Waste recycling policies in an E-DSGE model

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Abstract

Waste production is increasing worldwide, and waste management practices and performances are environmentally harmful in several areas all over the world. Italy is not an exception in this respect. Though the economic literature on optimal waste policy is well developed, our paper moves a first step in filling a gap, by adopting a DSGE approach in modeling waste management, waste policies and their impact on main economic variables, such as output, employment, consumption, etc. By developing a DSGE model featuring an intermediate input sector depending on recyclable materials consumption, as well as accounting for budget balancing waste policies, we simulate, respectively a productivity shock, a preferences shock, and a waste policy shock. Interestingly, our preliminary results show that changes in preferences towards recyclable consumption may be improved upon (in terms of output and employment impacts) by budget balancing waste policies encouraging (discouraging) consumption of recyclable (non-recyclable) goods.

JEL codes: D58, H23, O44, Q48.
Keywords: recycling, subsidies, waste.

1 Introduction

Waste is one of the "unresolved" environmental issues in the 21st century. Indeed, although awareness of the external effects of waste is increasing, and although in several countries capacity constraints and management problems are becoming increasingly evident, a lot of work has yet to be done. So, for example, policy initiatives undertaken by EU Member States governments, together with EU level Directives on specific flows of waste, have proven insufficient, so far, to change the trend, and waste volumes keep generally increasing as a result

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of higher incomes and urbanization rates, increased consumption of goods and services, and more intensive use of packaging materials. Also, recycling rates are still unsatisfactory in several countries, including some parts of Italy, where a North-South divide seem to be in place.

Although a more circular approach to economic activities calls for a reduction in the amount of produced waste, in the transition phase we are currently experiencing recycling still plays an important role, with the aim of subtracting resources and materials from final disposal, in line with what is recommended by the 2008 Waste Framework Directive.

The contribution of our work rests on the need to analyse policy actions aimed at increasing recycling. A limit of existing models in this respect is the reliance to a partial equilibrium analysis that, though informative, can neglect or overlook important systemic consequences, for example in terms of productivity and final consumption. We move a first step in extending standard analyses by building a micro-founded environmental dynamic stochastic general equilibrium (E-DSGE) model incorporating waste recycling in the production process and evaluating the role of different policies to stimulate the consumption of recyclable goods. These policies will be differentiated according to the source of the needed public revenue, to get to a better understanding of the interaction across environmentally beneficial subsidies and distortionary (but environmentally beneficial) taxes. We will focus our attention on simulations using italian data for calibration purposes, although the model can ideally be extended to other countries or to EU as a whole.

Our work links to two main streams of the literature. The first one deals with the microeconomic analysis and the drivers of waste management and waste policies. Under a theoretical point of view, seminal contributions in this respect include Fullerton and Kinnaman (1995) as well as, more recently, D'Amato et al. (2016), among others. The received contributions show the relevance of policies in driving behaviours aimed at reducing waste production and at enhancing recycling, both under a neoclassical and under a behavioural perspective (e.g. Brekke et al., 2003). Turning to the empirical literature, several papers assess waste generation and disposal drivers, focusing on specific areas and on the the role of policies (Hage and Soderholm, 2008; De Jaeger and Eyckmans, 2008; Dijkgraaf and Gradus, 2004; Kinnaman and Fullerton, 2000, among others) and, more generally, on the determinants of waste performance at the EU level (Mazzanti and Zoboli, 2009; EEA, 2007, 2009) and at the OECD level (Johnstone and Labonne, 2004). Some of these contributions specifically address the impact of waste polciies on waste production and separate collection, showing how incentive based public intervention may indeed affect waste related behaviours. In those works, the analysis is devoted to assess whether the provision of cheaper recycling facilities and/or the introduction of waste disposal fees have virtuous impacts on increased households' recycling effort. User fees or pay-as-you-throw (PAYT) schemes are for example suggested to affect separate collection as well as waste production, although there is not a widespread agreement on this conclusion (Bel and Gradus, 2016; Fullerton and Kinnaman, 1996; Kinnaman and Fullerton, 2000).

The second strand of literature which is relevant for our paper is the one addressing environmental policy in explicitly dynamic economic models. Among others, the closest to our work are those by Argentiero et al. (2017), who focus on renewable energy policies and Annicchiarico and Di Dio (2015), who develop a (New Keynesian) DSGE framework to analyse the linkages between environmental policy and business cycle fluctuations[1].

We apply the DSGE logic to a model of waste policy impact analysis, in order to understand the dynamic response of economic and waste and environmental variables in the presence of shocks related to productivity and to preferences. In the second respect, we specifically account for a shock implying more recycling oriented preferences. Finally, we also include a shock on the waste policy side, to address the dynamic impact on the economic system. To our knowledge, this is a novel approach in the literature on waste policy analysis. Also, we calibrate our model to Italian data, but our approach can be extended to broader geographical areas (e.g. OECD countries).

The paper is organized as follows: the next section describes the model setup and outilnes chosen parameter values. Section 3 discusses (preliminary) results. Finally, section 4 provides a few concluding remarks.

2 The model setup

This section describes tha basic structure of our E-DSGE model. The supply-side of the economy is comprised of four sectors: one is a final consumer goods sector, whereas the remaining three are intermediate goods sectors.

Final output, Y_t, is produced competitively according to a Cobb-Douglas production function making use of the three inputs of labor,N_t^y, private capital, K_t^y, and raw material M_t:

$$Y_t = A_t * (K^y)_{t-1}^{\alpha} * (N^y)_t^{\beta} * M_t^{1-\alpha-\beta} \tag{1}$$

where A_t is total factor productivity (TFP), whose law of motion is described by the following AR(1) process with zero mean and uncorrelated residuals ε_t:

$$\log A_t = (1-\phi^y) \log \bar{A} + \phi^y \log A_{t-1} + \varepsilon_t \tag{2}$$

where $\bar{A}^y$ indicates the steady state value of the final output TFP.

Raw material, i.e. the first intermediate sector, is composed of recyclable waste, $(RW)_t$, and natural reseources, E_t, which are assumed to be substitutes according to the following CES production function:

$$M_t = \left(\eta\,(RW)_t^{-\epsilon} + (1-\eta)\,(\ E_t)^{-\epsilon}\right)^{-\frac{1}{\epsilon}}$$

Furthermore, natural resorces, the second intermediate sector, are subject to the following dynamic constraint, where S_t is the level of the deposits and ξ representing the degree of the soil exploitation:

[1] In this respect, see also the seminal contributions by Fischer and Sprinborn (2011), Heutel (2012) and Angelopoulos et al. (2013).

$$S_{t+1} - S_t = \xi S_t - E_t$$

Finally, recyclable waste, i.e. the third intermediate sector, produces the corresponding output competitively according to a Cobb-Douglas constant returns to scale production function by using as inputs the recyclable consumer goods, C^r, labor, N_t^r and private capital, K_t^r:

$$(RW)_t = (C^r)^{\gamma} * (K^r)^{\delta} * (N^r)^{1-\gamma-\delta}$$

The economy's demand side is populated by an infinite number of infinitely living households with preferences defined over recyclable consumer goods, C_t^r, with share ν, non recyclable consumer goods, C_t^{nr}, with share $1-\nu$; pollution level, Z_t; labor services, N_t. These latter are allocated to final output production (N_t^y), and recyclable waste sector (N_t^r) on a period-by-period basis.

Each agent maximizes the expected value of an intertemporal utility function, i.e.:

$$E_0 \sum_{t=0}^{\infty} \rho^t U_t \left(C^r, C^{nr}, Z_t, N_t^y, N_t^r\right) \tag{3}$$

with ρ^t corresponding to the subjective discount factor.

Let the period utility function assume the following CRRA form:

$$U_t = \nu \left[\log \left(C^r\right)_t\right] + (1-\nu) \left[\log \left(C^{nr}\right)_t\right] - \frac{(N^y)_t^{1+\psi}}{1+\psi} - \frac{(N^r)_t^{1+\upsilon}}{1+\upsilon} - Z_t \tag{4}$$

where Υ_t is a taste shifter (Stockman and Tesar, 1995), whose law of motion is described by the following AR(1) process with zero mean and uncorrelated residuals ε_t^{Υ} :

$$\log \Upsilon_t = \left(1 - \phi^{\Upsilon}\right) \log \bar{\Upsilon} + \phi^{\Upsilon} \log \Upsilon_{t-1} + \varepsilon_t^{\Upsilon} \tag{5}$$

where $\bar{\Upsilon}$ indicates the steady state value of the taste shifter.

The maximization of the utility function is subject to the following budget constraint:

$$P_t^r C_t^r + P_t^{nr} C_t^{nr} + K_t^y + K_t^r = R_t^y K_{t-1}^y + R_t^r K_{t-1}^r + W_t^y N_t^y + W_t^r N_t^r + P_t^e E_t \tag{6}$$

where P_t^r is the price of the recyclable consumer goods, P_t^r the price of the non recyclable consumer goods, P_t^e is the price of the natural resources, W_t are the wages payed and R_t the gross interest rate. Waste policy affects exogenously the prices of recyclable and non-recyclable goods, depending on the chosen policy instrument. Moreover, the pollution dynamics follows this law of motion

$$Z_t = Z_{t-1} + C^{nr} * (d * \vartheta^1 + e * \vartheta^2 + (1-d-e)\vartheta^3)$$

where ϑ^1, ϑ^2 and ϑ^3 indicate the damages related to the waste disposal in landfill, to waste incineration and export, respectively, according to the weights d, e and $1 - d - e$.

The model dynamics depend on total factor productivity, households' preferences, the prices of natural resources, recyclable consumer goods and non recyclable consumer goods.

We calibrated the model according to italian data, where available. The following table reports the main selected parameter values, along with the related sources.

Parameters	**Definition**	**Source**
$\alpha = 0.3$	final output elasticity of capital	Ameco
$\beta = 0.5$	final output elasticity of labor	Ameco
$\eta = 0.35$	recyclable waste share	Euric
$\epsilon = -1$	elast. of substitution recycl.-nat.res.	Economics literature
$\phi^y = 0.9$	persistence in final output TFP	Economics literature
$\zeta = 0.2$	recycl. waste elast. of capital	Economics literature
$\nu = 0.26$	recycl. cons. share in the ut. func.	European Commission
$\psi = 3$	inverse of Frisch elast. of fin. output labor supply	Economics literature
$\upsilon = 3$	inverse of Frisch elast. of recycl. labor supply	Economics literature
$\phi^\Upsilon = 0.9$	persistence in taste shifter	Economics literature
$d = 0.54$	share of the envir. damage of landfills	Ispra
$e = 0.44$	share of the envir. damage of the waste incineration	Ispra
$\rho = 0.9$	intertemporal subjective discount factor	Economics literature
$\phi^\tau = 0.9$	persistence in tax rate	Economics literature

3 Analysis and Results

Using the model outlined in the previous section, we could get some interesting insights in terms of the impact of shocks related to productivity, preferences and waste policy on the economic variables under scrutiny. The waste policy we simulated in the model is a subsidy on recyclable consumer goods financed with a distortionary taxation on non recyclable consumer goods. The remaining part of this session will discuss the impact of those shocks.

3.1 Shock on productivity

We first describe the outcome of our modelling exercise when a (positive) shock on Total Factor Productivity (TFP) affects the economic system i.e. an exogenous increase in A_t from (1). Figure 1 shows the main related impacts.

Looking at figure 1 (top) a positive shock on TFP increases output (y) and there is substitution between labour (n_y) and capital (k_y) in the final output sector.

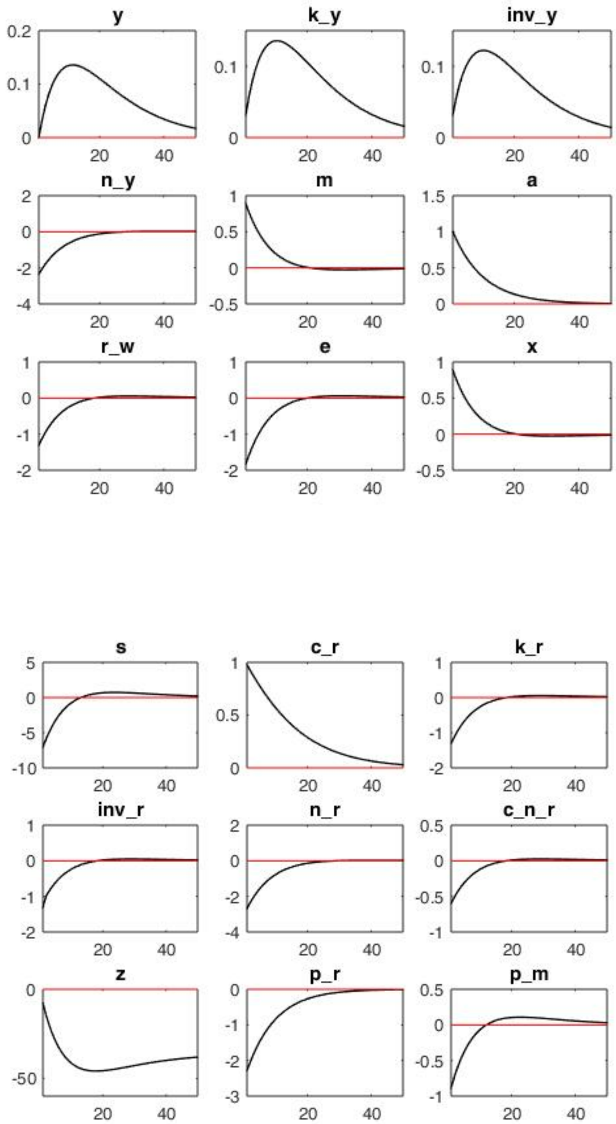
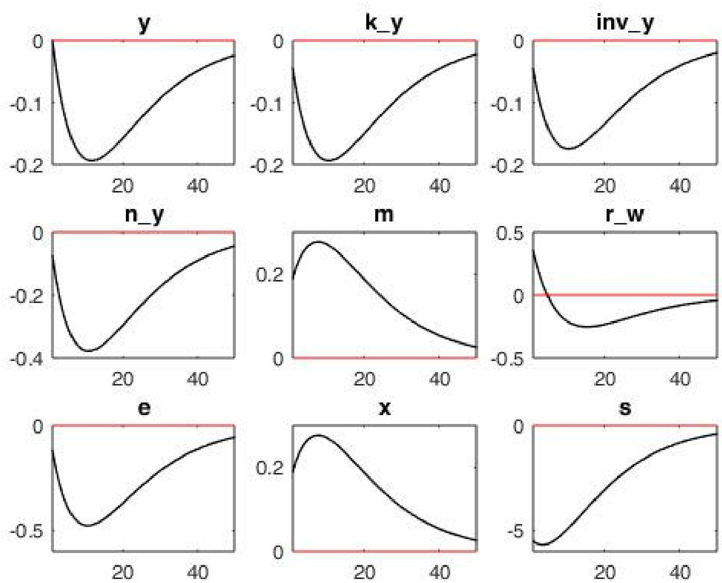


Figure 1. TFP shock

From the behaviour of raw materials, recyclable materials and natural resources (m, r_w and e, respectively), we can also notice that capital acts also as a substitute for recyclable and virgin raw materials, at least under our selected parametrization. The latter evidence, coupled with a decrease in price of recyclable consumption (p_r, Figure 1, bottom, leads to a substitution from non recyclable consumption (c_n_r) to recyclable consumption (c_r), which triggers a recovery both of the price for recyclables and for recyclable raw materials in the medium term. The overall environmental impact is positive, mostly due to people subsituting recyclable for non recyclable consumption. The latter also implies that a lower subsidy is needed on recyclable consumption (mu).

Looking at a shock on preferences, i.e. an increase in ν from (4) (Figure 2, top) we can notice that it has a short run negative impact on output (y) as well as on capital (k_y) and labour (n_y) in the same sector. Raw materials (m) react in the opposite way, fuelled by a short run increase in the use of recyclable materials, substituting for virgin materials. The latter seems to be fuelled (Figure 2, bottom)by a short run (expected) increase in recyclable consumption (c_r), which replaces non recyclable one (c_n_r). Overall, while environmental pollution (z) improves, there seem to be negative employment effects. In other words, our preliminary results suggest that a "short run green transition" is not expected to be costless in terms of jobs.



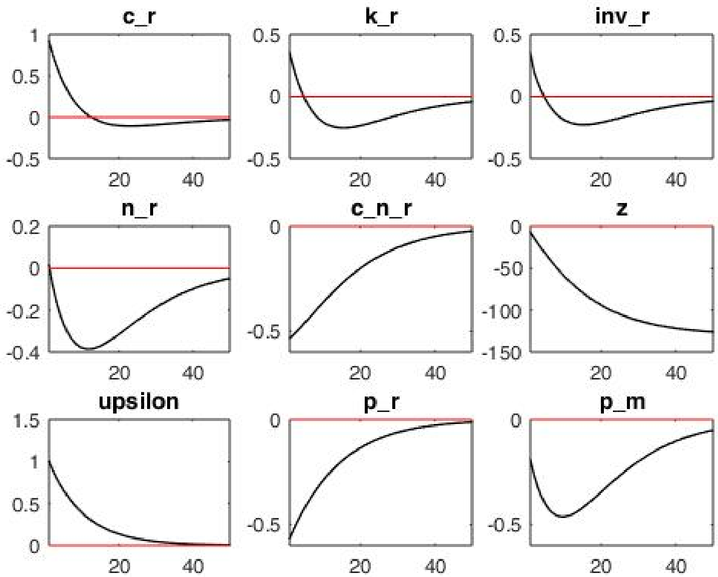


Figure 2. Preferences shock

We thus look at the impact of a shock in waste policy, namely, from (6), we assume an exogenous increase in the price of non recyclable consumption (P_t^{nr}) that finances a decrease in the price for recyclable consumption (P_t^r). Results are as reported in Figure 3. Interestingly, the waste policy boosts recyclable consumption (c_r) and the related recyclable waste production sector (both capital k_r and employment n_r increase, as well as recyclable waw materials production r_w). This appears, in our setting, to boost productivity in the final output market (at least for capital k_y, and to a lesser extent for labour n_y), boosting therefore output and employment. This potential win win situation deserves further attention. Indeed, notice that wages in the output sector decrease, and that the distortionary nature of this taxation is not visible in our preliminary analysis. On the other hand, the possibility of boosting output and environmental quality at the same time can be subject to additional scrutiny.

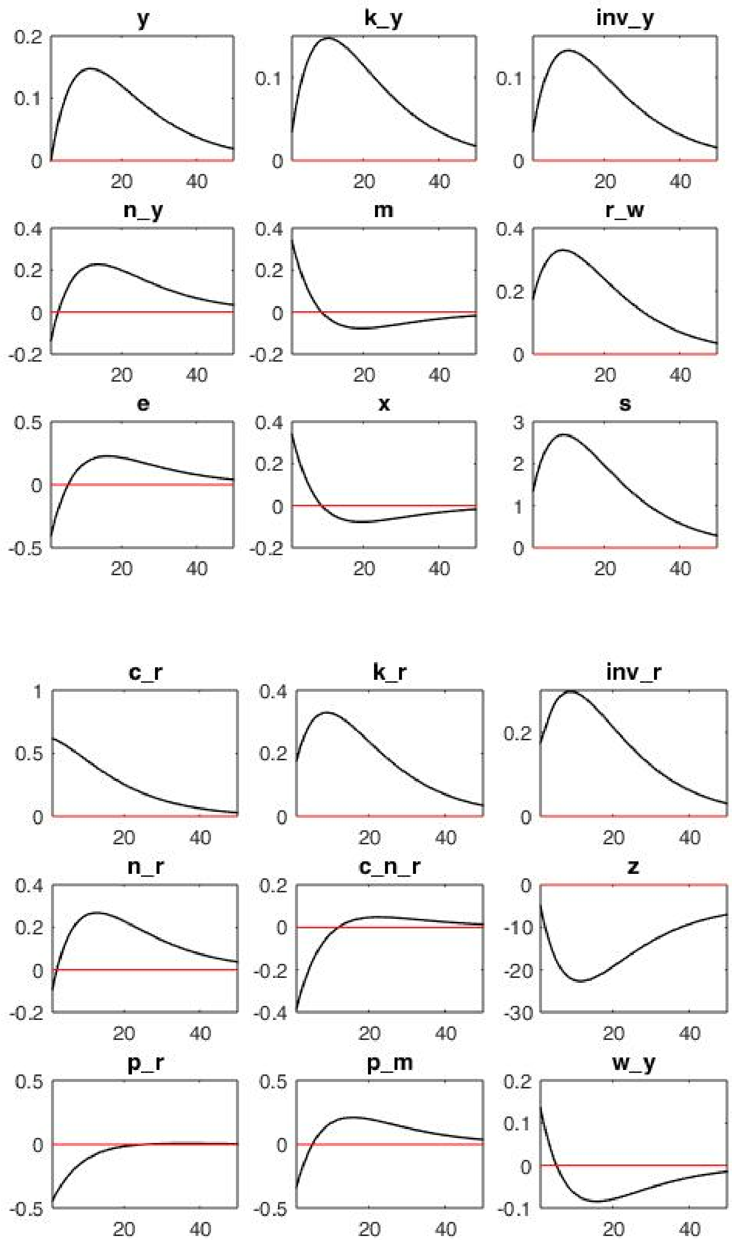


Figure 3. Waste policy shock

4 Concluding Remarks

We adopt a DSGE modelling framework, to investigate the impact of productivity shocks, preferences changes and waste policy changes in terms of economic variables and, more specifically, the dynamic response of the economic and environmental systems to those changes. Our adopted setting is, to our knowledge, new and, although significant additional work is needed, our results are promising in terms of relevance. So, for example, we show that shocks related to (broadly intended) waste policy options may have opposite impacts on output and employment: informational campaigns modifying consumers' taste are shown to be potentially worse than proper incentive based waste policies. Of course, a full assessment also rests on a welfare evaluation of the different options. This consideration, together with the generalization and the robustness of results, are the current avenues of our research.

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