Transition to Sustainability: Italian Scenarios Towards a Low-Carbon Economy

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Abstract. This paper analyzes different policies that may promote the transition to sustainability, with a particular focus on the energy sector. We present a dynamic simulation model where three different strategies for sustainability are identified: reduction in GHG emissions, improvements in energy efficiency and the development of the renewable energy sector. Our aim is to evaluate the dynamics that those strategies may produce in the economy, looking at different performance indicators: rate of growth, unemployment, fiscal position, GHG emission, and transition to renewable energy sources.

Keywords: Energy transition · System dynamics · Scenario analysis

1 Introduction

After twenty years since the 1992 "United Nation Conference for the Environment and Development" in Rio de Janeiro, the awareness on climate change and mass poverty is widespread and debated. However, the results in terms of emissions reduction and eradication of poverty are unsatisfactory. There was no radical political change able to invert the unsustainable trend followed by our societies. Beyond the lack of audacity of public authorities, there is a strong need for analytical tools that address, in an integrated way, the dynamics that policy changes can trigger at a macroeconomic level.

A wide range of models take into account issues such as energy transition, pollution and environmental limits, but only a few integrate the economic and the environmental spheres by considering the influence of energy policies. Several approaches are used to investigate the issue of energy transition, e.g. assessment management, agent based model, DSGE, econometrics and system dynamics. The latter seems a suitable tool to study complex systems, since it is characterized by flexibility and a simple recognition of feedback mechanisms. Moreover, the multidisciplinary nature of the possible applications allows for the integration of socio-economic and natural systems. Furthermore, scenario analysis gives the opportunity to deal with the uncertainty that characterizes societal behavior, availability of fossil energy source and climate change.

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In this approach, a first class of models focuses on the issue of peak oil and energy transition without analyzing the economic sphere [1–3]. A second group of contributions focuses on the economic and technological aspects but do not take into account the limits of fossil energy supply [4–6]. A third class of models investigates, in an integrated approach, energy, economy, and the environmental system. A well-known model is *World 3*, the dynamic simulation model used in the "Limits to Growth" [7]. That model was further improved thought the *World3/91* model used in "Beyond the Limits" [8] and the *World3/2000* model distributed by the *Institute for Policy and Social Science Research*. Recently, Millennium Institute's "Threshold 21" model was applied to energy policies in U.S. and North America [9,10]. Those contributions investigate the interdependence between the economic, social, and environmental spheres focusing on the role of energy policies in each one. Furthermore, Victor and Rosenbluth [11] and Victor [12] investigate how no- and low-growth scenarios for Canada can affect macroeconomic and environmental variables such as income, poverty, unemployment, government expenditure, and greenhouse gas emissions.

Following this stream of literature, the focus of this paper is to evaluate different policies that may promote the transition to sustainability, with a particular focus on energy sector. Indeed, people's well-being and economic stability are dependent on safe and sustainable energy availability. Our aim is to analyze the dynamics that those strategies may produce in the economy, looking at different performance indicators: rate of growth, unemployment, fiscal position, GHG emission, and transition to renewable energy sources.

Sustainability is a complex concept. In our framework we aim to take into account this complexity in three stages. First, we build a macroeconomic model where disequilibrium between aggregate demand and supply is possible since aggregate demand has autonomous components. Adjustments in consumption and investment shape the demand for production factors, in particular labour. This model allows us to analyze the dynamics of GDP, unemployment and public and private debt, when different policies are implemented.

Secondly, we integrate the core of the model, with an analysis of the energy sector. While this sector is often underestimated in economic analysis, some recent publications of European Commission recognize as a priority goal for Europe, the development of an efficient energy system. We investigate three different strategies: abatement in GHG emissions, investment in energy efficiency and the development of renewable energy sources (see, for instance, [13]). Those strategies can be seen as complementary in the transition to sustainability. Indeed, they aim both, to control climate change and to reduce the dependency of the economy from fossil energy sources. However, given budget constraints, there is a quite strong competition among those strategies. Scenario analysis is a powerful tool to evaluate the dynamics generated by alternative policies which tend to favor one of those strategies. Furthermore, an increase in public expenditure in the energy sector (e.g. through monetary incentives) may reduce the availability of resources for improvements in other performance indicators such as unemployment, inequality and poverty. The model allows for the investigation of this kind of trade-offs.[1]

Finally, while the model can be easily adapted to different countries, we apply it to Italy, making calibration and robustness analysis of the crucial parameters.

Preliminary results show that *business as usual* scenario is not able to attain European Commission prescriptions on renewable energy sources and emissions standard [14]. Moreover, limits on the exploitation of fossil resources generate irreversibility thresholds which may induce the collapse of the whole economy (see, for instance, [15]). Policies must take into account those thresholds and induce a significant increase in the investment in the renewable energy sector. However those investments are costly, and may reduce the rate of growth and increase unemployment at least in the short run.

At this stage of the analysis, we get that the three strategies have different outcomes. Abatements in GHG emissions and increases in energy efficiency are effective in the short run, while the development of renewable energy sector has higher effects in the long run.

The paper is organized as follow. Section 2 presents the essential theoretical structure of the model. Section 3 discusses the main results of the dynamic simulation model through scenario analysis. Section 4 concludes.

2 The Model

Production takes place according to the following technology

$$Y_t = \min\left\{A_t L_t^{\alpha} K_t^{1-\alpha}, \epsilon_t E_t\right\}, \tag{1}$$

where the subscript t indicates the time, Y is the GDP, L is the employment, K is the available capital, A captures the productivity of production factors, $\alpha \in (0, 1)$ is a technological parameter. Furthermore, production needs energy: E is the flow of energy, ϵ measures energy efficiency.

In every period, capital accumulates according to

$$K_{t+1} = (1 - \delta^k)K_t + I_t^k, \tag{2}$$

where $\delta^k > 0$ is the depreciation of capital per unit of time, and I_t^k is the level of investment in the capital sector.

We consider two composite energy sources, fossil fuels and renewable energy, and we use the standard, although strong, assumption that the two types of energy are perfect substitutes

$$E_t = Q_t + H_t, \tag{3}$$

where Q and H are the services of fossil fuel extraction and renewable energy resource harnessing respectively.

[1] At this stage, the analysis of inequality and poverty is not included in the simulation model.

The harnessing of renewable energy sources depends on "renewable energy source capacity" (henceforth RESC) and is indicated as R. For simplicity, we assume that renewable energy flow is produced through a linear technology which employes R_t and labour L_t^R,

$$H_t = h \min\{R_t, L_t^R\}. \tag{4}$$

In the model we assume that only fossil energy flows (Q_t) produce GHG emissions (P_t). Thus

$$P_t = \phi_t Q_t, \tag{5}$$

where ϕ_t indicates the technology available in period t.

We explore through a simulation model which size of investments in RESC (I_t^R), in energy efficiency (I_t^ϵ) and in the abatement of greenhouse gas emissions (I_t^ϕ) are necessary for moving Italian economy to a low-carbon economy in 2050.[2]

As we pointed out in the previous section, we allows for disequilibrium between aggregate demand and GDP. In particular, aggregate demand is given by

$$D_t = C_t + I_t^K + I_t^R + I_t^\epsilon + I_t^\phi + G_t + B_t, \tag{6}$$

where B_t is given by exports minus imports in period t, G_t is the public expenditure, C_t is the level of consumption. In the simulation we make a detailed specifications of the autonomous component of those variables. Given a certain cost of fossil energy $c(Q)$, at any period differences between net income $(Y - c(Q))$ and aggregate demand (D_t) generates a change in the stock of inventories. Those variations induce firms to adjust the demand of labour and the size of investment. We describe this process in the following section.

3 Dynamic Simulation and Scenario Analysis

Two main feedback loops drive the model outcomes. The first feedback is an engine of economic growth. If aggregate demand is higher than aggregate supply, then the stock of inventories decreases. Thus suppliers tend to increase the demand for production factors. Labour and investment increase inducing a further increase in the aggregate supply, if energy is available. Since some components of aggregate demand, such as consumption and investment, are positively related to production, demand increases. This process without continuous shocks or public intervention tends to converge in the long run (see Fig. 1).

The second feedback takes into account government expenditure and public incentive to the development of RESC. We assume that as long as unemployment increases, government expenditure has to increase to subsidize new unemployed and their families. Thus under budget constraint, government may renounce to stimulate energy transition. However, a positive feedback may emerge (see Fig. 2). An increase in the incentive for investment in RESC has two positive

[2] In this short paper we have no space for explicitly analyzing our analytical assumption about the impact of the investment on the three variables R, ϵ and ϕ.

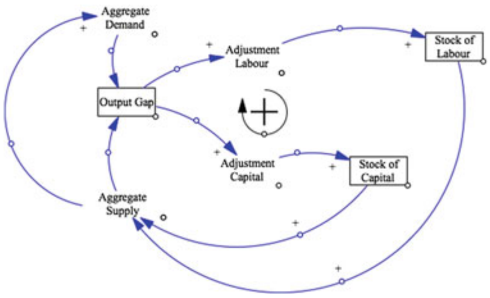

Fig. 1. Positive feedback through output gap.

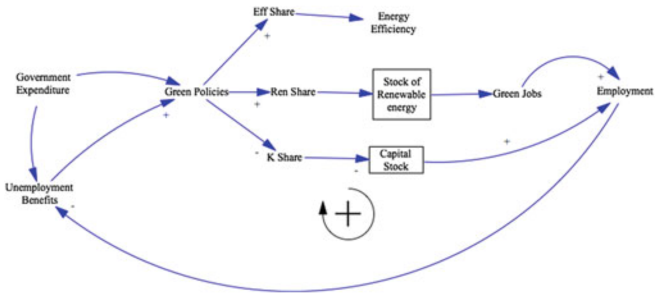

Fig. 2. Positive feedback through an increase in the incentive for renewable energy source.

effects on employment: (i) it directly promotes green jobs, (ii) it diverts part of the investment in capital to investment in RESC, reducing the accumulation of capital. Such change may induce firms to substitute labour for capital. Those two effects tend to increase the level of employment, thus government may further provide incentives for RESC without compromising its fiscal position.

At this stage of the project we are still working on the robustness analysis and in the choice of parameters through Italian statistics (from the ISTAT website). Hence, scenarios results are a qualitative analysis of the size of the investments in energy efficiency, in RESC and in physical necessary to follow the roadmap prescriptions for a low-carbon economy in 2050 rather than a quantitative answer to this problem. The Italian National agency for new technologies, Energy and sustainable economic development (ENEA) presents the possible evolution of National energy system in a time horizon of 30 years following three scenarios (see Fig. 3). The first one, Reference Scenario, adopts the set of policies at the end of 2009 and describes the evolution of the system following the actual trend. The second one, Current Policies Scenario, describes the effect of new actual policies. The third one, the Roadmap Scenario, evaluates the additional investment needed to reduce green house gas emissions following the prescriptions of the Impact Assessment for 2050 of [14].

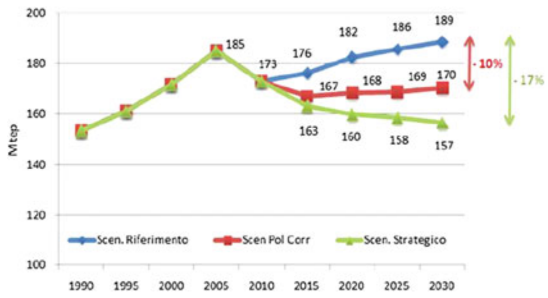

Fig. 3. Source [13]. Primary energy demand 1990–2030. Reference Scenario (blue); Current Policies Scenario (red); Strategic Scenario (green).

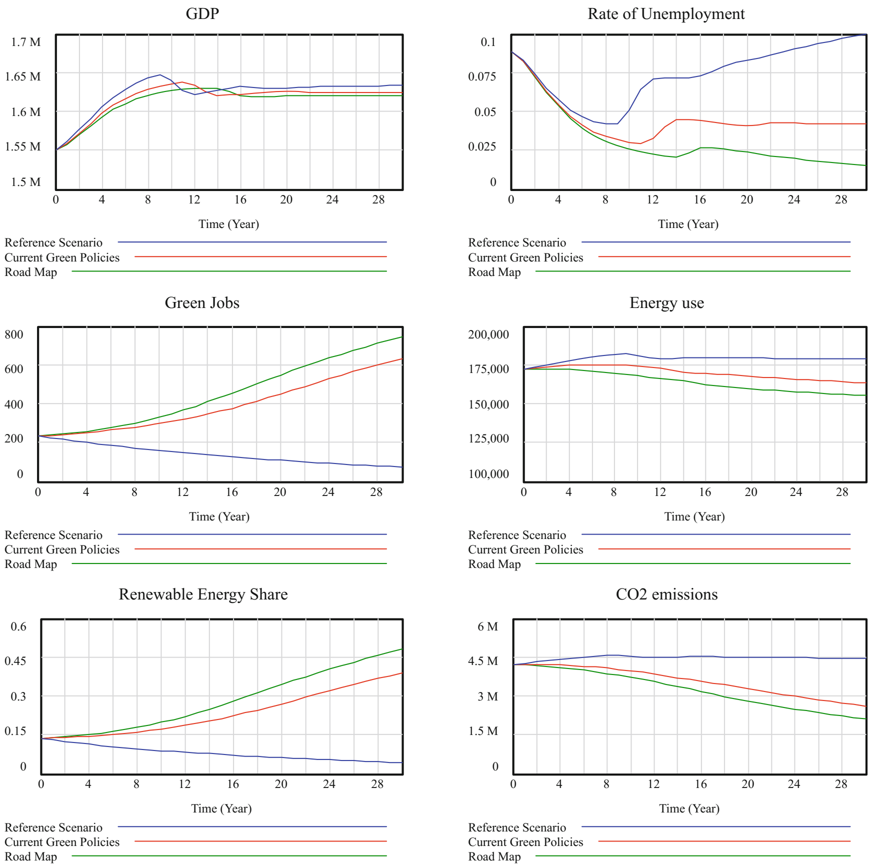

Fig. 4. Scenario analysis.

In our model those scenarios can be replicated by choosing a certain level of investment in the three areas stressed above. Figure 4 presents the results in terms of GDP, unemployment, green jobs, energy use, renewable energy share and CO_2 emissions. In order to following the roadmap scenario, investment in RESC must significantly increase in the percentage of total investment. In order to get such a result government has to divert public resources to support the profitability of investment in RESC.

4 Concluding Remarks

Preliminary results shows that *business as usual* scenario is not able to attain European Union prescriptions on renewable energy sources and emissions standard neither through the implementation of current policies. Investment in renewable energy source capacity (RESC) has to increase significantly in order to approach the roadmap for moving to a low-carbon economy in 2050. We obtained that investments in energy efficiency and greenhouse gas emission abatements are more effective in the short run, while the development of a large renewable energy sector is more effective in the long run by reducing the dependence on foreign sources of energy. This result raises several questions which we are aiming to deal with in the development of this research.

References

1. Nail, R., Budzik, P.: Fossil1: a policy analysis model of the U.S. energy transition. In: WSC 1976 Proceedings of the 76 Bicentennial Conference on Winter Simulation, pp. 145–152 (1976)
2. ASPO: Aspo newsletter no 95. Technical report, http://www.aspo-ireland.org (2008)
3. Bentley, R.: Global oil & gas depletion: an overview. Energy Policy **30**, 189–205 (2002)
4. Sterman, J.: A dynamic, disequilibrium model of energy-economy interactions. Int. J. Energy Syst. **2**, 159–163 (1982)
5. EIA: International energy outlook 2007, energy information administration. Technical report, US Department of Energy (2007)
6. IPCC: Ipcc special report on emissions scenarios. Technical report (2001)
7. Meadows, D., Meadows, D., Randers, J.: The Limits to Growth. Universe Books, New York (1972)
8. Meadows, D., Meadows, D., Randers, J.: Beyond the Limits: Global Collapse or a Sustainable Future. Earthscan, London (1991)
9. Bassi, A.: Modeling US Energy Policy with Threshold 21. VDM, Saarbrcken (2008)
10. Bassi, A., Powers, R., Schoenberg, W.: An integrated approach to energy prospects for North America and the rest of the world. Energy Econ. **32**, 30–42 (2010)
11. Victor, P., Rosenbluth, G.: Managing without growth. Ecol. Econ. **61**, 492–504 (2007)
12. Victor, P.: Managing Without Growth: Slower by Design, not Disaster. Edward Elgar, Cheltenham (2008)

13. ENEA: Rapporto energia ambiente. Technical report, National agency for new technologies, Energy and sustainable economic development (2012)
14. European Commission: A roadmap for moving to a competitive low carbon economy in 2050. Technical report, SEC 288 (2011)
15. D'Alessandro, S., Luzzati, T., Morroni, M.: Energy transition towards economic and environmental sustainability: feasible paths and policy implications. J. Clean. Prod. **18**, 291–298 (2010)