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REGULAR ARTICLE

Finance, energy and the decoupling: an empirical study

Zora Kovacic[1,2] · **Marcello Spanò**[3] · **Samuele Lo Piano**[1,2] · **Alevgul H. Sorman**[1,4]

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Abstract This paper investigates the empirical and theoretical basis of the decoupling between energy throughput and economic growth, with a critical view of the use of the decoupling concept as a policy priority. We provide an analysis of the historical trends of the metabolic pattern of European economies over a period of 18 years focusing on the changes in energy throughput and financial assets. The results show that energy consumption per hour of labor has remained constant, suggesting that no significant changes in production processes or technology have taken place in the productive sectors of the economy. The contribution of this paper is to establish a bridge between the economic analysis of financialization and the societal metabolism analysis of the economic process from a biophysical point of view. We argue that this bridge is crucial to draw attention to the biophysical consequences of financialization (a relative decoupling) and critically assess the pertinence of policies aimed at encouraging the decoupling in the context of increasing inequality.

Keywords Societal metabolism · Energy intensity · Financialization · Delinking · Inequality · GDP

✉ Zora Kovacic
zora.kovacic@uab.cat

[1] Institut de Ciencia i Tecnologia Ambientals, Universitat Autonoma de Barcelona, Edifici Z, Campus UAB, 08193 Bellaterra, Cerdanyola del Vallès, Spain

[2] European Centre for Governance in Complexity, Campus UAB, 08193 Bellaterra, Cerdanyola del Vallès, Spain

[3] Department of Economics, University of Insubria, Via Monte Generoso, 71, 21100 Varese, Italy

[4] Basque Centre for Climate Change (BC3), Sede Building 1, 1st floor, Scientific Campus of the University of the Basque Country, 48940 Leioa, Spain

1 Introduction

The decoupling between the environment and economic growth has been under scrutiny since the 1990s in a variety of forms: as an empirical question, as a theoretical question and as a policy priority. The theoretical basis of the decoupling hypothesis can be traced back to the work of Grossman and Krueger (1995), and Selden and Song (1994), who adapted the hypothesis originally developed by Kuznets on the inverted U curve that characterized the relationship between income per capita and inequality. The same hypothesis was put forward to explain the relationship between environmental degradation and income per capita, in what was popularized as the Environmental Kuznets Curve by the World Bank in 1992 (Stern 2004). Reddy and Goldemberg (1990) developed a similar interpretation in relation to energy throughput and GDP. A wide array of hypotheses are used to explain the decoupling, including technological innovation (Henriques and Kander 2010), increases in efficiency and labor productivity (EIA 2013; Jorgenson 1984), the tertiarization of the economy and the outsourcing of industrial production (Giampietro et al. 2012; Peters et al. 2011; Roberts and Grimes 1997).

As a policy priority, the idea of reducing environmental pressures through efficiency and innovation while sustaining economic growth can be traced back to 1992 (Fischer Kowalski et al. 2011). The term decoupling only appeared in 2001, deployed in a OECD strategy paper as a means of "ensuring that continued economic growth is accompanied by enhanced environmental quality" (OECD 2001: 11), and was put under the spot light by the United Nations Environmental Program in 2011 (Fischer Kowalski et al. 2011). With regard to policy, the decoupling is closely linked to technological optimism and a strong criticism of the limits to growth argument raised by Meadows et al. (1972). The recent renewed interest in the decoupling has also been explained as a response to the global financial crisis of 2008 (Borghesi et al. 2013).

Evidence is largely inconclusive in establishing whether a decoupling is happening, as hypotheses have both been empirically confirmed (Grossman and Krueger 1995) and disputed (Henriques and Kander 2010; Stern 2004). The debate also hinges on the question of whether observed instances of divergence signify a relative decoupling, in which economic growth accelerates faster than natural resource use, or an absolute decoupling, in which economic growth is accompanied by a decline in natural resource use (Marin and Mazzanti 2013). Disagreements on data interpretation stem from the fundamentally different stands taken by ecological economics, developed from Georgescu-Roegen's (1971) study of the economic process as a process of energy degradation, inseparable from its biophysical constraints, and neoclassical environmental economics, in which technological innovation is emphasized as a means to overcome biophysical constraints (Ramos-Martin 2003).

This paper aims at establishing a bridge between economic and biophysical theorizations of the economic process as a means to re-interpret the empirical basis of the decoupling hypothesis, with a specific focus on the role of financialization. We define financialization as the process of increasing financial leverage and of converting all sorts of values exchanged in the economy, including mortgages, salaries, pension funds, insurance premia, into financial assets. We provide a biophysical analysis of Energy Intensity trends, defined as the ratio between aggregate of the energy carriers (electricity, fuels, process heat) needed for different end uses (agriculture, building and manufacturing, energy and mining, transportation, services and government, households), and GDP, coupled with Financial Intensity (measured as the volume of financial assets over GDP) across different economic sectors. The empirical base used in this study covers the European Union at 14 countries (EU14) in the 18 -year period between 1995 and 2013. In the period under study, GDP growth outpaced the increase in energy throughput, leading to a decrease in energy intensity (energy throughput per unit of GDP) in the EU14 (Fig. 1). We acknowledge the limits of the short time period used, which is constrained by the timeframe of available data on the Eurostat database, but doing so allows for consistency in energy throughput accounting across countries and years.

Following Henriques and Kander (2010) the observed decoupling can be linked to an increasing share of the service sector in GDP, which is less energy intensive than building and manufacturing. The authors point out, however, that the structural changes in the economy do not provide conclusive evidence on the decoupling, since some economic activities comprised by the service sector, namely transport, are quite energy intensive. In order to avoid accounting for energy intensive activities of the service sector, we analyze the financial sector (FS) and the government sector (GOV) separately, and aggregate the remaining activities of the domestic economy (DE*).

According to a study published by McKinsey, global debt has been growing faster than global GDP, reaching 200 trillion US$ in 2014 (Dobbs et al. 2015), while global GDP for the same year is estimated at 75 trillion US$ (World Bank 2015). That is, the total debt as share of GDP is estimated to be 290%. Despite the practices of increasing credit and lowering interest rates that have characterized the last two decades, and intensified after the 2008 global financial crisis, the inflation rate (defined as the consumer price index) has been kept under control. By contrast, no control has been exerted on stock markets prices, on housing prices and on both volume and quality of financial assets. This phenomenon suggests that an increasing amount of credit avails transactions of assets already in place (housing, stock market) or of newly generated financial assets (securitization) (Bank for International Settlements 2011; Hudson and Bezemer 2012), but neither component has a net effect on GDP, according to current GDP accounting rules. To understand why, we shall recall how financial transactions are registered in national accounting. A financial transaction always has a counterpart transaction. This counterpart may be another financial transaction or a non-

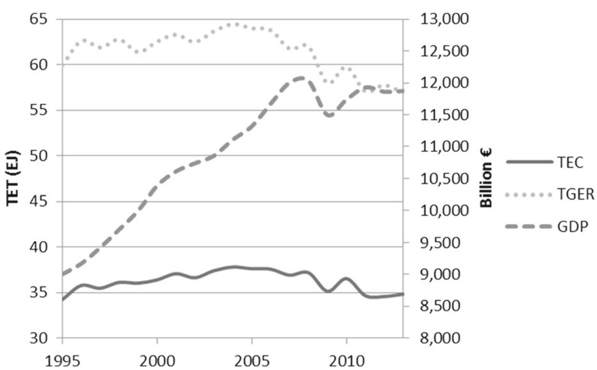

Fig. 1 Energy throughput and GDP in EU14 1995–2013. Acronyms: Total Energy Throughput (TET); Throughput of Gross Energy Requirements (TGER, Petajoules); Throughput of Energy Carriers (TEC, Pejtajoules); Gross Domestic Products (Billion €)

financial transaction, such as a transaction in products, a distributive transaction, a transaction in existing (non-produced in current period) non-financial assets. Where a transaction and its counterpart are both financial transactions, they change the portfolio of financial assets and liabilities and they may change the totals of both financial assets and liabilities of the holding institutions, but they do not change net lending/net borrowing or net worth. Trading in existing financial assets, or creating new financial assets, only affects the composition of the financial account balance of both counterparts of the transaction (Eurostat European Commission 2013: 129; Godley and Lavoie 2007). When the counterpart transaction of a financial transaction is not a financial transaction, net lending/net borrowing of the holding institutions will change. However, if the counterpart is an existing real asset (including houses) not produced in the current period, the change in ownership is simultaneously registered in the gross fixed capital formation of both the seller (debit) and the buyer (credit), so that "*the positive and negative values recorded* for gross fixed capital formation *cancel out for the economy as a whole* except for the costs of ownership transfer" (Eurostat European Commission 2013: 84, emphasis added).

The aforementioned rising transactions (and rising value) of assets are analyzed in the economic literature on financialization, which underlines that single individuals enhance indebtedness, risk-taking positions and participation to financial markets (Lapavistas 2011; Martin 2002), corporate management is increasingly targeted at maximizing shareholders value (Gallino 2005; Krippner 2005), and financial assets are increasingly used as sources of profitability in substitution to real production (Epstein 2005; Erturk et al. 2008; Pollin 2007; Van Treeck 2009). Financialisation of the economy has also been associated with income polarization and inequality (Onaran et al. 2011; Palma 2009; Stockhammer 2015), with endogenous financial instability and global imbalances (Crotty 2008; Keen 2011; Kindleberger 1986; Minsky 1986; Nersisyan and Wray 2010), and with the inadequacy of regulation (Lordon 2011). Throughout this paper, we refer to financial intensity as a proxy for financialization. Financial intensity is the ratio of the stock of gross financial assets (or liabilities) per unit of value added (and in the case of total economy, per unit of GDP).

The aim of this study is to explore whether the decoupling between energy throughput and economic growth in the EU14 can be connected to the process of financialization of the economy. Using data covering the period from 1995 to 2013, we provide a quantitative description of this phenomenon for different economic sectors, taking into account the different energy requirements of different economic sectors using the framework of societal metabolism. In light of our empirical findings, comparing temporal performance of Energy Intensity and Financial Intensity, we provide (in section 5) a tentative explanation of the decoupling between GDP and energy throughput based on the crucial role of the financial sector in the economies under study. We suggest that finance has generated a long-term wave of several rent-seeking practices that have made possible and encouraged the restructuring of production towards outsourcing and tertiarization, ultimately leading to the observed trends. Increasing financial intensity (the ratio of financial assets per unit of GDP) and decreasing energy intensity, therefore, can be interpreted as twin effects of the same phenomenon.

The paper is organized as follows: section 2 defines the theoretical framework of societal metabolism used to study the decoupling. Section 3 details the data and methods used. Section 4 presents the results of the analysis of the EU countries. We assess the performance of the individual economic sectors and their impact on the overall decrease in energy intensity at the national level and on the overall increasing financialization of the economy. Section 5 advances a tentative explanation of the decoupling by connecting observation on financial and biophysical trends. Section 6 concludes.

2 The interface between the financial and the biophysical economy

In order to assess the relationship between energy throughput and the economic process, we analyze socio-economic systems from the point of view of societal metabolism (Giampietro and Mayumi 2000a, b). Societal metabolism is an approach widely used in industrial ecology to study the flow of materials and energy consumed by a society. This approach makes it possible to characterize the economic process both from an economic and a biophysical point of view.

Metabolism is a term used in biology to describe the processes through which organisms consume energy and other materials in order to reproduce themselves. Similarly, in the societal metabolism approach, energy throughput is related to the reproduction of the socio-economic system. According to Ulanowicz (1986), it is possible to distinguish between (a) the hypercycle, that is, those activities that are net energy producers for the rest of society, and (b) the dissipative part, that is, those activities that are net energy consumers or degraders. The dissipative part stabilizes the system through the reproduction and operation of institutions, providing a control mechanism for the energetic surplus produced by the hypercycle. In the societal-metabolic perspective, the hypercyclic sectors consist of agriculture (AG), energy and mining (EM) and building and manufacturing (BM), providing food, energy, materials, and infrastructure, to the rest of the society. The dissipative part is represented by the services and government sectors (SG) and by households (HH) (Giampietro et al. 2014, 2013, 2012). It should be underlined that the term dissipative refers to energy transformation and not to the generation of value added: dissipative sectors are energy degraders, they are not necessarily non-productive in economic terms.

In order to provide a quantitative characterization of societal metabolism, we refer to Georgescu-Roegen's (1971) definition of a process as something that can be analyzed by differentiating between funds, that is elements that stay the same for the duration of the analysis and define the identity of the systems (e.g. Ricardian land, capital and the work force), and flows, that is, elements that are used or produced in the duration of the analysis (e.g. energy, material inputs, water). According to this definition, a process can be described in quantitative terms as the consumption or production of flows through a given fund. It should be noted that the definition of funds and flows cannot be determined in absolute terms, but depends on the scale of analysis and duration of the representation.

Societal metabolism can be re-defined, according to this framework, as the reproduction of fund elements, for example, a given society, through the consumption of energy, water, food and the production of waste flows. Economic growth, from the biophysical viewpoint, is the result of an acceleration in metabolic rates, that is, an acceleration in the throughput of a given flow per unit of fund (e.g. the quantity of energy (flow) used per hour of human activity (fund)). We refer to hours of human activity in order to acknowledge the diversity of activities carried out within society and distinguish between the working and non-working activities of the economically active population, as will be explained in section 3. The acceleration in the throughput of energy per hour of human activity is driven by the strength of the hypercyclic sectors, i.e. the capacity to deliver a surplus to the rest of the society using the least funds possible. For instance, in relation to the energy and mining sector, a higher energy surplus (i.e. net energy supply after subtracting the self-consumption of the energy and mining sector and distribution losses) provided per hour of human activity makes it possible to sustain a larger and more varied range of activities, such as higher education, the welfare system, the health care system, leisure activities, the army and so on. In the biophysical characterization, economic growth is directly linked to increased energy throughput. This characterization is consistent with the historical correlation between energy throughput and GDP (Granger 1969; Kaufmann 1994, 1992; Smil 2010; Stern 2011; Stern and Cleveland 2004).

In order to explain changes in energy intensity, we distinguish between economic activities that present different metabolic rates (measured as energy throughput per hour of human activity). For instance, the industrial sector presides over the biophysical transformations and presents a high correlation between energy throughput and value added. By constrast, the financial sector provides the means of payment that make biophysical production viable and presides over the production of surplus measured in monetary value. The creation and circulation of financial instruments is not technically linked to a significant energy throughput.

To assess the sectorial financial intensity, defined as the volume of financial assets per unit of GDP, we adopt a broad measure of the amount of financial assets. There are different possible options in measuring financial aggregates: from the narrower definition of M1 traditionally used for money (which aggregates the deposits of the banking system), to broader definitions including less liquid assets (Domanski et al. 2011). Given the increasing diversification of financial assets circulating in the economy observed in the last 20 years, we adopt the broader definition. This choice is justified by two reasons. First, in principle, any financial asset can be used as a means of payment, as well as a store of value, i.e. as a substitute for money. Second, the practice of using financial assets as money substitutes has risen in the last 20 years, where the complexity and diversification of assets has allowed transforming traditionally illiquid assets, such as mortgage credits, into liquid and marketable means of payment.

The generation and circulation of financial assets is indispensable for the reproduction of GDP over time, as expenditure in the economy is generated out of financial stocks. This interpretation of the role of finance is developed by a strand of the economic literature describing the evolution of the whole economic system integrated with all financial transactions (Schumpeter 1949; Keynes 1937; Graziani 2003; Godley and Lavoie 2007; Keen 2010; see Bezemer 2010, for a survey). An important implication of this analysis is that, when financial assets are oriented to support economic production, a steady level of investment (i.e. a nearly zero level of net saving) requires a more or less constant amount of financial assets. This result derives from the assumption that aggregate demand (and income) must be equal to the demand generated by the turnover of existing means of payment, plus the demand generated by the newly created lending: a stable level of aggregate demand does not require new creation of lending (Keen 2015, 2009; Keynes 1937).

In financialized economies, however, the monetary value of financial assets has been increasing over the last decades, while investment, gross saving and national income have been proceeding at a much lower rate (Palma 2009; Spanò 2015). This suggests that what has been going on is some independent, massive activity of endogenous creation of borrowing for non-productive purposes, such as fuelling transactions in existing assets and liquidation of non-tradable assets. This, in turn, created speculative bubbles in both share and housing markets, thereby fuelling further borrowing. The multiplication of financial assets oriented to speculation and transactions of existing assets (Minsky's 'financial instability hypothesis') is largely unrelated to the activity of producing goods and services (and GDP).

Based on this theoretical framework, we provide an analysis of the historical trends of energy and financial intensity in the EU14 economies and focus on the changes in metabolic pattern that can explain energy throughput trends and financial assets generation.

3 Data and methods

The empirical analysis of the paper is based on the changes in energy intensity and financial intensity from 1995 to 2013 in the EU. The time frame of the analysis is limited by the availability of time series data on financial assets. Energy intensity is considered to assess to what extent a decoupling between energy throughput and GDP has taken place in the EU. Financial intensity is introduced in order to assess to what extent the financial balance sheets have increased independently of GDP.

Energy intensity is defined in this study as the ratio between energy throughput and Gross Value Added (GVA), and is measured in MegaJoules of energy carriers used per unit of GVA expressed in Euros at constant prices. At an aggregate level, GVA is equivalent to GDP net of taxes. We use GVA in order to be able to assign a value of GVA to each economic sector considered. Energy throughput is calculated according to the protocol developed by Diaz-Maurin and Giampietro (2013), Giampietro et al. (2013, 2012), Giampietro and Sorman (2012), Mayumi and Giampietro (2014), and Sorman (2011), based on energy accounting in terms of energy carriers. According to this protocol, energy can be accounted either in terms of primary energy sources (e.g. oil, coal, wind, solar radiation, uranium, et cetera) or in terms of energy carriers, that is, the final form in which energy is consumed by end users (e.g. gasoline, diesel, electricity, heat, et cetera). Since different primary energy sources have to undergo different transformation processes (and require different energy inputs) in order to be available as energy carriers for final consumption, the total energy throughput of a society depends both on the final energy consumption and on the processes required to produce energy carriers. For this reason, we calculate energy throughput in terms of energy carriers by differentiating between mechanical (electricity) and thermal energy (fuels and process heat). This distinction makes it possible to account for the differences in quality between different primary energy sources (e.g. coal and wind) used to produce energy carriers (e.g. electricity) (Cleveland et al. 2000; Fleay 2003).

The Total Gross Energy Requirement is a proxy for the total Primary Energy Supply measured in thermal equivalent, and the sum of the Energy Carriers represents the total final Energy Consumption by society. The primary energy equivalent of hydroelectricity and nuclear electricity (as for any other electricity not generated from thermal power plants) is accounted for by considering the amount of primary energy needed if fossil fuels were used as Primary Energy Sources. According to thermodynamics, to calculate primary energy equivalent it is necessary to define a conversion factor between Joules of thermal energy/Joules of electricity (the efficiency of the thermal power plant) (Giampietro et al. 2016). To this end, the Total Gross Energy Requirement (see Fig. 1) is derived by multiplying each energy carrier by the appropriate transformation coefficients (approximately 2.8 for electricity, 1.7 for fuel and 1.1 for process heat). For electricity, the factor used refers to the average efficiency achieved in the European Union: 30.7% once the plant self-consumption has been accounted for (EEA 2015). This value translates into a conversion factor: 1MWh = 0.086toe/0.307 (1 J of electricity has a thermal energy equivalent of 2.8 J). For fuel, the coefficient represents the ratio between output of finished oil products used for transportation (liquefied petroleum gas, motor spirit, gas/diesel oil and total fuel oil used for transport) and input of crude oil and additives/oxygenate in the refinery. The average conversion factor for European refineries in the years under study is 1GJ of fuel per 1.7 GJ of primary energy sources (Barthe et al. 2015). For process heat, the coefficient represents an average of heat generation for non-industrial and industrial uses, taking into account the thermal losses of industrial processes and the benchmarks for district heating plants (EEA 2015). Typically 1.1 GJ of primary energy sources (natural gas, solid fuels, etc.) expressed in thermal equivalent are required for 1 GJ of process heat.

This approach allows us to sum “apples” with “apples” and “oranges” with “oranges.” The methodology used responds to the observation that different accounting methods may lead to very different estimates of energy throughput (Cleveland et al. 2000; Giampietro et al. 2013). By accounting for energy carriers, we overcome the challenge of aggregating different primary energy sources such as nuclear power and renewable energy sources, and different conversion processes, by converting all primary energy sources to energy carriers. The differences in quality are reflected by the use of conversion coefficients.

Estimated flows of energy carriers are re-aggregated in this study in order to obtain a proxy of the total energy throughput, however a more in-depth study of energy flows would require a separate accounting of different energy carriers. In order to overcome this limitation, the variation of the shares of each energy carrier has been acknowledged throughout the manuscript. Data are taken from Eurostat tables of Supply, transformation, consumption of solid fuels (nrg101a), oil (nrg102a), gas (nrg103a), electricity (nrg105a), renewable energies (nrg107.a) and non-renewable waste (nrg108a) (Eurostat 2014).

Financial intensity is given as the ratio between the financial assets (or liabilities) and GVA. Financial intensity can be seen as a measure of the level of financialization of the economy. Financial assets and liabilities data are taken from Eurostat table Financial balance sheets (nasa_10_f_bs) (Eurostat 2015a), non-consolidated accounts. Nominal values of financial assets and liabilities are expressed at constant prices, base year 2005, using the Harmonized Indices of Consumer Prices (HICP) (Eurostat 2015b). Data for Ireland are not available for the years 1995–2000.

Gross Value Added (GVA) and Gross Domestic Product (GDP) data are taken from Eurostat GDP and main components - Current prices (nama_gdp_c) data tables (Eurostat 2015c). There are different accounting procedures that can be used to calculate GDP. The sum of the Gross Value Added in the various economic sectors is a measure of GDP at factor cost. Data for Ireland and the United Kingdom are not available for the years 1995, 2012 and 2013; data for Portugal are not available for 2013. Also in this case, nominal values of GVA are expressed at constant prices, base year 2005, using HICP.

In order to relate energy throughput and the volume of financial assets within the societal metabolism framework, we estimate the energetic metabolic rate and the financial metabolic rate. The energetic metabolic rate is defined as the ratio between energy throughput and human activity, measured in terms of MegaJoules of aggregated energy carries per hour of human activity.[1] The financial metabolic rate is calculated as the ratio between financial assets (or liabilities) and human activity, measured in Euros (at constant prices) per hour.

Total human activity is calculated as the total amount of hours in one year available to a given population. The use of hours of human activity makes it possible to distinguish between the working and non-working hours of the economically active population. This distinction takes into account the fact that the working population also contributes to the dissipative part of the economy, that is, to the consumption of energy. The human activity of each economic sector is calculated as the average weekly hours of work per year multiplied by the average number of yearly working weeks (assumed to be 46) multiplied by the number of employees in each sector. Data are taken from Eurostat tables Employment by sex, age and economic activity (1983–2008, NACE Rev. 1.1) (lfsq_egana) and from 2008 onwards (NACE Rev. 2) (lfsq_egan2) (Eurostat 2015d).

More details about the calculation of the indicators used are available in Appendix.

The countries considered are the European Union at 14 (EU 15 countries excluding Luxemburg[2]) for a eighteen-year time period from 1995 to 2013. This period of time is the longest span available to guarantee a consistent treatment of the data and the quality of the results. The time span is constrained by data availability of the Eurostat database for a large enough sample of countries. Although the analysis should ideally include past decades, we claim that nearly two decades of observations are enough to assess the change in correlation between real GDP and energy throughput in the EU. Smil (2010) has analyzed the correlation between energy and GDP for the US economy for the same period.

4 Results: the relationship between energy and finance

This section presents the empirical results of the characterization of the EU14 economies in terms of energy intensity and financial intensity. We first present the result of the analysis at the national level and relate our results to a brief overview of the main

[1] Data for energy throughput in terms of energy carriers for the financial sector and government sector were not available in the Eurostat database. We assume that these sectors have the same energetic metabolic rate of the service sector, given that the service sector presents a very stable metabolic rate across the countries of the sample.

[2] Luxemburg has been disregarded from the dataset of analysis of the EU15 countries because of the lack and the inconsistency of data measurements.

arguments used to explain the decoupling. Second, we discuss the trends in energy intensity and labor productivity by distinguishing between economic sectors.

A decline in energy intensity can be observed in our sample for the period 1995–2013, coupled with an increase in financial intensity over the same period (Fig. 2). Energy intensity values have declined by about 20% during the period analyzed, with an average annual pace of about 1.5%.

At the level of the whole economy, financial intensity, illustrating the financial expansion in national income, rose by 65%, with an average of roughly 4% per year. This trend is so significant that ample bodies of literature have been published on the financialization of the economies (Epstein 2005; Erturk et al. 2008; Fine and Milonakis 2011; Lapavistas 2010; Pollin 2007; Van Treeck 2009).

Since the use of the energy intensity indicator for the economy as a whole hides important differences among economic sectors, we study how this decrease has taken place in selected economic sectors: the financial sector (FS), the government (GOV) and the rest of the domestic economy (DE*). The focus on the financial sector is driven by the fact that financial intensity has increased at an unprecedented rate. The government sector is also analyzed in order to assess its role in the financialization of the economy. The DE* sector includes agriculture, building and manufacturing, services other than finance and government, and households. This typology makes it possible to overcome the issue of accounting for energy intensive activities, such as transport, generally attributed to the services sector, and household energy consumption. Figure 3 shows the energy intensity and financial intensity trends for the three sectors, DE*, GOV and FS, for Austria. The same analysis is provided for each country analyzed in the following data repository:

https://docs.google.com/spreadsheets/d/12pY7WWrH2sa0CtSS_E3ItAkL9osC84NMasishTZ0GAw

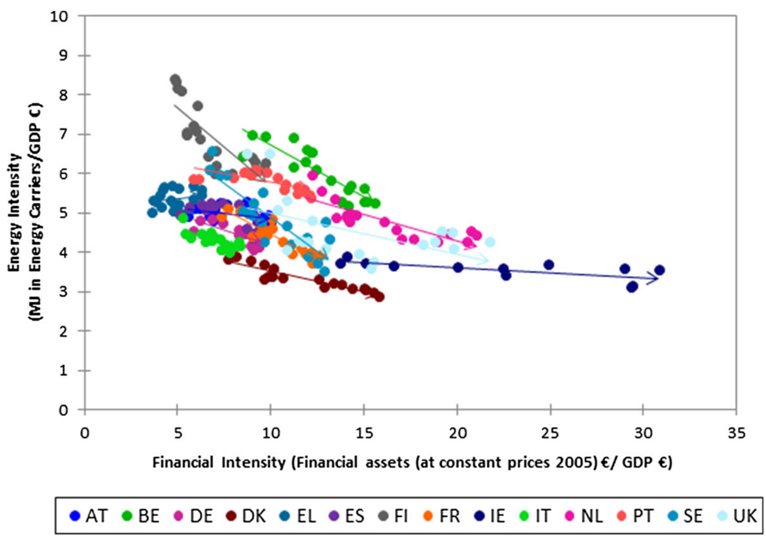

Fig. 2 Evolution of Energy Intensity and Financial Intensity over time for the EU14 (national level) from 1995 to 2013

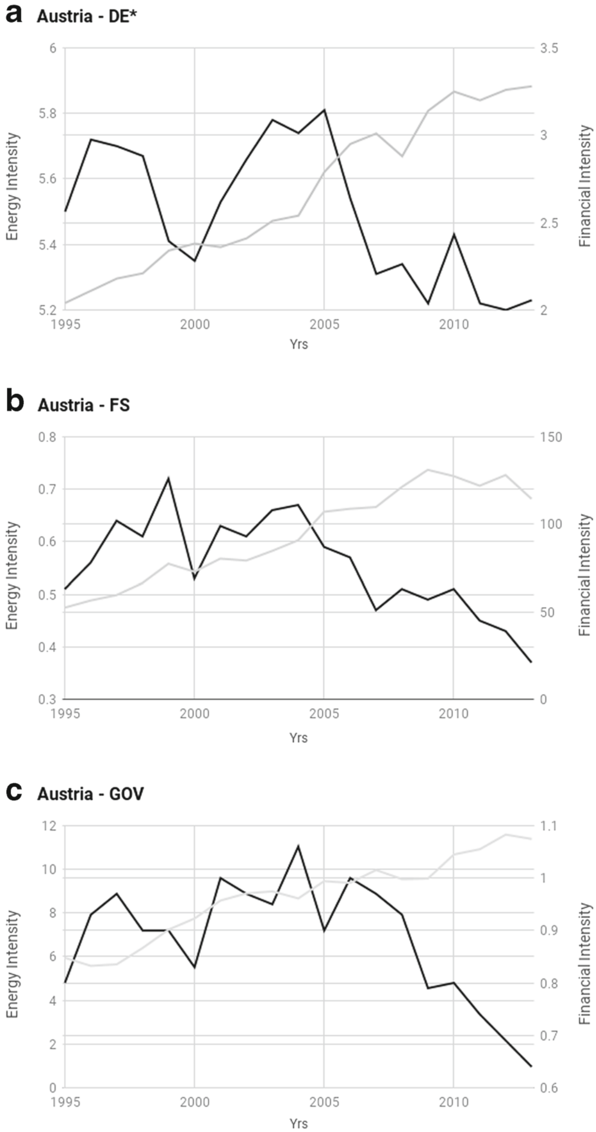

Fig. 3 Break-down of energy intensity and financial intensity by sector

The DE* sector (rest of the economy) presents the highest energy intensity in all countries considered because it includes both transport and the building and manufacturing sectors (the main energy consumers). The government and financial sectors display almost negligible energy throughput with respect to the total, and no clear trend in terms of energy intensity. By contrast, the financial sector unsurprisingly shows the highest levels of financial intensity for all countries in the sample, with values several orders of magnitude above the other sectors. The relative share of GVA of the three sectors considered does not present significant changes over the period analyzed. The DE* sector accounts for about 88% of GVA in the sample analyzed. The government share of total GVA slightly decreased, from 7.0% in 1995 to 6.3% in 2007, before the crisis, increasing afterward again to 6.9% in 2013. The size of financial sector slightly increased from 5.4% of total GVA in 1995 to 5.9% in 2009 with a following mild decrease to the final figure of 5.6% in 2013.

We analyze the three sectors separately and in more detail below.

The performance of the financial sector varies considerably across countries (Table 1 and Fig. 4). In terms of financial intensity, there has been a huge and disproportioned growth in the value of financial assets (EU14 average financial intensity for the FS sector goes from 60 in 1995 to 140 in 2013). The rate of growth varies markedly across countries. The increase in financial intensity has been particularly sharp in Finland, Spain, Ireland, Portugal, the UK and Denmark, while it has been much more limited in the Netherlands, Belgium and Greece. A reversal of the financial intensity trend after 2007 can be observed in Belgium, the Netherlands, France and Sweden, corresponding with the financial crisis.

The stark increase in financial intensity (the ratio between financial assets and GVA) is determined by the constantly and rapidly increasing value of items in the balance sheet of financial institutions, and an almost constant share of GVA of the financial sector. The gross level of the financial sector's assets and liabilities at a given date may not provide sufficient information on the degree of financialization of the economy, as it may depend on institutional rules of financial assets creation and accounting as well as on instant time in monetary circuits. By contrast, the fact that the financial intensity of the financial sector is increasing over time is a clear indicator of financialization; it illustrates that there have been financial transactions very weakly related to GVA changes. Rising financial intensity is the result of a twofold effect of the creation of new financial assets (and liabilities) and the increase in value of existing financial assets. These two effects are not independent of each other. On the contrary, they had been feeding off each other over nearly three decades before 2007, leading some economists to interpret this phenomenon as an extended, rent-seeking Ponzi bubble (Hudson and Bezemer 2012; Keen 2011; Palma 2009).

Differences in financial intensity across countries are the consequence of different capacities to attract investors (financial reputation). Financial assets are particularly over-dimensioned in countries able to attract multinational companies (namely, Ireland because of fiscal incentives and the UK because of the importance of London's financial market). This is the result of accounting assets in the country of residence, regardless of the company's nationality.

Given that governments have assumed part of the private debt generated by private businesses, they have been the focus of attention of European policy as a means to regulate the financial market. In order to evaluate the impact of public debt on the performance of the economy, we analyze the performance of the government sector through financial intensity measured in terms of liabilities. Table 2 and Fig. 5 illustrate the government's share of financial liabilities over the period 1995–2013. During the period analyzed, financial intensity once again presents very different trends in different countries. In order to analyze the trend we shall distinguish between two periods: before and after the financial crisis of 2007–08.

Before the crisis, for nine of the EU14 countries, financial intensity of the government sector was either stable or decreased steadily. This is the result of the efforts to fulfill the requirement of fiscal balance either self-imposed (countries not adopting the Euro) or agreed upon within the stability and growth pact of the Eurozone. Austria,

Table 1 Financial intensity (volume of financial assets/GVA) of the financial sector, 1995–2013

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	52	57	60	66	77	73	80	79	85	91	110	110	110	120	130	130	120	130	110
BE	65	69	79	95	93	85	95	88	100	100	120	130	150	150	130	120	120	110	110
DE	65	67	74	86	86	110	110	100	100	96	100	110	120	150	120	120	130	130	130
DK	72	85	95	100	120	120	120	110	120	130	130	140	140	130	130	140	150	140	150
EL	43	40	38	38	47	44	49	45	43	36	41	43	50	58	60	70	72	73	69
ES	49	51	54	59	66	63	59	59	66	72	84	90	88	87	87	110	120	130	130
FI	42	46	50	51	59	59	59	70	84	91	93	96	93	110	120	160	190	190	170
FR	87	91	100	110	120	110	120	120	120	130	140	150	160	170	160	140	160	160	150
IE							130	130	120	130	160	180	180	200	230	240	240	240	230
IT	41	43	50	51	56	54	51	55	55	58	60	64	59	63	74	73	73	79	76
NL	110	120	120	140	140	140	140	130	140	140	160	190	230	220	180	160	190	180	180
PT	43	50	52	57	63	65	61	61	64	64	69	67	68	65	82	96	89	100	110
SE	71	63	60	69	79	85	86	88	90	88	98	130	130	120	130	140	130	120	120
UK	71	85	98	96	120	120	130	120	120	130	130	130	120	180	150	170	200	180	170
EU14	64	68	73	80	88	89	92	89	94	96	100	110	120	130	120	130	150	140	140

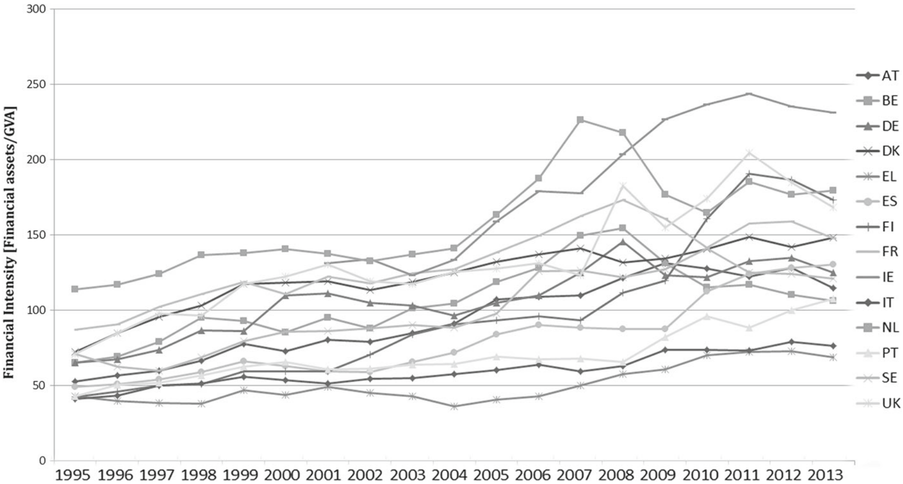

Fig. 4 Financial Intensity of the Financial Sector 1995-2013

Belgium, Germany, France and Portugal were the only exceptions, showing overall a mild rise of liabilities financial intensity, although with some fluctuations in the years just preceding the crisis.

From 2007 to 08 onwards, the financial intensity of the government sector increased in all countries (sharply in the UK and Ireland) with no exception, as governments raised debts partially to cushion the fall in private consumption and in some cases to rescue financial institutions considered “too big to fail.”

The latter observation is in stark contrast with the austerity policies imposed on peripheral countries of the Eurozone by the European Central Bank, the European Commission and the International Monetary Fund on the grounds of an increasing spread. The spread of a country is a measure of the difference between the government’s borrowing cost and the borrowing cost of the lending government. The interest rate is set in order to cover the costs of the expected default risk. If perceived risk increases, the spread also tends to increase in order to attract enough capital through higher yields, thereby raising the share of liabilities used to finance borrowing costs. The analysis of financial stocks instead of interest rates allows us to suggest that the austerity policies applied did not respond to a factual increase in government debt, but rather to a perceived increase in risk.

Finally, the DE* sector (rest of the Domestic Economy) is composed of agriculture and the building and manufacturing sectors (the economic sectors with the highest energy throughput), services excluding finance and government, and household activities. The DE* sector comprises about 99% of total human activity. Given its characteristics, we analyze the DE* sector with reference to the fund population. The metabolic rates considered are the energy metabolic rate, measured as energy throughput (MegaJoules) per hour of human activity (Table 3 and Fig. 6a), and the financial metabolic rate, measured as financial assets (at constant prices) per hour of human activity (Table 4 and Fig. 6b).

The energy metabolic rates of the DE* sector tend to be stable over the period analyzed (Table 3). This suggests that there has been no decrease in the energy throughput of European economies per hour of work. This result is consistent with

Table 2 Financial intensity (volume of financial liabilities/GVA) of the government sector, 1996–2013

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	12	13	12	13	14	14	15	16	16	16	19	18	19	19	20	21	22	24	23
BE	23	23	23	24	21	21	21	20	19	19	18	17	17	17	18	18	19	19	19
DE	8.8	9.2	9.7	10	10	10	10	11	11	12	12	12	12	13	13	15	15	16	15
DK	17	16	16	16	15	14	14	14	14	13	12	11	10	11	12	12	14	15	14
EL	14	15	15	14	14	16	17	17	17	17	17	18	17	17	16	16	14	19	21
ES	13	14	14	14	14	13	12	12	12	11	11	10	9.1	9.7	12	13	15	19	22
FI	15	16	15	16	14	12	11	11	11	11	9.8	9.3	8.8	8.4	9.6	11	11	12	13
FR	10	10	11	11	11	11	11	12	12	12	12	12	12	13	14	15	15	16	16
IE				13	12	9.9	9	8.8	8.5	8	8.4	7.5	7.6	11	15	20	27		
IT	23	24	23	24	23	23	22	21	20	19	20	20	19	19	20	20	19	22	23
NL	13	13	12	13	12	11	9.9	9.9	9.8	9.9	9.9	9.1	8.8	11	11	11	12	13	13
PT	9.7	9.8	9.4	9.4	9.1	8.6	9.3	9.7	10	11	11	12	12	13	14	16	17	24	
SE	18	17	18	18	18	15	15	15	15	15	15	14	13	12	14	14	14	14	13
UK		13	14	14	14	13	12	12	12	11	12	12	12	13	17	20	25		
EU14	15	15	15	15	14	14	13	14	13	13	13	13	13	13	15	16	17	18	17

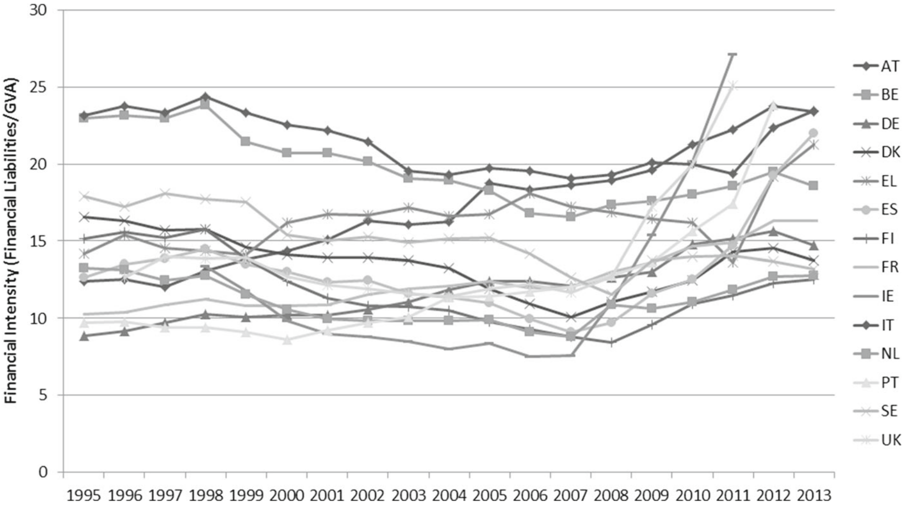

Fig. 5 Financial Intensity of the Government Sector 1995-2013

the findings of Henriques and Kander (2010). The only exceptions are Spain, Greece, Austria and Portugal, displaying a slight increase in energy metabolic rate, possibly linked to the large-scale investments in construction and infrastructures that preceded the crisis. This result suggests that the decoupling is relative, although this conclusion must be taken with caution.

The financial metabolic rate has increased consistently in all countries analyzed (Table 4). Increases in the financial metabolic rate are particularly steep for Ireland, Denmark, Finland and Sweden. The financial metabolic rate peaks in Spain in 2007 (more than a two-fold increase with respect to 1995) in correspondence with the boom in construction and the associated real estate bubble that burst during the financial crisis and then decreases constantly.

Most of the countries that experienced a sharp increase in the financial intensity of the financial sector also display a marked increase of financial metabolic rate in the DE* sector. This result confirms the hypothesis that the real economy has been involved in the process of financialization, albeit not on the same scale as the financial sector. The DE* sector presents the lowest values of financial intensity, although increasing (from 3.2 in 1995 to 5.2 in 2013, EU14 average).[3] Due to the fact that financial assets and liabilities are increasingly internationalized, the DE* sectors increased their external liabilities, namely, their foreign held debt, making the correlation between the financialization of the domestic FS and DE* sectors only partial.

5 Decoupling and the role of finance

Based on the empirical findings presented in section 4, we now advance some tentative explanations about the mechanism through which the relative decoupling between

[3] Data for the UK and Ireland are not available for the years 1995, 2012 and 2013; and data for 2013 are not available for Portugal.

Table 3 Energy metabolic rate (Mega Joules of energy carriers/h of human activity) of the DE* sector, 1996–2013

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	14	14	14	14	14	14	15	15	16	16	16	16	16	16	15	16	16	16	16
BE	17	18	18	18	18	18	18	18	18	18	17	17	17	18	16	17	16	16	16
DE	13	13	13	13	13	13	13	13	13	13	13	13	12	13	12	13	12	13	13
DK	12	13	12	12	12	12	12	12	12	12	13	13	13	12	12	12	12	11	11
EL	7.7	8.2	8.3	8.7	8.6	8.9	9.1	9.3	9.7	9.6	9.8	10	10	9.9	9.5	8.8	8.7	8.0	7.4
ES	8.3	8.5	8.9	9.3	9.6	10	11	11	11	11	11	11	11	11	9.7	9.7	9.4	8.8	8.8
FI	19	19	20	21	21	20	20	21	21	21	20	21	21	21	19	20	20	19	19
FR	12	13	12	13	13	13	13	12	13	13	12	12	12	12	11	12	11	11	11
IE	11	11	11	12	13	14	14	14	14	14	15	15	15	14	13	13	12	11	11
IT	10	10	10	11	11	11	11	11	11	11	11	11	11	11	10	10	10	10	9.6
NL	16	17	16	16	15	16	16	16	16	16	16	16	16	16	15	16	15	15	15
PT	7.1	7.2	7.6	8.1	8.4	8.8	8.8	8.9	8.9	9.0	9.0	8.8	8.9	8.7	8.5	8.4	8.0	7.6	7.8
SE	18	18	18	18	17	17	17	17	17	17	16	16	16	15	15	15	15	15	14
UK	13	13	13	13	13	13	13	13	13	13	13	13	12	12	11	12	11	11	11
EU14	13	13	13	13	13	14	14	14	14	14	14	14	14	14	13	13	12	12	12

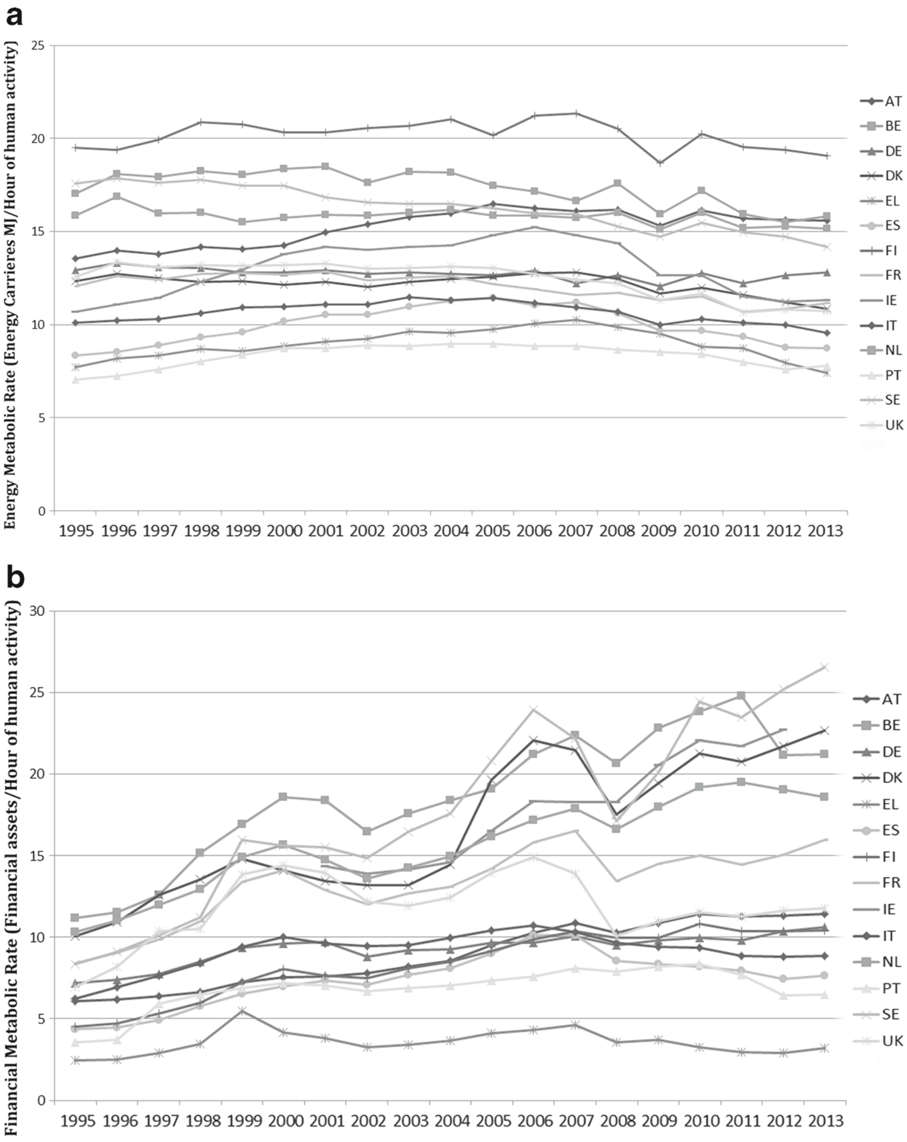

Fig. 6 Energy Metabolic Rate of the Domestic Economy excluding Financial Sector and Government 1995-2013 (6**a**) and Financial Metabolic Rate of the Domestic Economy excluding Financial Sector and Government 1995-2013 (6**b**)

GDP and energy throughput is taking place and the central role plaid by the financial sector.

The energy intensity of the EU14 has decreased by 20% over the period analyzed, confirming that there has been a relative decoupling between energy throughput and GVA in all national economies of our sample (EU14). We speak of relative decoupling because no decrease in energy metabolic rates can be observed in the DE* sector of the countries analyzed (Table 4). This result is in line with previous studies (Giampietro et al. 2012; Peters et al. 2011; Roberts and Grimes 1997) that emphasize that declining

Table 4 Financial metabolic rate (financial assets/h of human activity) of the DE* sector, 1996–2013

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	6.1	6.2	6.4	6.7	7.2	7.5	7.6	7.8	8.2	8.6	9.5	10	11	10	11	11	11	11	11
BE	11	12	13	15	17	19	18	16	18	18	19	21	22	21	23	24	25	21	21
DE	7.2	7.4	7.7	8.5	9.4	9.6	9.7	8.8	9.2	9.3	9.7	9.7	10	9.5	9.8	10	9.8	10	11
DK	10	11	13	14	15	14	13	13	13	14	20	22	21	18	19	21	21	22	23
EL	2.5	2.5	2.9	3.4	5.5	4.2	3.8	3.3	3.4	3.7	4.1	4.3	4.6	3.6	3.7	3.3	2.9	2.9	3.2
ES	4.3	4.4	4.9	5.8	6.5	7.0	7.3	7.1	7.7	8.1	9	10	10	8.5	8.4	8.2	7.9	7.4	7.7
FI	4.5	4.7	5.3	6.0	7.2	8.0	7.6	7.5	8.1	8.5	9.1	9.8	10	10	10	11	10	10	10
FR	8.4	9.1	9.8	11	13	14	13	12	13	13	14	16	16	13	15	15	14	15	16
IE							14	14	14	15	16	18	18	18	21	22	22	23	
IT	6.2	7.0	7.6	8.4	9.4	10	9.6	9.4	9.5	10	10	11	10	9.7	9.4	9.3	8.9	8.8	8.8
NL	10	11	12	13	15	16	15	14	14	15	16	17	18	17	18	19	19	19	19
PT	3.6	3.7	5.9	6.5	6.9	7.2	7.0	6.7	6.9	7.1	7.3	7.6	8.1	7.9	8.2	8.4	7.7	6.4	6.5
SE	8.3	9.1	10	11	16	16	16	15	16	18	21	24	22	17	20	24	23	25	27
UK	6.9	8.2	10	11	14	14	14	12	12	12	14	15	14	10	11	12	11	12	12
EU14	6.9	7.4	8.4	9.1	11	11	11	10	11	11	12	13	13	11	12	12	12	12	12

energy intensity is not the result of some increasing productivity or increasing efficiency in energy use, but the effect of the increasing share of the services sector in the GDP of mature neo-liberal economies combined with the outsourcing of industry and agriculture to developing countries (Huntington 2010). It should be noted that this is a controversial point, as other studies point to technological innovation and increased efficiency (Henriques and Kander 2010).

In support of the argument that decoupling relates to tertiarization and not to energy efficiency, Fig. 7 illustrates that: (i) the share of human activity (HA) allocated to the building and manufacturing sector (BM) decreases, whereas that allocated to services and government (SG) increases; (ii) the Energy Metabolic Rates did not change significantly in either the BM or SG sector, suggesting that no significant innovation or change in energy efficiency has taken place; (iii) the energy metabolic rate of the

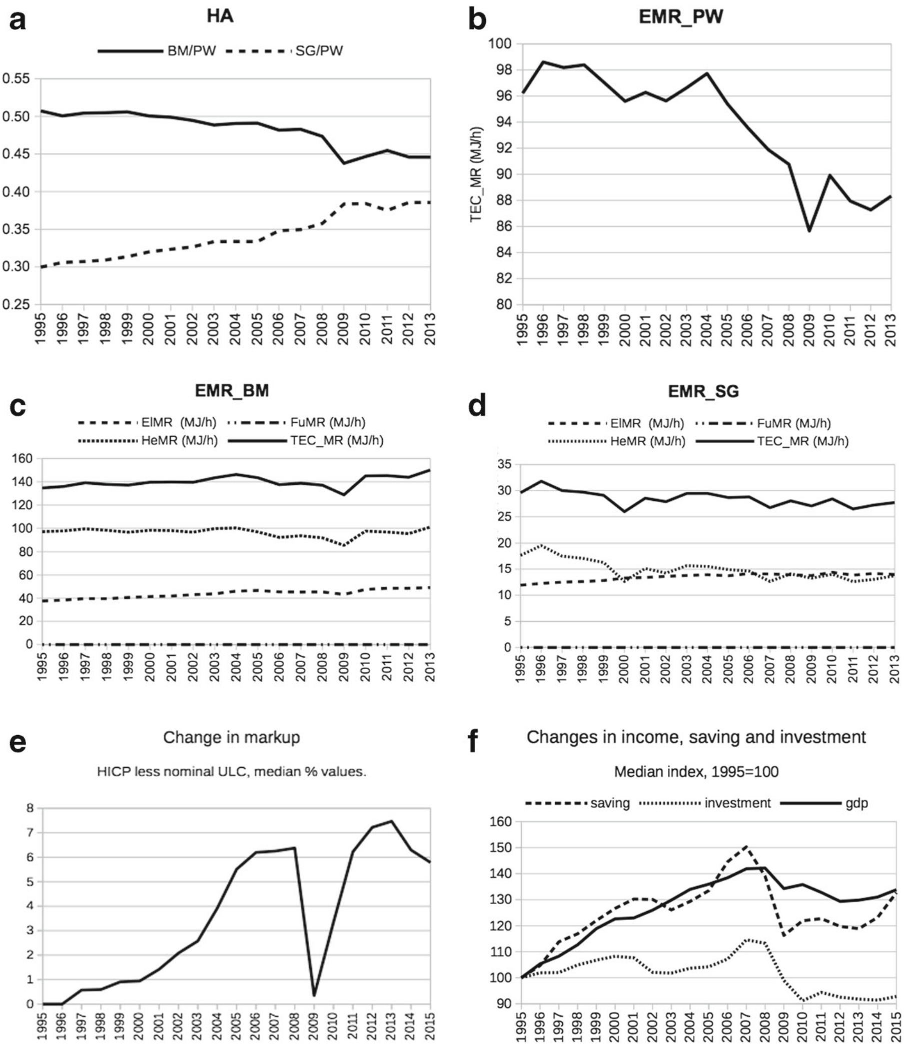

Fig. 7 Tertiarization, energy metabolic rates, markup and macroeconomic indexes in EU14

economy as a whole (PW) has decreased by nearly 10% in the period analyzed, a trend that we suggest is more likely to be explained by the increasing relative share of working hours and GVA of the services sector than by changes in technology (sectorial EMRs are nearly constant).

As Milberg and Winkler (2013) document, outsourcing (relocating parts of the production process to other countries) is associated with both deindustrialization and the reduction of labor's share of national income in many industrialized countries. A higher share of the services sector in the domestic economy, generally speaking, would imply lower average production costs and a corresponding fall in average prices due to lower physical capital and energy inputs needed by the services sector compared to agriculture and the building and manufacturing sectors. Given the nominal unit labor cost (defined as the ratio of nominal wage to real productivity of labor), if costs of intermediate goods in production fall, the price level of output should also fall, unless some offsetting effect occurs. It should be remarked that increasing productivity of labor (due, for example, to higher level of education and technical skills), besides being difficult to measure in the services sector (Bosworth and Triplett 2000; Rutkauskas and Paulaviciene 2005), may act as a further determinant of a lowering general price level, if it does not translate into higher nominal wages (thereby keeping constant the unit labor cost). The fact that the general price level does not fall, therefore, must be explained by the increasing share of non-labor remuneration in the income distribution, i.e. the markup (Kalecki 1954). The markup includes profits and rents, and its rising level is related to the decreasing share of wages and increasing inequality (Gallino 2011; Lapavistas et al. 2012; Palma 2009).

Our dataset provides evidence on the change in income distribution. As illustrated in Fig. 7, despite the declining EMR of the Paid Work (PW) sector, which is the aggregate of agriculture (AG), Building and Manufacturing (BM) and services and government (SG), the mark up, measured as the gap between the price index (HICP) of the produced goods and services and the nominal unit labor cost (ULC) in EU14 countries, has increased of around 7% in the period considered.

Finance can be seen as a key element in explaining how the shift to less energy intensive sectors occurred and how it is connected to rising markup. As many scholars have underlined (Epstein 2005; Erturk et al. 2008; Pollin 2007; Van Treeck 2009), the financialization of the economy is characterized by both financial and non-financial sectors multiplying financial practices. Traditional non-financial companies have become increasingly akin to financial holding companies and their financial assets have been used as sources of profitability in substitution to production of goods and services. Their profits have been increasingly diverted into financial spending aimed at maximizing shareholders value (Gallino 2005; Krippner 2005). In contrast with the prediction of Tobin's theory, heightened values in the stock market have not translated into more investment and expenditure on innovative efforts (Milberg and Shapiro 2013). Our evidence is consistent with this stylized fact, which can be illustrated by observing the changes in saving, investment and GDP occurred over the period under consideration in EU14 countries (Fig. 4). The evolution of GDP over time is comparable with the evolution of savings (defined as the value of output less consumption expenditure, thus including corporate revenues), which is not followed by an equivalent growth of investment. The financial sector has driven this process by continuously generating credit, in the form of both traditional and non-traditional assets, oriented to finance transactions of assets already in place or of newly generated financial assets (Bank for International Settlements 2011; Hudson and Bezemer 2012). The extraordinary expansion of balance sheets of both financial and non-financial sectors relative to their value added, leading to rising financial intensity reported in section 4, is associated with the multiplication of financial assets and the uncontrolled asset price inflation, through the practices of corporate share buyback, shadow banking, creation of exotic financial products, all practices generating virtual wealth (increasing value of intangible assets of non-financial corporations and net worth of private non-corporate entities) coupled with a high concentration of wealth (Palma 2009).

In light of this discussion, consistent with our empirical analysis and with other studies on financialization, it seems possible to consider the financial sector as the engine of a long-term wave of several rent-seeking practices that have made possible and encouraged the restructuring of production towards outsourcing and tertiarization. Financial practices have helped the non-financial corporate sector to increase the markup even in a context of deindustrialization, stagnating investment and slow (relative to past decades) economic growth. To this purpose, the non-financial sector increasingly acted like the financial sector, diverting genuine profits into rents and increasing short-run shareholder returns. Ultimately, financialization has played a crucial role in the determination of the declining energy intensity and the decoupling between GDP and energy throughput in the major industrialized economies, by making outsourcing and tertiarization economically viable.

6 Conclusion

This paper investigates the decoupling between energy throughput and GDP in the economies of the EU. We use a highly interdisciplinary approach based on the theoretical framework of societal metabolism, heterodox economic theories and financial economics to analyze the decoupling, and the financialization of the economy.

We document empirically that energy intensity (energy throughput per unit of GDP) declined in the period 1995–2013, while the energetic metabolic rate (energy throughput per hour of human activity) remained constant. The energy throughput per hour of work remained constant or increased slightly in the sample analyzed, indicating that the observed decoupling is relative and casting doubt over the hypothesis of increasing energy efficiency.

On the financial side, both financial intensity (financial assets per unit of income) and the financial metabolic rate (financial assets per hour of human activity) increased in all countries (with some important heterogeneity) and in all economic sectors, although both indicators clearly rose at much higher rates in the financial sector. This result indicates that the increasing volume of financial assets, rather than fuelling the production of goods and services, assists transactions in assets already in place or in newly generated financial assets.

The financial sector has played an increasingly important role in the process, generating a long-term wave of several rent-seeking practices that have made possible and encouraged the restructuring of production towards outsourcing and tertiarization, which in turn are responsible for the decoupling at the level of the domestic economy (decreasing energy intensity). Financial practices, in particular, have allowed the non-financial corporate sector to increase the markup even in a context of deindustrialization, stagnating investment and relatively slow economic growth, while generating an extraordinary expansion of balance sheets of both financial and non-financial sectors relative to their value added (rising financial intensity).

In response to our research question, we thus conclude that the decoupling between energy throughput and economic growth in the EU14 reflects a process of financialization, rather than a change in metabolic patterns or production processes. The contribution of this paper is to establish a bridge between the economic analysis of financialization and the societal metabolism analysis of the economic process from a biophysical point of view. We argue that this bridge is crucial to draw attention to the biophysical consequences of financialization (a relative decoupling without changes in productive processes or technology) and critically assess the pertinence of policies aimed at encouraging the decoupling in the context of increasing inequality.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

A	Financial assets (non-consolidated, €)
EI	Energy Intensity ($MJ_{EC} \cdot €^{-1}$)
El	Amount of the energy carrier Electricity (MJ_{EC})
EMR	Energy Metabolic Rate ($MJ_{EC} \cdot h^{-1}$)
FI	Financial Intensity ($€ \cdot €_P{}^{-1}$)
FMR	Financial Metabolic Rate ($€ \cdot h^{-1}$)
Fu	Amount of the energy carrier Fuel (MJ_{EC})
GVA	Gross Value Added (€)
HA	Human activity (h)
He	Amount of the energy carrier Process Heat (MJ_{EC})
HICP	Harmonized Index of Consumer Prices (relative scale, reference year 2005)
L	Financial liabilities (non-consolidated, €)
TEC	Total amount of energy carriers (MJ_{EC})
TGER	Total amount of gross energy requirement (MJ_{GER})

The HICP index has been applied to the market values in the following way:
$A = A^{xxx} \cdot (100/HICP^{xxx})$
$GVA = GVA^{xxx} \cdot (100/HICP^{xxx})$
$L = L^{xxx} \cdot (100/HICP^{xxx})$

Where XXX represents a generic year included in the inquired range (1995–2013).

$EI = TEC\ GVA^{-1}$
$FI = A\ (L)\ GVA^{-1}$
$EMR = TEC\ HA^{-1}$
$FMR = A\ (L)\ HA^{-1}$
Practical examples:

$$HA_{FS}{}^{BE,2010} = 156.7k\text{employees}\cdot 37.7\text{ h weeks}^{-1} 46\text{ weeks y}^{-1} = 2.7\cdot 10^8\text{h y}^{-1}$$

$$GVA_{FS}{}^{FI,2002} = 3,566.0\text{ M€}\cdot 100/97.82 = 3,645\text{ M€}$$

$$TEC[El, FuHe]$$

TEC can be represented as a vector, whereby each item identifies the share of the related energy carrier.

$$TEC_{DE}{}^{ES,2012}[El, Fu, He] = 3,600\text{ MJ}_{EC}[0.25; 0.30; 0.45]$$

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