp	Air transport
51	cmn	Communications: post and telecommunications
52	ofi	Other Financial Intermediation: includes auxiliary activities but not insurance and pension funding (see next)
53	isr	Insurance: includes pension funding, except compulsory social security
54	obs	Other Business Services: real estate, renting and business activities
55	ros	Recreation & Other Services: recreational, cultural and sporting activities, other service activities; private households with employed persons (servants)
56	osg	Other Services (Government): public administration and defense; compulsory social security, education, health and social work, sewage and refuse disposal, sanitation and similar activities, activities of membership organizations n.e.c., extra-territorial organizations and bodies
57	dwe	Dwellings: ownership of dwellings (imputed rents of houses occupied by owners)

More information on the correspondence between the GTAP sectors and UN general classifications ISIC and CPC is available here.