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Sviluppo di una metodologia per la valutazione dell'impatto occupazionale per interventi di efficienza energetica nella green economy

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SVILUPPO DI UNA METODOLOGIA PER LA VALUTAZIONE DELL'IMPATTO OCCUPAZIONALE PER INTERVENTI DI EFFICIENZA ENERGETICA NELLA GREEN ECONOMY

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Il presente documento descrive le attività di ricerca svolte all'interno dell'Accordo di collaborazione "Sviluppo di una metodologia per la valutazione dell'impatto occupazionale per interventi di efficienza energetica nella green economy"

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Sommario

Il rapporto di ricerca è organizzato in due parti. La prima parte del rapporto descrive in modo approfondito l'intera filiera economica relativa al settore dell'efficienza energetica. Tale analisi descrittiva si configura come una mappatura derivante da un'analisi sistemica che prende in considerazione i principali aspetti del settore dell'efficienza energetica nel suo complesso. A tal fine, la prima parte del rapporto descrive una metodologia di raccolta, omogeneizzazione e integrazione di diverse fonti di dati utilizzate per rappresentare tale sistema in chiave complessa e sistemica. I dati raccolti comprendono tutti i settori economici relativi ai settori industriali e dei servizi in base alla classificazione standard NACE a 2 digit e il settore pubblico. I dati sono raccolti in un arco temporale che va dal 1995 al 2009 per tutti i paesi dell'Unione Europea a 27 membri, al fine di avere una rappresentazione complessiva. Le politiche per l'efficienza energetica sono infatti in larga misura dettate dalla Commissione Europea e poi adottate a livello nazionale. Nel dettaglio, i dati (tutti su scala temporale annuale) riguardano l'output economico dei singoli settori, gli investimenti in capitale, il numero di occupati, l'ammontare di energia consumata, la propensione all'innovazione. Quest'ultima è misurata attraverso una metodologia di attribuzione dei brevetti presentati all'ufficio brevetti europeo (European Patent Office, EPO) ai settori economici qui investigati.

Oltre alla mappatura settoriale, è stata costruita una banca dati relativa alle politiche pubbliche (che includono tutte le tipologie di strumento, market-based, command and control, e soft instrument, quali gli strumenti volontari di labelling o di informazione) a sostegno dell'efficienza energetica realizzate a livello nazionale, derivabili dalle banche dati IEA-Energy Efficiency database e IEA-Energy Efficiency in the Building Sector.

A fianco di indici di tipo discreto associati all'esistenza o meno di tali politiche pubbliche, è stato costruito, sempre su scala nazionale, un indicatore complesso definito come "energy tax bundle", che esprime il peso della tassazione energetica rispetto al prezzo finale dell'energia ponderato per i consumi fisici delle diverse fonti primarie.

Infine, è stato costruito un indice sintetico che rappresenta i guadagni di efficienza nei consumi energetici ottenuti anno per anno dal settore pubblico in ogni nazione investigata. Questo ultimo indicatore rappresenta una misura indiretta delle politiche e dei guadagni ad esse associati, ottenuti attraverso la realizzazione di interventi di efficientamento energetico nel solo settore pubblico.

La descrizione puntuale delle modalità di raccolta e sintesi delle informazioni sopra citate consente la piena replicabilità della costruzione dei dati qualora si volesse ulteriormente allargare il set di paesi inclusi nell'analisi ovvero qualora si avesse la disponibilità di dati per estendere la dimensione temporale.

A completamento della prima parte del rapporto, si propone una prima mappatura del comportamento dei diversi settori economici nei paesi dell'UE a 27 rispetto alle dinamiche occupazionali e alle dinamiche di efficienza energetica nell'arco temporale considerato. Numerose considerazioni possono derivare già dalla mera analisi descrittiva, laddove si evidenzia un gap soprattutto tra i paesi dell'UE a 15 e i paesi nuovi entrati, che presentano ancora andamenti in crescita rispetto ai consumi energetici, a fronte di una dinamica occupazionale moderata, in linea con la media europea. Considerando la dimensione temporale qui analizzata, è necessario sottolineare come gli andamenti che si possono evidenziare sono solo parzialmente influenzati dalla crisi economica di fine decennio.

Sulla base della banca dati sopra descritta, la seconda parte dell'analisi propone un modello di stima econometrica volto a identificare quali siano i driver principali legati anche agli interventi di efficienza energetica che spiegano le dinamiche occupazionali. Attraverso un modello di tipo panel a effetti fissi emergono alcuni risultati di particolare rilievo. Qui di seguito se ne sintetizzano i principali.

In primo luogo, si evidenzia un lieve impatto negativo sulle dinamiche occupazionali in tutti i settori dell'economia associati a interventi specifici di settore per efficienza energetica. In sostanza, a parità di altre condizioni, in quei settori dove si sono ottenuti guadagni di efficienza energetica maggiori da un anno all'altro si manifesta una ridotta capacità di incrementare l'occupazione (che non significa una riduzione dell'occupazione, ma solo una relativa minore capacità di incrementarla). Tale risultato è spiegabile in base alla complementarietà tra occupazione e uso dell'energia come input nella funzione di produzione, che in molti settori hanno una sostituibilità limitata.

In secondo luogo, appare molto interessante il contributo positivo dei guadagni di efficienza ottenuti nel consumo di energia da parte del settore pubblico sulle dinamiche occupazionali degli altri settori dell'economia. Considerando questo indicatore come una misura indiretta degli sforzi di policy fatti a livello nazionale, la spiegazione dell'effetto positivo si basa su due punti. Il primo canale di influenza è rappresentato dalla domanda di lavoro generata dalla necessità di realizzare gli interventi di efficientamento energetico nel comparto edilizio pubblico (si pensi all'installazione di apparecchiature per l'audit energetico o di supporti isolanti, ecc.), che rappresenta almeno nel breve termine il canale più immediato per incrementare i livelli di occupazione. Il secondo canale di influenza è invece rappresentato dal risparmio sulla bolletta energetica del comparto pubblico che riduce i costi di gestione ordinaria e quindi libera risorse pubbliche che possono essere reimpiegate incrementando i tassi di occupazione attraverso sgravi fiscali alle imprese o fornendo incentivi per nuove assunzioni, effetto questo più di medio termine rispetto al primo ma con un potenziale effetto positivo sulla crescita economica e occupazionale di più lungo respiro.

Considerando la sola Unione Europea a 15 membri è stato poi possibile sviluppare alcune analisi più specifiche legate alla realizzazione delle politiche pubbliche in campo dell'efficienza energetica e al sistema di tassazione energetica.

In primo luogo le politiche in vigore per promuovere l'efficienza energetica hanno prodotto, a parità di altre condizioni, una maggiore probabilità di incrementare i livelli di occupazione nel tempo. Il fatto che tale risultato sia statisticamente valido per la sola UE15 dipende direttamente dal fatto che in questi paesi le politiche per l'efficienza energetica sono in vigore da un numero di anni maggiore e manifestano quindi in modo più evidente il loro impatto (tipicamente di medio e non di breve termine) sulle dinamiche occupazionali.

Il secondo risultato specifico per l'UE15 degno di nota riguarda l'interazione tra i guadagni di efficienza energetica a livello settoriale e il peso della tassazione energetica su scala nazionale. A parità di guadagno di efficienza energetica a livello settoriale, i settori che si trovano in paesi con un peso della tassazione energetica maggiore ottengono incrementi di occupazione nel tempo maggiori rispetto agli stessi settori collocati in paesi con minore peso della tassazione energetica. Questo risultato può essere interpretato nel seguente modo: nonostante ci sia complementarietà tra il consumo di energia e gli altri input nella funzione di produzione, laddove il guadagno di efficienza sia tale da risparmiare ingenti risorse finanziarie (e questo è possibile laddove il costo dell'energia è particolarmente elevato), queste possono essere reimpiegate a favore di incrementi della produzione, ottenendo anche un effetto positivo nei livelli occupazionali.

Dall'analisi descrittiva e dai risultati dell'indagine econometrica risulta evidente come il miglioramento dell'efficienza energetica a livello nazionale possa portare a guadagni sui livelli di occupazione con un orizzonte temporale di media durata. La natura di tale incremento di occupazione non appare legata a dinamiche puramente congiunturali.

1 Introduction

Energy efficiency (EE) represents one of the most effective means for achieving several goals, as increasing energy security, fostering international cost competitiveness, and reducing polluting emissions. In particular, achieving a more secure, sustainable and affordable energy system is a key challenge for the future world development [23; 39; 41]. In this context, the availability and adoption of new energy-efficient technologies represents a key driver for reducing the overall energy demand. This aspect appears to be particularly relevant in the residential sector, where the demand for energy to power residential appliances and equipment has shown a continuous growth over the last 20 years.

According to Linares and Labandeira (2010) [48] energy conservation can be designed as the absolute reduction in energy demand compared to a certain baseline (in energy units), while energy efficiency is the improvement (increase) in the efficiency with which energy is used to provide a certain product or service, (units of output per energy unit). Energy conservation allows saving scarce economic resources, thus preventing the depletion of the limited fossil resources (on which our current energy supply mostly depends) and, finally, it is considered as one of the better alternatives for reducing carbon dioxide emissions. Indeed, EE is a sub-set of the energy saving or energy conservation technological domain. This latter is a broader concept since energy saving can be achieved by increasing the EE or by reducing the level of economic activity which may also reflect a change in consumers' behaviour. Thus, a general characteristic of EE is the use of less energy inputs for an equivalent (or even augmented) level of economic activity or service. In other words, gains in EE can raise the level of energy services, reduce the level of energy inputs or produce both effects.

After the first oil shock energy consumption trends have changed substantially, due to several modifications occurred in energy policy as well as in consumption behaviours in the last decades, especially in the developed world. Decreasing dynamics in energy and carbon intensity may be detected in almost all economic sectors, with a stronger effect in the manufacturing industries. On the contrary, there are large divergences when the residential sector is under scrutiny, where some countries have reduced efforts to improve EE with respect to others, while other countries obtained EE gains especially in this sector. Several reasons are behind these divergences. The most important explanation can be found in the different policy strategies adopted at the country level during the last two decades [17].

According to the new EU climate and energy strategy for 2030 agreed by EU leaders on 23 October 2014 on the basis of the European Commission proposal (COM(2014) 15 final), in order to achieve a greenhouse gas emissions reduction target of 40%, it would be required an increased level of energy savings of approximately 27% in 2030. The still open question is how best to deliver the optimal energy savings in 2030, which should be detailed in a review of the Energy Efficiency Directive [24].

As for the US energy policy, the current Energy Act has been complemented by federal and specific national Energy Efficiency Resource Standard (EERS) policies, which address specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs. As of August 2014, twenty-four states have fully-funded policies that establish specific energy savings targets. The strongest EERS requirements are in place in Massachusetts, Rhode Island, and Vermont, which require almost 2.5% savings annually [1].

In both cases, while the EE targets are clear, the specific policies, and the potential interactions among them, are far from being fully designed, since further analysis on the proper policy mix is explicitly requested by the norms and laws themselves.

The objective of this research report is to develop and apply a methodology for the impact evaluation of energy efficiency actions on employment dynamics. Such an analysis is carried out both through descriptive statistics and by implementing an econometric model. The report is structured as it follows. The first section describes the issues at stake and provides an overview of the main policy actions for energy efficiency. The second paragraph offers the data description and the methodology followed to build the database, while section 3 includes the empirical analyses. Finally, the last section summarizes the main results obtained by the research.

1.1 Economy, Employment, Energy and Environment as multiple policy targets

The ongoing economic and financial crisis has engendered increasing attention towards a broadly defined transition to the green economy as a powerful mechanism to escape from the current downturn, especially in the European Union context. This implies that not only environmental objectives should be achieved without harming economic competitiveness, productivity and economic growth, but also that the framework of policies designed to promote environmental sustainability should be able to sustain economic recovery and employment growth. To reach these objectives, a roadmap for the development and diffusion of environmental-friendly technologies combined with a coherent and effective governance framework for the achievement of both environmental and economic goals is widely acknowledged as necessary [23]. In this respect, within an international policy framework that suffers from lack of coordination, the EU has led the way in setting targets – such as the Lisbon Agenda and the 20-20-20 strategy on energy, CO_2 and renewable energies. Moreover, the launch of Horizon 2020 is expected to provide new stimuli for the transition towards a resource efficient, low carbon and more competitive and inclusive economy [23].
Though such steps are important, the real outcome of this process is far from being clear for several reasons. First, the compliance with the Lisbon Agenda has been poor and although the Kyoto targets have been achieved, this was mainly due to the ongoing crisis [5], and it is not clear whether the 20-20-20 targets will be achieved when the economy eventually recovers from the recession. Second, the link between environmental policy and eco-innovation is still at the centre of economic debate, which showed that the drivers of innovations in environmental technologies are multifaceted and touch upon various spheres of society and policy making [36; 11; 12]. Only properly designed policies can spur eco-innovations since they can reduce uncertainty risks for firms, that will invest more in innovation activities since the offsets are expected to be greater than regulatory costs [14]. Third, the interpretation of environmental and economic consequences due to the introduction and adoption of new environmental technologies is not unambiguous.
With respect to the former issue, on the one hand new technologies can favour the reduction of carbon emissions and the usage of energy, on the other hand, gains in the efficiency of energy consumption will result in a reduction in the per unit price of energy services, leading to increasing consumption of energy services (i.e., “rebound” effect), partially offsetting the impact of the efficiency gain in fuel use [31]. Regarding the economic effects, the actual dimension of the macroeconomic impact of eco-innovations is still unclear. In particular, the net employment effects of new environmental technologies and sustainable transition is currently under scrutiny as the outcome of a process of creative destruction, in which both job creation and job destruction are jointly operating [36].
As already mentioned, the willingness to invest public resources on the transition to the low-carbon economy also reflects the opinion that such a transformation is likely to increase employment levels at a time of high involuntary unemployment due to the effects of the current economic crisis [27]. The impact of policies reducing GHG emissions on the labour market can fall into one or more of three broad categories: a reduction of aggregate employment; technical change which reduces emissions with no change in employment; or a change in the distribution of employment in favour of industries with relatively low emission intensity. Policies designed to promote green jobs tend to fall into the last of these categories [8]. However, the employment impact of flows of environmental innovations induced by policy actions is far to be clear. Recent attention has been placed by scholars on this topic [35; 29], and the employment effects of innovations have also been studied extensively outside the green economy paradigm. Such studies showed that technological change plays a major role in shaping the quantity and quality of employment. Firm-level studies have shown that innovations in products and in processes generally lead to a positive direct employment effect on the firms that introduce them. Innovative firms tend to increase jobs faster than non-innovative ones. However, sectoral analyses highlighted that innovation appears to have a net job-creating effect in those manufacturing and service industries characterized by high demand

growth and an orientation towards product innovation, whereas new processes generally result in job losses [62; 54; 55; 50].
When the specific effects of eco-innovations have been addressed it has been found that, while product or service eco-innovation has a significantly positive effect on the probability of an increase in employment, end-of pipe innovations tend to imply employment decrease [58]. This result is confirmed by Horbach and Rennings (2013) [37], who highlight that the relationship between eco-innovation and employment within a firm strongly depends on the nature of innovation, especially between process and product innovation. Hence, as the introduction and diffusion of eco-innovations entail both job creation and job destruction effects, in the design of policy mix appears to be crucial taking into account the potential contrasting effects between environmental, technological and employment objectives.
Moreover, the impact of eco-innovation on the quality of jobs, the skills and competences required, is another relevant aspect to consider. The availability of dedicated skills for green jobs plays in fact a crucial role in triggering change and facilitating sustainable transition [7].
Previous general finding of the literature is that the diffusion of technologies might have strong skill bias and wage polarisation effects [9; 2; 55; 16]. These issues might be of particular relevance for policy design as the speeding up of transition processes may contrast with important social challenges such as reducing inequalities and promoting inclusive growth.

1.2 Energy efficiency policies by type

The EU has promoted different ways to improve energy efficiency as, for instance, the mandatory energy performance certificates accompanying the sale and rental of buildings together with improvements recommendation and the promotion of renovations in central governments buildings. There are also minimum EE standards and energy labels for a variety of products, e.g. many everyday products such as washing machines, refrigerators, cooking appliances, boilers, household appliances, lighting and televisions. Furthermore, energy audits for large companies and National Energy Efficiency Action Plans to be conducted, respectively, at least every four and three years. The EU is also promoting a modernization of the energy system through the planned introduction of smart meters for electricity and gas by 2020 and the promotion of easy and free access to data on real-time and historical energy consumption for consumers. Two further relevant issues to achieve the EE targets need to be considered. Firstly, cogeneration technologies have been promoted because simultaneously produce electricity and useful heat, being a cost-effective EE option. Second, there is a need to design appropriate funding schemes to overcome the challenges of obtaining long-term EE financing. Although the EU has increased the amount of public funds, there is an increasing need to boost private investments, with more involvement of the private sector in supporting energy efficiency interventions, through ESCOs and energy utilities. The IEA estimates that if implemented globally and without delay, the proposed actions could save as much as 7.6 gigatonnes (Gt) CO_2/year by 2030 – almost 1.5 times current US annual CO_2 emissions. In 2010, this corresponded to energy savings of more than 82 EJ/year by 2030, namely 17% of the current annual worldwide energy consumption.
Different types of policy instruments have been introduced to foster EE and Table 1 summarises the main policies included in the different types of public interventions. In general, countries seem to have preferred to implement first regulatory instruments (e.g. codes and standards, obligation schemes), then economic instruments (e.g. direct investment, fiscal/financial incentives[1], white and green certificates[2] and

[1] Financial incentives include subsidies for energy audits or investments and soft loans. Fiscal incentives include tax reduction, tax credit or accelerated depreciation, as well as tax on inefficient equipment (appliances and cars). Economic incentives can be defined as a fixed amount, as a percentage of the investment (with a ceiling), or as a sum proportional to the amount of energy saved.
[2] White certificates often imply a legal obligation for energy companies (suppliers and retailers or distributors, usually electricity and gas utilities) to undertake energy-efficiency interventions, whereas green certificates are associated to legal obligations to generate electricity using renewable energy sources.

information and education instruments, e.g. performance labeling). Policy support tools, research, development and deployment (RD&D) instruments and voluntary approaches however started to be implemented only during the 2000s [13].

Table 1: Policy type and instruments

Policy type	***Instruments***
Economic Instruments	Direct investment Fiscal/Financial incentives Market-based instruments (GHG emissions allowances, Green and White certificates)
Information and Education	Advice/Aid in implementation Information provision Performance label (Comparison and Endorsement label) Professional training and qualification
Policy Support	Institutional creation Strategic planning
Regulatory Instruments	Auditing Codes and standards (Product, Sectoral, Vehicle) Monitoring Obligation schemes Other mandatory requirements
Research, Development and Deployment (RD&D)	Demonstration project Research programme (Deployment and Diffusion, Development)
Voluntary Approaches	Negotiated agreement (public-private sector) Public voluntary schemes Unilateral commitments (private sector)

Source: IEA (2015).

Gillingham et al. (2006) [30] examined the performance of many US policies and programs that promote energy efficiency and addressed some important questions related to the cost-effectiveness of demand-side energy policies. Their conclusions suggest that the appliance standards appear to be cost-effective and typically yield positive net benefits from energy savings alone and additional benefits from ancillary reductions in air pollution. Financial incentive programs as Utility-based Demand-Side Management (DSM) also appear to be cost-effective, but to some degree the unaccounted costs to consumers are high and make these programs less convenient. Still, the quite heterogeneous net benefits, including the additional environmental benefits from reducing GHG emissions, which could add about 10% to the value of energy savings from energy efficiency programs.
EE improvements could be a response to mitigate the effects of rising energy prices and market competition forcing firms to cut all types of costs (including energy costs), but they could also result from ongoing technological progress. This is coherent with the induced innovation hypothesis, according to which increased demand and technological opportunities affect the production of additional knowledge. On the one hand, labelling helps stimulating technological innovation and the introduction of new, more efficient products, while technological standards promote the gradual removal from the market of the least energy-efficient appliances. Therefore, support to EE innovation and technology diffusion processes is crucial to improve the productivity of the energy inputs and reduce energy costs. Such effects are relevant not only for improving the security of energy supply but also for stimulating competitiveness, economic growth and job creation.

1.3 Energy efficiency policies by region

Common European Energy Efficiency framework

Almost all OECD countries are implementing a wide range of policy measures on EE, and the effort is particularly high in the EU countries. The last European Energy and Climate Strategy to 2030 approved in October 2014 follow the approach of the previous 20-20-20 strategy and set a 27% increase in level of energy savings by 2030. The European Commission also specifies that: "It will be delivered in a cost-effective manner and it will fully respect the effectiveness of the ETS-system in contributing to the overall climate goals" and "will propose priority sectors in which significant energy-efficiency gains can be reaped, and ways to address them at EU level, with the EU and the Member States focusing their regulatory and financial efforts on these sectors." [24].

The Energy Efficiency Directive 2012/27/EU [21], to be reviewed shortly in order to reach the EU target set by 2030, is a crucial pillar of EU EE strategy. The Directive includes legal obligation to establish energy saving schemes in all Member States: energy distributors or retail energy sales companies are obliged to save every year 1.5% of their energy sales, by volume, through the implementation of energy efficiency measures, such as improving the efficiency of the heating system, installing double glazed windows or insulating roofs, among final energy customers [44]. The Directive set binding measures rather than binding targets for each member state. It also includes specific advice for public sector, as the legal obligations to purchase energy efficient buildings, products and services and to achieve the required renovation works covering at least 3% of their total floor area. With respect to households and consumers, it is especially relevant the promotion of accurate individual metering to empower consumers to better manage their energy consumption. For the industry sector, the Directive designs incentives for SMEs to undergo energy audits and implement best practices, while large companies are required to make an energy audit to identify the potential for reduced energy consumption.

In 2010, two important Directives have been approved. The first is the Directive 2010/30/EU [19] on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related product (Energy Labelling Directive). It defines the labelling requirements for individual product groups in order to help consumers to choose energy efficient products.

The second is the Directive 2010/31/EU [20] on the energy performance of buildings. Key aspects of this measure are energy performance certificates to be included in sale or rental advertisements for buildings, inspection schemes for heating and air conditioning systems, minimum energy performance requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of building elements. All new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018) and each EU country need to identify national financial measures to improve the energy efficiency of buildings. Moreover, from 2015 new EE measures reinforce the role of energy labels for online sales, cooking appliances, automatic standby for networked devices and cooking machines, which will help households saving more energy and foster the competitiveness of EU firms.

Linked to these 2010 measures, the Directive 2009/125/EC [18] establishes a framework setting the ecodesign requirements for energy-related products (Ecodesign Directive). Otherwise, firms in the industry sector can also sign voluntary agreements to increase the EE of their products, given that the Commission officially recognises such agreements and monitors their implementation.

Main national policies by country: key elements of EU energy efficiency policy framework[3]

Denmark

Building codes (2013)

Building codes for new buildings were tightened in several stages from 1977 to 2013, making the Danish building code among the strictest in the world. The building code contains three performance levels: minimum requirements, a voluntary building class 2015, and a voluntary building class 2020. The main

[3] Source: IEA (2015).

requirement is on energy performance for the building as a whole. It is supplemented by rather detailed requirements on the building envelope and on installations, for instance minimum requirements on thermal resistance of different parts of the building envelope, on air tightness of the building envelope as a whole, on efficiency of boilers, energy performance of windows etc.

Danish Energy Agreement for 2012-2020 (2012)
The Agreement establishes a framework for the policy on climate and energy to reach the 34% reduction in CO_2 emissions by 2020 (w.r.t. 1990 level) and outlines the direction Denmark will take until 2050. It includes fiscal and financial incentives and RD& D support for the residential sector, industry and energy utilities. This framework includes the expansion of renewable energy sources in power generation, building and industry, EE and Green heating measures, development of Smart Grids and Biogas installations.

Germany

3rd National Energy Efficiency Action Plan (NEEAP 2014)
In line with the Energy Efficiency Directive, the main two targets are the average annual increase of 2.1% in energy productivity from 2008 to 2020 and a reduction of primary energy consumption from 2008 levels by 20% by 2020. Primary esenrgy consumption is also set to be reduced and by 50% by 2050. The NEEAP sets measures for the residential sector as well as for industry and energy utilities. The main instruments are: Quality control and optimisation of existing energy consultancy services, Tax incentives, CO_2 Building Refurbishment Programme (to increase funds to finance EE), Increased guarantee provision for long-term energy efficiency contracting, Mandatory energy audits and labelling, Energy Efficiency Network Initiative to sustain the implementation of EE plan at a local level.

Support of Energy Management Systems (2013)
Funding Programme to increase energy efficiency in industry and services sectors. The aim is to promote a widespread implementation of energy management systems. It subsidises certification of an energy management system or an energy controlling system and secondly, the purchase of measuring equipment and software that is necessary for the introduction of such a system. It implies direct investment and code and standards with Multi-Sectoral application but especially focused on industry sector.

Support of energy-efficient and climate-friendly production processes (2013)
This is a funding programme to improve EE in industrial production processes. This measure supports companies in deciding to invest in the most energy efficient and environmentally friendly solutions in the design of their production processes. It subsidises production process conversions to energy efficient technologies.

KfW Special Fund for Energy Efficiency in SMEs (2013)
Considering the industry target sector with special focus on small and medium-sized companies (SMEs), it combines information and education program, to identify limits and propose concrete schedules of measures for energy- and cost-saving improvement, with economic instruments: subsidies are granted for qualified and independent EE counselling sessions in SMEs.

Ireland

Energy-saving targets for energy suppliers (2011)
The programme runs on a voluntary basis, with 19 energy suppliers – spread across electricity, gas, solid fuels and oil importers – currently signed up for voluntary energy savings agreements. Legislation underpinning these agreements allows the minister to impose energy savings targets on energy suppliers if they choose not to sign an energy savings agreement. It includes a list of 26 approved measures and associated energy savings. All new measures, and actions undertaken by energy suppliers, are subject to appropriate monitoring, verification and audit. Energy suppliers are required to submit an annual plan, setting out their programme of activity. Trading is allowed in the event an energy supplier exceeds its energy savings target.

Italy

3rd National Energy Efficiency Action Plan (NEAAP 2014)[4]

It sets the EE targets established by Italy for 2020, the policy measures implemented for achieving them and the progress made as at 2012.
In particular, relevant issues are:

1. Italy complies with Article 7 of the Energy Efficiency Directive (EED) through the White Certificate scheme (also known as Energy Efficiency Certificates - EEC).
2. Large industrial companies with production sites in the national territory will be required to undergo a quality energy audit by 5 December 2015 (ISO 50001 management system, SMEs).
3. Metering and billing; smart grids, i.e. market signals (electric tariffs); system signals (mandatory electric parameters); energy markets (electricity and gas).
4. Consumer Information and Training programmes. The main instruments adopted to encourage final customers to change their habits have been also represented by the provision of information, flagship/exemplary projects, workplace activities and energy saving education. Most pilot studies have proven that even small information actions can bring about measurable reductions in energy consumption, achievable via individual[5] or combined actions, ranging between 5 and 20%.
5. Availability of qualification, accreditation and certification schemes. There are already a number of certification schemes for operators and services in the field of energy efficiency, specifically for Energy Management Experts and ESCOs.

The NEAAP 2014 also defines sector specific policies: Energy efficiency in the Building sector (Residential, Non-residential), Public buildings, Industry, Transport, Heating and cooling (Cogeneration), Energy transformation, transmission, distribution and demand response.
It is worth noticing that such measures have been further detailed or modified in the Transposition Decree (102/2014) of Energy Efficiency Directive issued in June 2014. The decree also introduces sectoral plans for energy efficiency, one of which is devoted to the Energy Upgrading of Central Public Administration. A "National Fund for Energy Efficiency" is also created by the decree, designed to facilitate efforts for the rehabilitation of buildings of the public sector and the reduction of energy consumption in the sectors of industry and services.

White Certificate Trading for End-Use Energy Efficiency (2005)

In compliance with specific energy conservation targets, all Italian electricity and gas distributors with at least 100,000 end customers at the close of 2001 can trade White Certifictes (or EEC). Energy service providers, subsidiaries of electricity and gas distributors and distributors themselves will all sell EEC, each representing primary energy savings of one tonne of oil equivalent (toe). Distribution companies must meet specified energy savings targets, either by implementing energy conservation projects that benefit their customers, which will earn them EEC, or through the purchase of EEC produced by energy conservation projects undertaken by others.
Three types of white certificates can be produced and traded. Type I certificates are for savings achieved in the electricity sector, Type II certificates for those achieved in the gas sector, and Type III for those in neither sector (from other fuels).
Targets for 2008 and 2009 were made more stringent and new targets have been introduced for 2010-2012; the implementation period was extended from 2009 to 2012. A change introduced by a new law (DL 02/2009) is represented by the so-called "large projects": EE projects concerning relevant infrastructures, industrial processes, or linked to interventions in the transport sector, which generate, in a year, savings of no less than 35,000 toe and which have a technical life exceeding 20 years. Another important regulatory intervention is represented by the Ministerial Regulation adopted in December 2012 (DM 28/12/2012), determining the new challenging targets for the period 2013-2016.

[4] Available online at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf
[5] Examples are direct and indirect feedback (smart meter or enhanced billing), energy audits and EU-based measures.

65% tax rebate schemes (2007)

This programme for the building sector provides tax credits to households for comprehensive or single retrofit EE measures, such as thermal insulation, installation of solar panels, replacement of heating and air-conditioning systems or comprehensive refurbishments. Tax credit can currently cover 65% of the cost, but cannot exceed a maximum value that is determined by the type of measure taken. Tax credits are reimbursed over 10 years, starting from the year of work completion. Until the first half of 2013 the deduction rate was set to 55%.

Heating and cooling support scheme (2013)

This policy tool provides incentives for small projects designed to increase energy efficiency and generate thermal energy from renewable sources. Public administrations, private individuals, condominiums and small business or agricultural activities, can access the mechanism, and incentives will be available for actions to improve the efficiency of existing buildings, replace existing systems for winter heating with higher efficiency ones, replacement or new installation of systems using renewable energy. The actions may be implemented via an ESCO, by means of a third-party financing contract, an energy service contract or an energy performance contract and incentives will be paid to beneficiaries in a period of minimum two and maximum five years, depending on the project type.

Luxembourg

Energy Performance of Residential and Non Residential Buildings (2010)

According to these regulatory instruments all new buildings and existing buildings undergoing significant renovation must meet new energy performance requirements. New buildings must be accompanied by an energy performance certificate. For existing buildings, an energy performance certificate is required in case of change in the building's owner or tenant, as well as if significant renovation is undertaken. The certificate provides a rating of the buildings energy performance, as well as advice on improvements that can be made.

Portugal

Energy Efficiency Programme in Public Administration (ECO.AP) (2011)

This is a policy support measure for non-residential buildings that aims to achieve a 20% improvement in energy efficiency in public services and bodies of Public Administration by 2020. This program translates into a set of EE measures for implementation into services, agencies and public equipments aiming to change behaviours and promote the rational management of energy services, notably by hiring Energy Services Companies (ESE). This Resolution also aims to show the Government recommendation on the mandatory disclosure of energy bills by Public Administration, as well as creating a White Certificates scheme for the Public sector.

Spain

New National Energy Plan 2008-16 (2008)

This programme is a policy support measure targeted for energy utilities. The plan predicts an annual growth of 1.4% in energy demand and assigns a total investment of almost EUR 20 million in improving electrical and gas infrastructure. It calls for increased energy production capacity and diversifying the energy mix, by increasing wind- and gas-fired capacity and a reduction in other fossil fuel and nuclear generation. Extra effort to support renewables is also promised.

Sweden

An integrated climate and energy policy framework: "A sustainable energy and climate policy for the environment, competitiveness and long-term stability" (2009)

This is a policy support programme targeted for residential appliances, multi-sectoral policy, industry, transport, buildings and energy utilities. The targets to be achieved by 2020 are: 50% and 10% share of renewable energy of, respectively, the total and transport energy usage; 20% EE increase; 40 % reduction in GHG gas emissions. The proposed instruments are: the development of the electricity certificate scheme for renewable electricity generation, carbon dioxide tax, international emissions trading and certificates for renewable electricity (fundamental to the long-term energy policy); technology development initiatives and information and initiatives to remove institutional obstacles.

A vehicle fleet independent of fossil fuel by 2030 (2009)

A number of regulations and economic incentives have already been introduced to fulfil the vision of a vehicle fleet independent of fossil fuels by 2030. However, this vision is not unequivocally defined. The Swedish taxation system supports the purchase of environment-friendly vehicles through a tax exemption throughout the first five years. To promote alternative fuels, high-ratio blends of renewables into gasoline and diesel are subject to a full tax exemption. In addition, pumping stations which sell more than 1 000 cubic meters per year are required to offer a renewable fuel. Another government priority has been research, development and deployment of clean vehicles and advanced biofuels, with the focus on the production of biofuels based on feed-stocks originating from forestry.

Energy, Carbon Dioxide and Sulphur Taxation (1991)

Sweden has a complex system of energy and carbon taxation. The general energy excise tax was introduced in the 1950s. In 1991 Sweden's energy tax system was modified, with the introduction of a CO_2 tax, a reduction in the general energy tax, a tax on sulphur emissions and various value-added taxes on electricity and fuels. Electricity consumption is also taxed. As of 2011, all installations covered by the EU ETS are exempt from payment of the CO_2 tax, but not the energy tax.

United Kingdom

Green Deal (2013)

This measure sets fiscal and financial incentives, as grants and subsidies, loans and direct investment for the building sector. It provides a framework of accredited market participants, through which people cover some of the cost of improving the energy performance of their homes and businesses using a type of loan that is paid back with the savings they can expect to make on their fuel bills. A requirement on larger energy suppliers – the Energy Company Obligation (ECO) – will work alongside the Green Deal to provide additional support for viable packages of EE measures that are unlikely to be fully financed by the Green Deal (as insulation of hard-to-treat cavities or solid walls). The ECO will also support the implementation of insulation and heating measures to low-income and vulnerable households and insulation measures to low income communities.

1.4 Energy efficiency policies in residential sector

When exclusively considering the residential-related EE policies, public regulations can be divided according to the three main residential target audiences offered by the IEA, namely “buildings”, “lighting“ and “appliances” (see Table 2).

Table 2: EE residential main target and specific sub-domains

Buildings	Building Code, Building Type (Residential vs Non-Residential, Industrial), Energy class, Existing buildings,

	New buildings
Lighting	Residential (vs Commercial), Technology focus (Fittings and controls, Lamp technologies)
Residential Appliances	Computer, Cooking & Laundry, Home entertainment, Other, Refrigeration, Space cooling, Space heating, Standby, Ventilation, Water heating

Source: IEA (2015)

2 Data description and methodology

In order to develop the evaluation impact analysis on the employment effects related to energy efficiency gains, it has been necessary to build a complex and original database gathering information from different statistical sources on four main dimensions: employment, energy, innovation and economic variables. In particular, this section of the report describes in detail the characteristics of different data sources and the methodology followed for the construction of the integrated database. Such a description allows the full replicability of the analysis and the possibility to periodically update the database when new data will become available.

2.1 Data Sources

a. EU-HARMONIZED LABOUR FORCE SURVEY (EU-HLFS)

The European Union Labour Force Survey (EU LFS) is conducted in the 28 Member States of the European Union, 2 candidate countries and 3 countries of the European Free Trade Association (EFTA) in accordance with Council Regulation (EEC) No. 577/98 of 9 March 1998 [26]. The EU LFS is a large household sample survey providing quarterly results on labour participation of people aged 15 and over as well as on persons outside the labour force. All definitions apply to persons aged 15 years and over living in private households. Persons carrying out obligatory military or community service are not included in the target group of the survey. The national statistical institutes are responsible for selecting the sample, preparing the questionnaires, conducting the direct interviews among households, and forwarding the results to Eurostat in accordance with a common coding scheme. Data for individual countries are available depending on their accession date and the surveys are conducted by the national statistical institutes across Europe and centrally processed by Eurostat. This latter guarantees the data harmonization through the use of the same concepts and definitions, following International Labour Organisation guidelines, common classifications (NACE, ISCO, ISCED, NUTS) and the same set of characteristics in each country.
The data collection in the present dataset covers the years from 1995 to 2009 and 27 EU Member States. This latter can be broken down according to multiple dimensions including age (by 5-year bands), sex, educational attainment, distinctions between permanent/temporary and full-time/part-time employment, by nationality/country of birth (up to 15 predefined groups), by industry sector (NACE classification) and by type of occupation (ISCO classification up to 3-digit level). Each quarter, some 1.8 million interviews are conducted throughout the participating countries to obtain statistical information. The sampling rates in the various countries vary between 0.2% and 3.3% of total population.

Sample Design

The sampling designs in the EU-LFS are very varied. Most statistical institutes use some kind of multistaged stratified random sample design, especially those that do not have central population registers available. Population registers and the latest Population Census or list of addresses used in that Census are the two main sources for the sampling frame. Other sources include lists of addresses from, e.g., the Postal Authorities or Utility databases. Belgium, Italy, Lithuania, Austria, Norway, Finland, Sweden, Iceland, and Slovenia use the Population Registers as the sole basis while the Netherlands complete this information with postal data, Denmark with other registers, Latvia and Spain with Census information. Germany grounds the sample frame on the 1987 Census in the western part and on the Central Population Register, based on the 1981 Census, in the east, both updated by the Register of new dwellings. France uses the tax register. Denmark, Germany, Cyprus, Estonia, Luxembourg, Malta, Austria, Slovenia, Finland, Sweden, the United Kingdom, Iceland, Lithuania and Norway use a single stage sampling or single stage cluster sampling design. All other countries use a two or three stage sampling design, usually selecting municipalities, administrative districts or census enumeration areas in the first stage. Ireland uses a two-stage cluster design. Three types of ultimate sampling units are employed: 1) households, 2) dwellings/ addresses and 3) persons. Germany, France, Portugal and Romania sample clusters of dwelling units. In samples of dwellings or addresses, usually all persons and thus all households residing within the dwelling/address are interviewed. When persons constitute the primary sampling units, the selected persons either constitute the final sample (Finland, Sweden, Denmark, Iceland, and Switzerland) or the sampled persons lead to a final sample comprised of the sampling units and their household members (Estonia, Lithuania, Norway and Slovenia).

Accuracy

The accuracy of statistical outputs is the degree of closeness of estimates to the true values. Statistics can be different from the true values because of random variability (the statistics change from implementation to implementation of the survey due to random effects) and/or bias (the average of the possible values of the statistics from implementation to implementation is not equal to the true value due to systematic effects). Several types of error, stemming from all survey processes, contribute to the error of the statistics (their bias and variability). A certain typology of errors is widely adopted in statistics. Sampling errors affect only sample surveys; they are due to the fact that only a subset of the population, usually randomly selected, is surveyed. Non-sampling errors affect sample surveys and complete enumerations alike and comprise: 1. Coverage errors; 2. Measurement errors; 3. Processing errors; 4. Non-response errors.

Sampling errors - Sampling errors affect only sample surveys and arise from the fact that not all units of the frame population are surveyed. The frame is a device that permits access to population units, such as a list of households with addresses. Frame population is the set of population units which can be accessed through the frame and the survey’s conclusions apply to this population. Official surveys, like the EU-LFS, use probability sampling. This makes it possible to quantify the sampling errors and can be expressed in terms of confidence intervals.

Non-sampling errors - Coverage errors - Coverage errors (or frame errors) are due to divergences between the target population and the frame population. Possible divergence types are undercoverage (i.e., the frame population does not include all units of the target population), overcoverage (i.e, the frame population includes units which do not belong to the target population) and misclassification (i.e., units in the frame population which belong to the target population but are wrongly classified).

Measurement errors - Measurement errors are errors that occur during data collection and cause the recorded values of variables to be different from the true ones. Their causes are commonly categorized as:

- Survey instrument: the form, questionnaire or measuring device used for data collection may lead to the recording of wrong values.
- Respondent: respondents may, consciously or unconsciously, give erroneous information.
- Interviewer: interviewers may influence the answers given by respondents.

No regular estimates of these errors are available.

Processing errors - Between data collection and the beginning of statistical analysis for the production of statistics, data must undergo a certain processing: coding, data entry, data editing, imputation, etc. Errors introduced at these stages are called processing errors.
Non response errors - The difference between the statistics computed from the collected data and those that would be computed if there were no missing values is the non-response error. Most of the countries calculate non-response on the basis of the household unit, except Denmark, Finland, Sweden, Iceland, Norway and Switzerland, which calculate non-response on person basis. The treatment of non-response in the follow-up waves is also different between countries. Some participating countries do not take previous non-response into account when calculating the non-response in later waves, whereas others do. Thus the former countries may show lower non-response rates on the average than the latter. No estimates can be produced indicating the rate of processing errors in the EU-LFS.

Comparability over time
Every year, a certain number of changes are introduced in some national LFSs, to take into account changes introduced at European level, to better align the national surveys to the already existing EU regulations or methodological guidelines, or to take into consideration national needs. These changes can concern the conceptual level (i.e. concepts and definitions used by the LFS, the survey coverage, i.e. the target population, the legislation, the classifications used, the geographical boundaries) or the measurement level (i.e. the sampling frame, the sample design, the rotation pattern, the questionnaire, the instructions to interviewers, the survey modes, the weighting scheme, the use of auxiliary information) and normally may introduce some discontinuity in the time-series.

Comparability over space
A common framework regulation, variable definition, explanatory notes and regulation regarding the definition of unemployment and a set of principles of questionnaire construction go a long way to ensure comparability of the statistics between the participating countries. This is, however, mainly true for the main characteristics, employment and unemployment where particular definitions and sequence of questions are part of the EU legislation. For other variables, each country has the responsibility to ensure that the national survey provides data that are compatible with the EU definitions and of the same quality. Over the last years, Eurostat has commissioned several reports to examine the degree to which the participating countries adhere to the common set of definitions. The most recent study of this kind was carried out on the 2008 questionnaires. As a general conclusion it emerges that, in spite of the progress regarding the adherence to the EU regulations, principles and guidelines (i.e. the explanatory notes), the national questionnaires still largely differ even in the collection of key variables such as labour status in the reference week. Hence, even if labour market statistics are subject to quite comprehensive international definitions, principles and guidelines, which make it one of the most harmonised statistical domains not only in Europe but worldwide, there is still room for further improvement of cross-country comparability.

Variables of Interest:
- *Labour force status*

  Employment: employed persons comprise persons aged 15 years and more who were in one of the following categories: (i) persons who during the reference week worked for at least one hour for pay or profit or family gain; (ii) persons who were not at work during the reference week but had a job or business from which they were temporarily absent. This definition is applicable to employees, self-employed persons and family workers.

- *Educational attainment:*

  Population skill: the EU-LSF provides information based on three levels: low, medium and high.

- *Employment - principal activities and professional status*

  Economic activity: this is the economic activity of the establishment where the work is performed. The EU-LFS uses the Eurostat Statistical classification of economic activities in the European Community (NACE) to code the economic activity.

Occupation: the International Standard Classification of Occupations (ISCO) developed by the International Labour Organisation (ILO) is used to measure the occupational status of employed persons. The LFS uses ISCO on 1-digit level. The classification was last revised in 2008 (ISCO 08). The LFS uses the revised classification (ISCO-08) since 2011; ISCO-88 (COM) was used until 2010. Table A2 sums up the ISCO codes and descriptions used in the dataset.

- *Employment - Working time*

  Working time: the EU-LFS collects data on the "number of hours usually worked per week". The number of hours usually worked per week comprises all hours including extra hours, either paid or unpaid, which the person normally works, but excludes the travelling time between home and workplace and the time taken for the main meal break (usually at lunchtime) are excluded.

- *Geographical coverage*

  Member States of the European Union have been assigned a two-letter country code, always written in capital letters. Country codes are based on the ISO 3166 (International Organisation of Standardisation – alpha-2 format), with the exception for United Kingdom that is coded as UK.

While at the general level data are available for all EU member States, it is worth mentioning that the disaggregation at NACE sector level adopted in this report allows including some dimensions only for the EU15 countries aggregate.

b. REGPAT DATABASE

The REGPAT database covers data on patent applications, our proxy for innovation activity at the sectoral level, to the European Patent Office (EPO). Data mainly derives from the latest version of the EPO's Worldwide Patent Statistical Database (PATSTAT) and have been linked to regions according to the addresses of the applicants and inventors. The data are regionalised at a very detailed level (up to NUTS-3) so that more than 2000 regions are covered across OECD countries. Hence, REGPAT allows patent data to be used in connection with other regional data such as GDP or labour force statistics, and other patent-based information such as citations, technical fields and patent holder characteristics (industry, university, etc.), thus providing researchers with the means to develop a rich set of new indicators and undertake a broad range of analyses to address issues relating to the regional dimension of innovation.

Data Coverage

The REGPAT version here employed covers patents for the whole period where employment data are available, going from 1995 to 2009. It is worth mentioning that REGPAT includes explicit classes identified as "Technologies or applications for mitigation or adaptation against climate change". This disaggregation allows to specifically consider 'green technologies' (including energy efficiency) over the total stock of patents. These classes are tagged as Y02, and envisage the following sub-classes a 4-digit level:

- Y02B (indexing scheme relating to climate change mitigation technologies related to buildings, e.g. including housing and appliances or related end-user applications);
- Y02C (capture, storage, sequestration or disposal of greenhouse gases [GHG]);
- Y02E (reduction of greenhouse gases [GHG] emission, related to energy generation, transmission or distribution);
- Y02T (climate change mitigation technologies related to transportation).

c. IEA ENERGY EFFICIENCY POLICY DATABASE

Policy data are taken from the IEA's Energy Efficiency Policy Database available online, which provides comprehensive, up-to-date information on EE policies.

It includes policies in seven demand sectors: buildings, commercial/industrial equipment, energy utilities, industry, lighting, residential appliances and transport on policy measures across these sectors in EU27 countries.
Policies are also differentiated by type: economic instruments, information and education, policy support, regulatory instruments, RD&D, voluntary approaches.
In particular, for the empirical analysis we selected all the policies in force between 1995 and 2009.
Therefore, the EE policies for the EU27 countries considered here are mapped and we shape the institutional framework by building a discrete variable as the stock of EE policies (at the country level). This is a discrete stock variable calculated as the cumulative number of policy instruments in force at time *t* in country *i*, as follows:

$$KPOL_{i,t} = \sum_{s=1}^{t}(POL_{i,s}) \quad (1)$$

This modelling choice allows the whole range of policies still in force at time t in country i to be considered for each year, revealing not only a simple impulse given by the existence or not of EE policies, but also a sort of qualification of the intensity and dynamics of the policy setting.

d. OECD SECTOR-BASED ENVIRONMENTAL POLICY DATABASE

Policy data are also available for the 14 manufacturing sectors at NACE 1 digit level regarding the existence or not of a sector-specific policy concerning an environmental domain. The original database used for this purpose is the online tool OECD Database on instruments used for environmental policy. While the sector coverage is almost complete at the NACE 1 digit level here adopted, effective availability of data allows covering only the manufacturing sectors.
The whole coverage of the dataset is given by:

- *Policy type*
  Taxes, fees, targets, tradable permits, deposit and refund systems, subsidies, voluntary approaches.
- *Environmental domain*
  Water pollution, air pollution, climate change, land contamination, waste management, noise, energy efficiency, transport, waste management.
- *Geographical coverage*
  Member States of the OECD.
- *Sectoral coverage*
  All sectors at the NACE 1 digit level.

e. IEA PRICE AND TAXES DATABASE

The monetary value of taxes and prices paid for each energy type consumed at the sector and country level is provided by the IEA Energy Prices and Taxes Statistics [42].

- *Type of information*
  Import prices, industry prices and consumer prices, taxes as monetary values or in percentage terms with respect to the relative price.
- *Geographical coverage*
  Member States of the OECD.
- *Sectoral coverage*
  End-user prices and taxes for selected petroleum, natural gas and coal products as well as for electricity are also provided for industry, electricity generation and households.

f. IEA OECD ENERGY BALANCE STATISTICS

Data on energy consumption are taken by IEA Energy Balance Statistics [43]. Information are provided for the following dimensions:

- *Type of information*

  Supply and consumption of coal, oil, gas, electricity, heat, renewables and waste expressed in million tonnes of oil equivalent. Data are available also in terms of production, trade and final consumption levels.

- *Geographical coverage*

  Member States of the OECD.

- *Sectoral coverage*

  Industry, transport, residential.

g. WORLD INPUT-OUTPUT DATABASE

The World Input-Output Database (WIOD) consists of a series of databases and covers 27 EU countries and 13 other major countries in the world for the period from 1995 to 2011.

The Environmental Accounts consist of data on energy use, CO_2 emissions and emissions to air at the industry level.

Variables of Interest:

- Gross energy use by sector and energy commodity (in TJ)
- CO_2 Emissions modelled by sector and energy commodity in (kt)

The *Socio-Economic Accounts* include data on employment (number of workers and educational attainment), capital stocks, gross output and value added at current and constant prices at the industry level.

Variables of Interest:

- Gross value added at current basic prices (in millions of national currency)
- Gross output by industry at current basic prices (in millions of national currency)
- Nominal gross fixed capital formation (in millions of national currency)

all of which with their respective deflator (with 1995=1).

While some authors, such as Lee (2005) [47] and Soytas and Sari (2007) [60] have used investment data as a proxy for capital stock, in the majority of cases, the Perpetual Inventory Method (PIM) is applied to derive capital stock from data on investment flows [6; 10; 22]. Under this approach, capital stock for the first year is calculated by dividing the annual GFCF (I = investment flow) by a factor given by the sum of a constant depreciation rate (d=0.15) and the average annual sector and country specific growth rate (g) of GFCF variable from the overall time period as expressed as:

$$K_{ij(t0)} = I_{ij(t0)}/(g + d) \quad (2)$$

Then, capital stock at each time t+1 is the sum of the capital stock at the previous year, discounted by the depreciation rate of 15%, with the investment at year t+1 as given by eq. (3):

$$K_{ij(t)} = K_{ij(t-1)} \cdot (1 - d) + I_{ij(t)} \quad (3)$$

2.2 Dataset building

Matching Patents with Manufacturing Sectors

As Lybbert and Zolas (2014) [49] point out, “While patent data often serve as useful proxies for technological change [32; 3] and diffusion [46], fully exploiting patent data in economic analyses would require that patents be linked to economic activity at a level of disaggregation that allows for different technological, industrial and spatial patterns. Such a detailed link between technological and economic activity would further improve our assessment of policies that aim to promote innovation, as well as assess the relationship between technological change and economic development” (pp. 530). In light of this, further attempts for industry-level linkages that associate patents and economic data based on the domain of goods and services they represent are strongly required for enrich the economic analysis. The literature seem to have focused on two main concordance systems: the one developed by Schmoch et al. (2003) [59] and, more recently, the one developed by Lybber and Zolas (2014) [49]. Both the methodologies are briefly described below. However, only the concordance method by Lybbert and Zolas is adopted for building the final dataset, since this better represents the state-of-the-art in matching industrial sectors to patent data.

Concordance System by Schmoch et al. (2003)

By focusing on the manufacturing sector, Schmoch *et al.* (2003) [59] provide a concordance system between technical fields and industrial sectors by a four-step procedure, and namely: (i) identification of 44 matched technical and industrial fields; (ii) linking patent codes to industrial classification; (iii) analysis of patents deriving from a large international sample of companies classified by industrial sectors; (iv) computation of a 44x44 concordance matrix between technologies and industrial sectors based on empirical analysis of the company sample. The concordance process relies both on expert assessment and the review of sectoral patent activity through the analysis of companies. The concordance assigns 625 International Patent Classification (IPC) subclasses to one of 44 different manufacturing sectors, of which one or more ISICs are associated. The final sample corresponds to 3133 applicants accounting for 154,238 patents in the three years period. Given the limited number of technological fields (44) defined by a set of IPC subclasses, the work has requested a limited amount of time to build a 44x44 concordance matrix (see Table A3), in which the diagonal elements indicates full correspondence. In this respect, a set of driving principles have been followed, namely:

- only large firms were considered;
- only firms from manufacturing sector were taken into account, as the share of patents deriving from service sector were considered negligible [4];
- only the principal industrial activity of a firm was taken into account;
- only the first IPC code was taken into account.

According to the authors, the concordance table is robust to international comparisons, as it follows international classification systems (NACE and ISIC for industrial sectors, IPC for patents) with a reasonable level of disaggregation (see Table A4).

Concordance System by Lybbert and Zolas (2014)

Patent data and the EU-HLFS have been merged using the methodology by Lybbert and Zolas (2014) [49]. In order to construct a higher resolution concordance system, researchers have to rely on data mining methods and probabilistic matching that create direct linkages between patent data and a variety of economic classification schemes. This is, broadly speaking, what specifically characterizes the approach followed by Lybbert and Zolas (2014) [49]. By the means of the Algorithmic Links with Probabilities (ALP) approach, Lybbert and Zolas analyse patents in the PATSTAT database with the aim of identifying relevant keywords extracted from industry classification descriptions. The search is performed using patent titles and abstracts. Then, patents are tabulated by IPC code, and frequency matches between the industry and IPC classifications have been identified. By analysing these frequencies, it is possible to generate a probabilistic mapping that works in two directions: from IPC to the industrial classifications (SITC, ISIC, North American Industry Classification System, Harmonized System) and vice versa. Given that the method relies on empirical procedures, minimal manual or subjective intervention is required in order to replicate the concordance system. The ALP methodology follows the principles described below:

- Use of descriptive content of individual patents as the basis for the concordance. Since technical features classified in the IPC can pertain to several different classes of economic activity, it is important to consider each patent individually.
- Eliminate the need for concordance layering by constructing direct concordances. To avoid the composite concordance problem, most common economic classification schemes are applied, including SITC (Rev. 2 and 3), ISIC (Rev. 2, 3, 3.1 and 4), NAICS, HS and SIC.
- Automate the construction process as much as possible in order to: (i) involve minimal manual work to rapidly process millions of patents at a time; (ii) be relatively easy to implement and flexible enough to capture changing technologies and industries; (iii) rely more on objective algorithms than subjective judgments.

Since the ALP concordance is constructed as a probability distribution, the weights represent the probability that the origin classification system was matched into the destination classification system. Thus, the use of concordance is straightforward: one simply multiplies the values of the origin classification system by the weights to get the new values as measured by the destination classification scheme.

Building the Database

Once patents are assigned to the industrial sectors according to the Lybbert and Zolas' methodology, the two data sources, namely the EU-HLFS and the patent database are merged together. To this aim, the ISIC classification in accordance with the NACE information is used in order to match patents with employment data, since both contain now a code referring to the industrial sector. A many-to-many matching algorithm is proposed for the matching procedure, as it necessary to analyse each patent and to assign this latter to the corresponding industrial sectors with possibility of non univocal matching (e.g., one patent can belong to many industrial sectors). By eliminating double matching, a new panel dataset, which includes information on employment and innovative effort by industrial sector, constitutes the final result.
As a final step, patents assigned for each year to the specific sector/country combination have been used for calculating the patent stock as a measure of the installed technological capability at the sector level. The formulation adopted for such a patent stock accounting has been taken by a standard procedure according to the following equation:

$$KPAT_{i,t} = \sum_{s=1}^{t} PAT_{i,s} e^{[-\mu(t-s)]} \qquad (4)$$

where $PAT_{i,s}$ represents the number of patents applied in country *i* in year *s* where *s* represents an index of years up to and including year t, whereas μ is the decay rate, here assumed as a standard 15% value as suggested by [33].
All the other variables adopted in this research report for the development of the descriptive and the econometric analyses have been homogenised in terms of sector classification (when relevant). For the sake of clarity they are summarized in Table 3 where we report the name of the variable, a short description, the unit measure, the available dimensions and the statistical source.

Table 3: Variables description and source

Name	Unit	Dimension	Description	Source
Employment	No/1000	Sector/Country (all sectors, EU27)	Number of persons engaged (in 1000)	EU-HLFS (Eurostat)
Value added	Const USD	Sector/Country (all sectors, EU27)	Total value added	WIOD
Capital stock	Const USD	Sector/Country (all sectors, EU27)	Total capital stock at time t as given by the PIM formulation applied to annual investment flows eqs. (2)-(3)	WIOD
Patent stock	No	Sector/Country (all sectors, EU27)	Patent stock calculated according to eq. (4)	EPO

Energy consumption	Ktoe	Sector/Country (all sectors, EU27)	Total primary energy consumption	WIOD
CO2 emissions	ton	Sector/Country (all sectors, EU27)	CO2 emission flows yearly	WIOD
EE policy stock	No	Country (EU27)	Stock of policies oriented toward fostering energy efficiency in all policy domains and tools still in force at year t	IEA
Energy price	USD	Country (EU15)/Commodity (diesel, electricity, natural gas)	End-use energy prices USD (converted into constant values)	IEA
Energy tax	USD	Country (EU15)/Commodity (diesel, electricity, natural gas)	End-use energy taxes USD (converted into constant values)	IEA
Environmental policy stock	No	Sector/Country (manufacturing, EU15)	Stock of policies oriented toward environmental protection in all domains and policy tools still in force at year t applied to each sector (manufacturing only)	OECD

2.3 Country, year and sector coverage

After the matching of different data sources we ended up with a database including information on 27 EU countries, 34 sectors of economic activities for the years 1995-2009. Table 4 reports the countries covered in the database, which have been grouped in three European regions: EU15-North, EU15-South and EU12. Table 5 shows the sectors included in the analysis.

Table 4: Countries classification

Code	Country	Region	Code	Country	Region
AUT	Austria	EU15 – North	IRE	Ireland	EU15 – South
BEL	Belgium	EU15 – North	ITA	Italy	EU15 – South
BGR	Bulgaria	EU12	LTU	Lithuania	EU12
CYP	Cyprus	EU12	LUX	Luxembourg	EU15 – North
CZE	Czech Republic	EU12	LVA	Latvia	EU12
DEU	Germany	EU15 – North	MLT	Malta	EU12
DNK	Denmark	EU15 – North	NLD	The Netherlands	EU15 – North
ESP	Spain	EU15 – South	POL	Poland	EU12
EST	Estonia	EU12	PRT	Portugal	EU15 – South
FIN	Finland	EU15 – North	ROU	Romania	EU12
FRA	France	EU15 – North	SVK	Slovakia	EU12
GBR	United Kingdom	EU15 – North	SVN	Slovenia	EU12
GRC	Greece	EU15 – South	SWE	Sweden	EU15 – North
HUN	Hungary	EU12			

Table 5: Sector classification: NACE 1 digit and equivalent ISIC Rev. 3.1. 2 digits[6]

Description	*ISIC code*	*Macro Sector*
Manufacture of food products and beverages; Manufacture of tobacco products	15-16	Manufacturing
Manufacture of textiles; of wearing apparel; dressing and dyeing of fur	17-18	Manufacturing
Tanning and dressing of leather; manufacture of luggage, handbags, saddler, harness and footwear	19	Manufacturing
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20	Manufacturing
Manufacture of paper and paper products; Publishing, printing and reproduction of recorded media	21-22	Manufacturing
Manufacture of coke, refined petroleum products and nuclear fuel	23	Manufacturing
Manufacture of chemicals and chemical products	24	Manufacturing
Manufacture of rubber and plastics products	25	Manufacturing
Manufacture of other non-metallic mineral products	26	Manufacturing
Manufacture of basic metals; of fabricated metal products, except machinery and equipment	27-28	Manufacturing
Manufacture of machinery and equipment n.e.c.	29	Manufacturing
Manufacture of office, accounting and computing machinery; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments, watches and clocks	30-33	Manufacturing
Manufacture of motor vehicles, trailers and semi-trailers; other transport equipment	34-35	Manufacturing
Manufacture of furniture; manufacturing n.e.c.; Recycling	36-37	Manufacturing
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50	Trade
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	Trade
Retail trade (except of motor vehicles, motorcycles); repair of personal and household goods	52	Trade
Land transport; transport via pipelines	60	Transport
Water transport	61	Transport
Air transport	62	Transport
Supporting and auxiliary transport activities; activities of travel agencies	63	Transport
Post and telecommunications	64	Public Sector
Real estate activities	70	Real Estate
Renting of machinery and equipment without operator and of personal and household goods; Computer and related activities; RD; Other business activities	71-74	Real Estate
Agriculture, hunting and forestry; Fishing	A-B	Agr-Fish
Mining and quarrying	C	Other
Electricity, gas and water supply	E	Electricity
Construction	F	Construction
Hotels and restaurants	H	Other
Financial intermediation	J	Other
Public administration and defence; compulsory social security	L	Public Sector
Education	M	Public Sector
Health and social work	N	Public Sector
Other community, social and personal service activities	O	Public Sector

[6] The sectors falling within the broadly defined Public Sector have been identified following previous studies, which considered not only the government sector but also those industries carrying out public services. See for instance the report by Europe Economics (2006), "Evaluation of Public Procurement Directives" [25] or the Ramboll Report (2012) [57].

3 Empirical Analysis

3.1 Descriptive analysis

Before presenting the econometric analysis, this section highlights the main trends and characteristics of key variables, accounting for the relevant differences by country (or region) and by the sectoral economic activity.

Firstly, Figure 1 presents the trend of total final energy consumption from 1995 to 2009 as the sum among all EU27 countries. There are three sectors responsible for the large majority of energy consumption: considering the industry, transport and residential sectors, the share on total final energy consumption of each of them is almost of 30%, while other sectors (as Fishing, Agriculture/Forestry, Services) are much less energy consuming. Considering the entire time period, only in the industry sector there is a net reduction in the energy consumed in 2009 with respect to 1995 level (the annual average reduction rate is of 1.44%), while in both residential and, especially, transport sector the trend has slightly increased.

Figure 1 – Final Energy Consumption in EU27 (Ktoe)

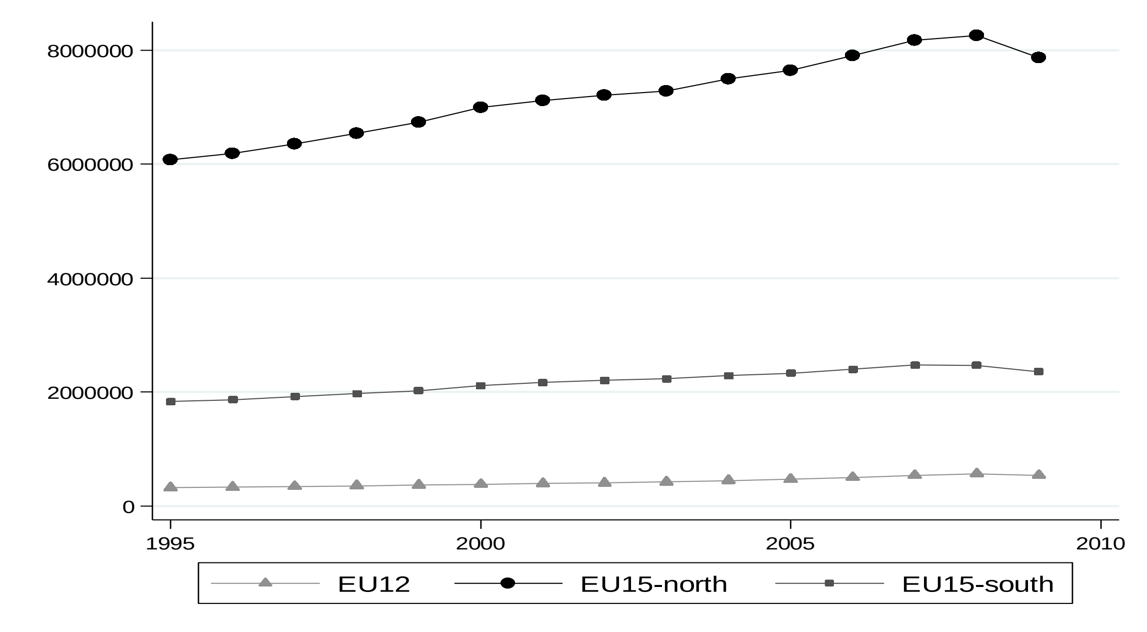
Source: Own elaboration on Eurostat data (2015).

In the next figures, we will present the relevant trends for EU27 countries distinguishing by region, according to the classification presented in Table 3: EU15-North, EU15-South and EU12. In this case, we do not account for the sectoral differences but we consider the total economy.

Figure 2 illustrates the trends of regional value added (VA), in millions USD. Firstly, we can notice the relevant gap in the level of VA across the identified EU regions. In fact, the EU15-North region shows a level equivalent to almost three times the EU15-South value (and the difference with respect to EU12 level is even greater). Besides the differences in level, the VA in EU15-North is the only case where the trend has significantly increased over time, except for the last year when the trend is downward.

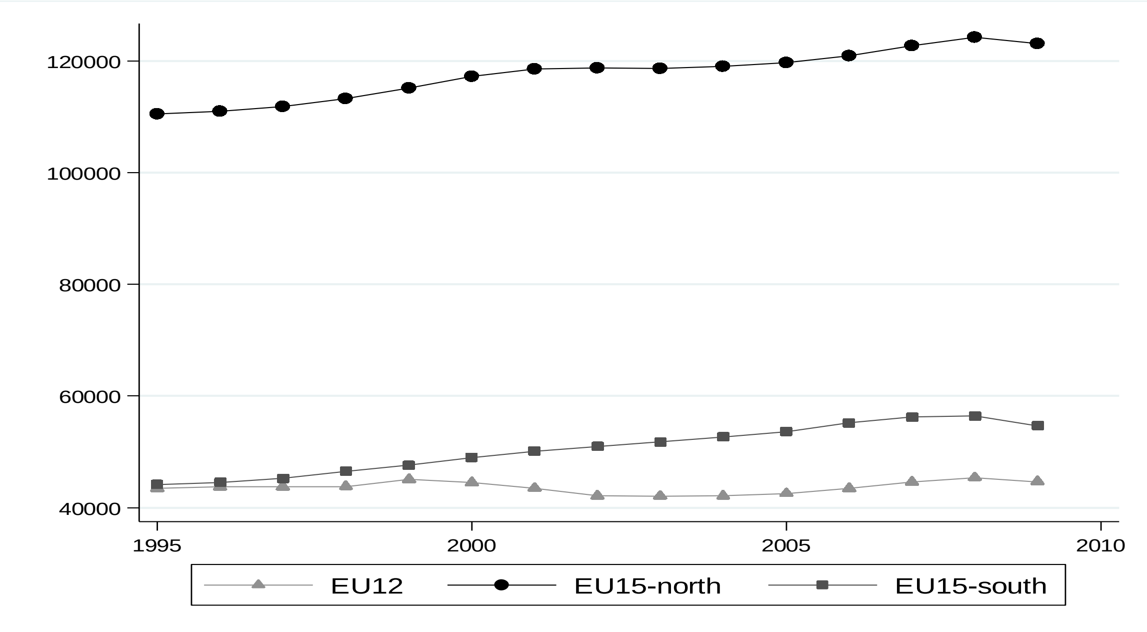
Considering the occupational data, Figure 3 presents the employment level by region, measured in terms of number of persons engaged (in 1000). As before, in the EU15-North region the level is significantly higher than in the other two regions, which show – relative to 1995 - a rather lower and very similar level respectively. However, while EU15-South follows a trend similar to the increasing one registered in the EU15-North region, in EU12 the trend is nearly flat (except for a decline in 2002 and 2003).

Figure 2 – Value added in EU27 by region (millions USD)



Source: Own elaboration on WIOD data.

Figure 3 – Employment in EU27 by region (number of persons engaged in 1000)

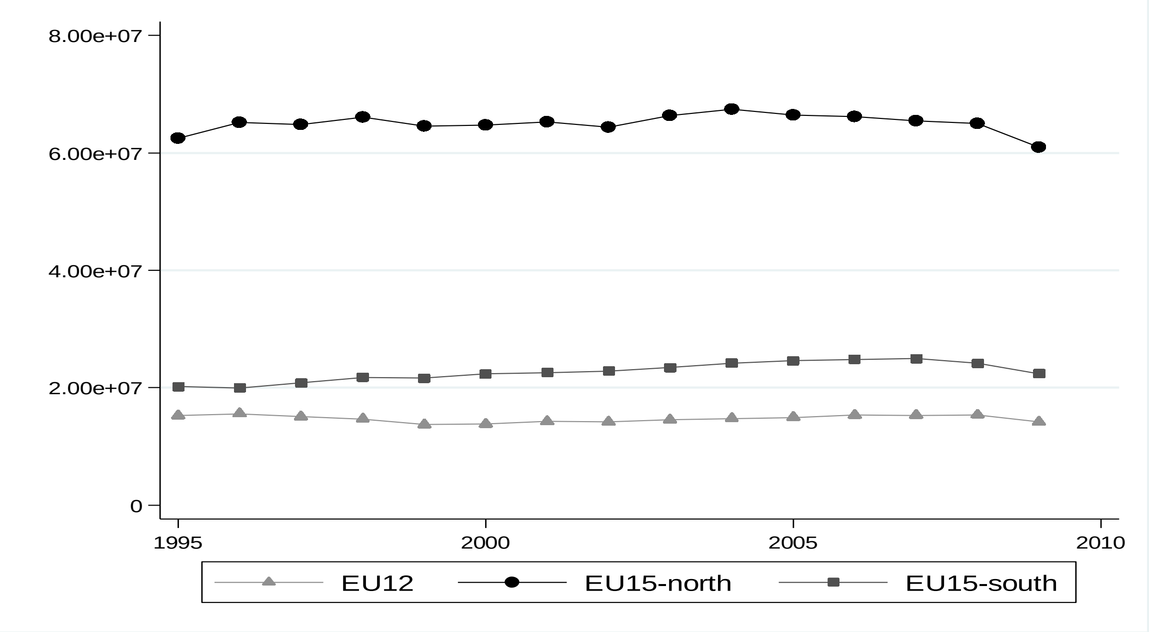


Source: Own elaboration on EU-HLFS data.

Moving from the Socio-Economic Accounts to the Environmental Accounts, when looking at the energy consumption pattern across regions (Figure 4), the differences in level are similar as in the previous figures, where EU15-North shows a level that is almost three time higher than in the other two regions. The trend is almost constant in all the three regions, except for EU15-North that shows small variation during the entire period and a stronger reduction in the last year.

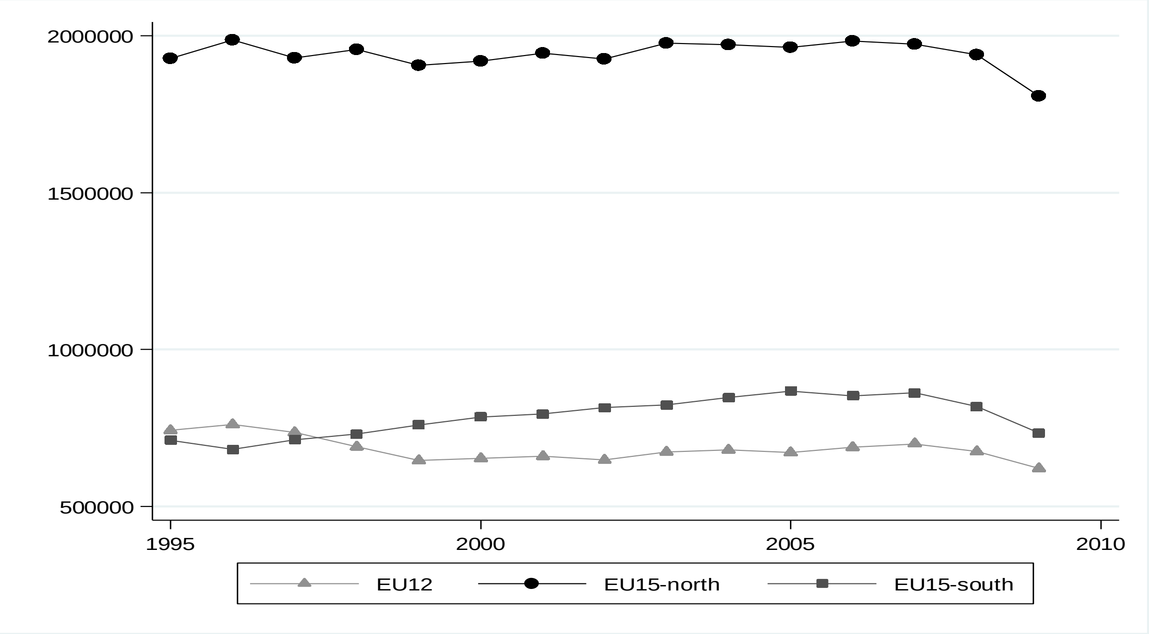
While energy consumption level is almost constant in the entire 15-year period, the level of CO_2 emissions (Figure 5) shows heterogeneous trends among the different regions considered: almost flat in EU15-North, increasing in EU15-South, and first decreasing (1996-1999) and then constant in EU12. However, all the three regions show a common reduction trend from 2008 in the level of CO_2 emissions.

Figure 4 – Energy consumption in EU27 by region (Ktoe)



Source: Own elaboration on WIOD data.

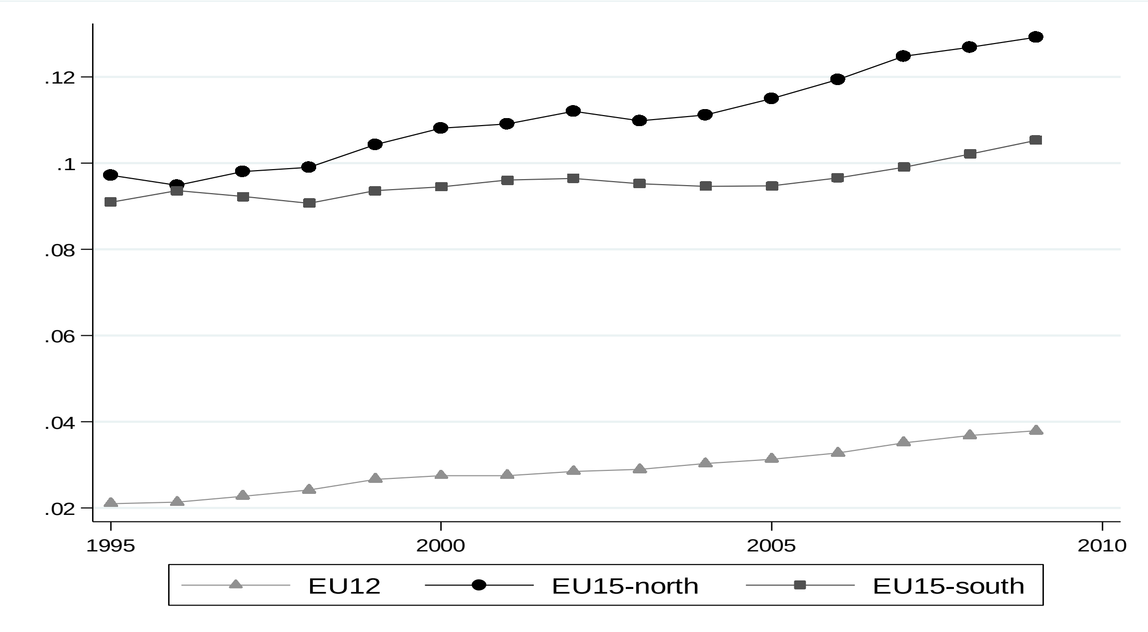
Figure 5 – CO_2 emissions in EU27 by region (ton)



Source: Own elaboration on WIOD data.

Considering two variables among those previously analysed, Figure 6 shows the trend of a proxy of energy efficiency, calculated as the ratio between valued added and energy consumption (million USD/toe). An increase in this indicator reflects an improvement in energy efficiency performance, as more output per unit of energy is generated. In this case, there is a clear gap between EU15 and EU12 countries, where in the former the VA for unit of energy consumed is much higher than in the latter. However, when considering the percentage change between 1995 and 2009, the EU12 countries show the greatest increase (about 80%) followed by EU15-North and EU15-South (respectively 33% and 15% increase). In other words, in the time horizon analysed, the greatest reduction in energy intensity has been registered in the EU12 region, while in EU15 the corresponding reduction in energy intensity was lower, due to a higher starting level of efficiency in energy use.

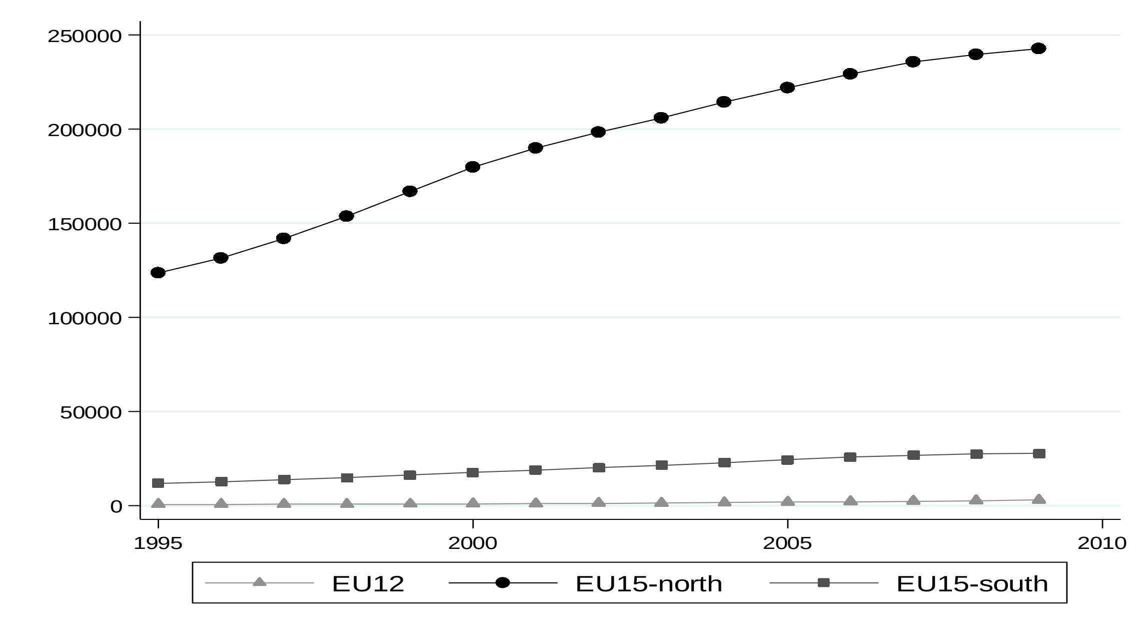
Figure 6 – Value added to energy consumption ratio in EU27 by region



Source: Own elaboration on WIOD data.

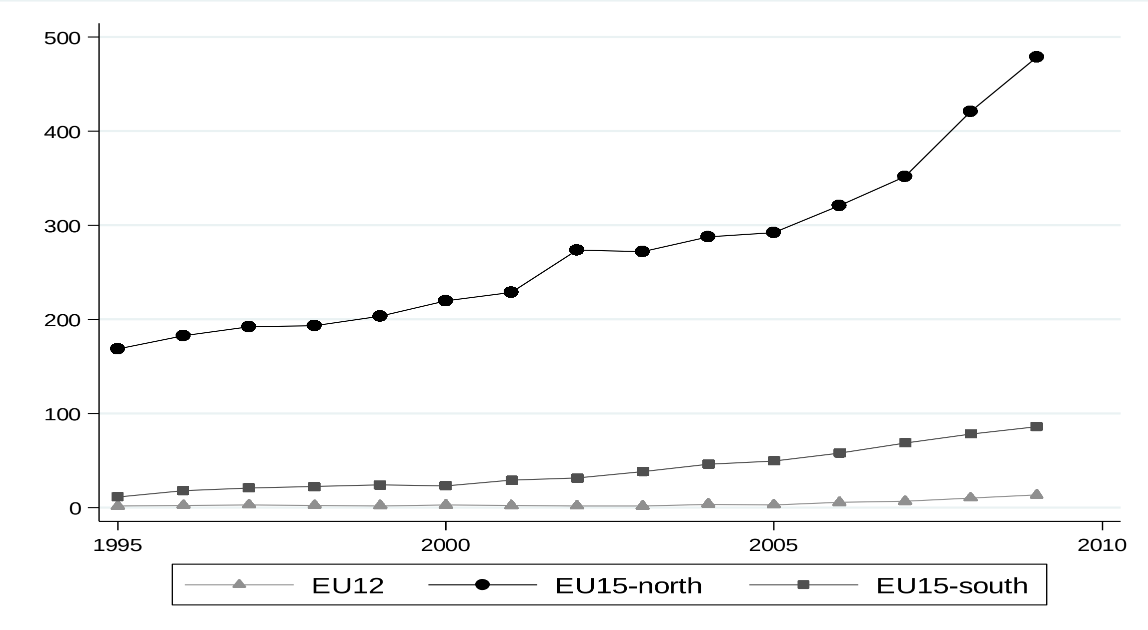
The next two indicators represent two alternative proxies to account for the technological content of production processes and characterise the technology and innovation pattern of the economic sector under scrutiny. The technology level here adopted is a measure of the technological capacity in terms of stock of patents applied by sector, often used alternatively to R&D investment. In Figure 7, we report the total stock of patent applied by EU region, while Figure 8 shows the number of patents applied in a particular class of "green technologies" that includes patents for climate change mitigation technologies related to buildings (residential sector), e.g. including appliances or related end-user applications. In both cases, in the EU15-North the increase in patenting activity has been particularly strong, and this is especially true with respect to the stock of patents in residential EE domain and during the last years. The share of the patent class in residential energy efficiency with respect to the total stock is particularly low, but the ratio has increased strongly especially since 2003.
Finally, in Figure 9, we also consider a policy variable representing all available information on (still in force) policy measures classified as energy efficiency policies at the country level (from IEA EE Policies database). In 1995, there were only few policies in place promoting energy efficiency, but through the 15-years period under scrutiny there has been a great increase in policy effort, especially in EU15 between 1997 and 2000 and after 2005. In EU12, even if the trend is increasing, the growth rate is much lower than in EU15. This also shows the crucial role of European Commission as key actor in promoting climate change mitigation policies and requiring the Member states to actively implement European directives.

Figure 7 – Stock of total patent in EU27 by region



Source: Own elaboration on REGPAT data.

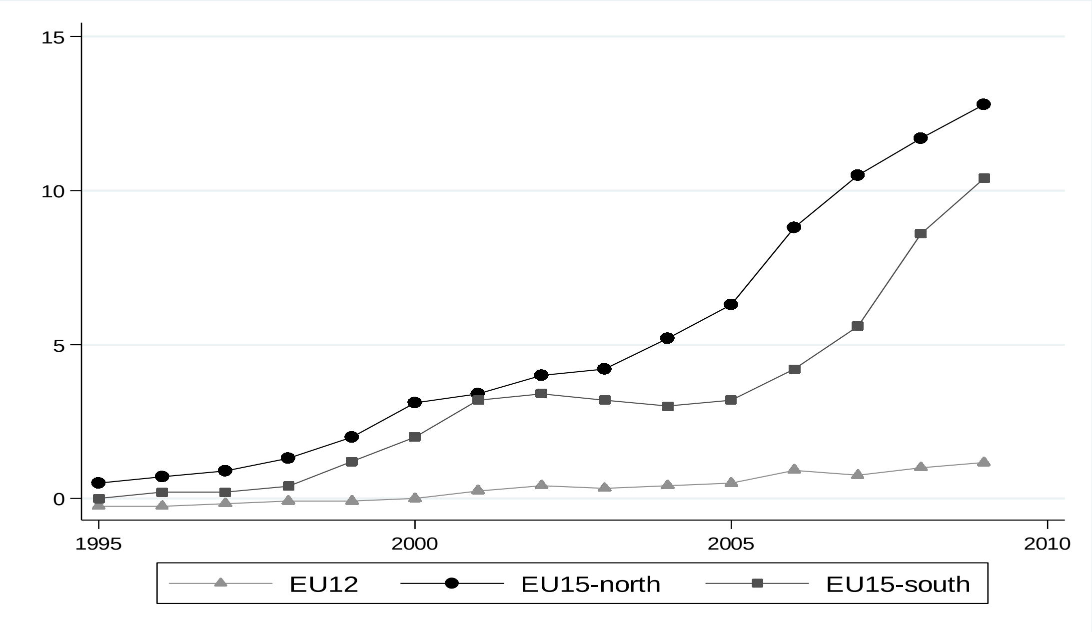
Figure 8 – Stock of patents in residential energy efficiency domain in EU27 by region



Source: Own elaboration on REGPAT data.

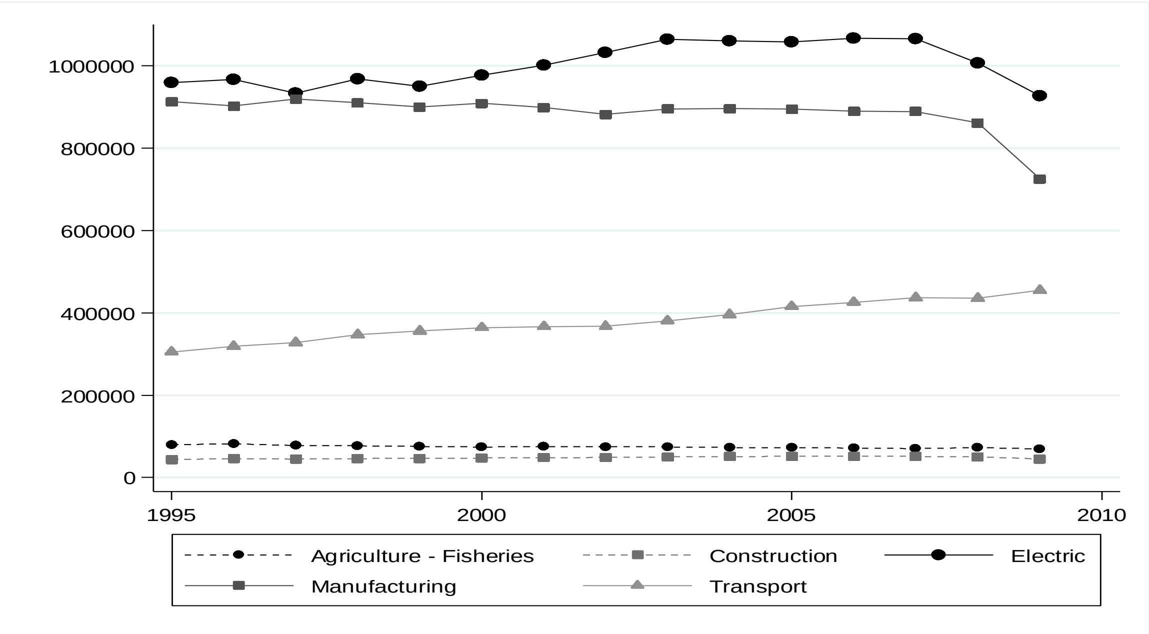
We now focus on EU15 countries considering the differences among the selected economic macro-sectors according to the classification in Table 4. Limiting the attention to the most developed European countries, the next figures compare the differences among economic sectors in terms of environmental, energy and economic performances. Firstly, Figures 10.a and 10.b show a distinction among sectors in terms of CO_2 level. As expected, Electric sector, Manufacturing industry and Transport (followed by Agriculture and Fisheries and Construction) are the most polluting activities. While the latter shows an increasing trend, Electric and Manufacturing sectors have an almost flat level of CO_2 emissions, though they also show a decrease in 2008 and 2009, particularly large in Manufacturing sector. In this case, this mitigation effect is due to energy and climate change mitigation policies in force, but also to the effects of the economic crisis.

Figure 9 – Energy efficiency policy stock in in EU27 by region



Source: Own elaboration on IEA data.

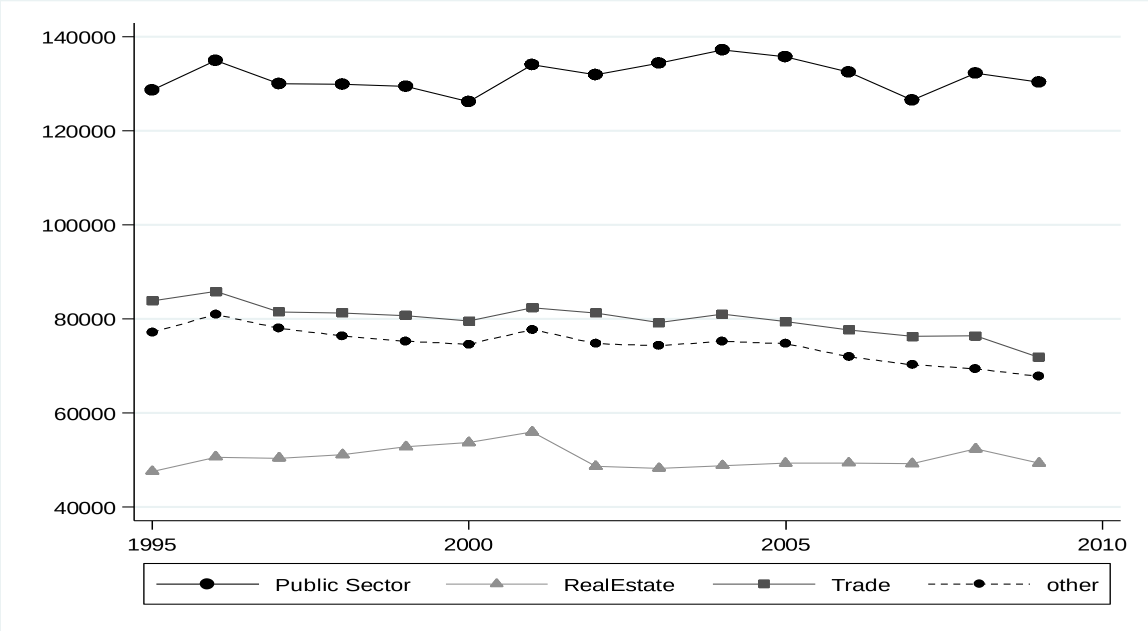
Figure 10.a – CO_2 emissions in EU15 by sector (ton)



Source: Own elaboration on WIOD data.

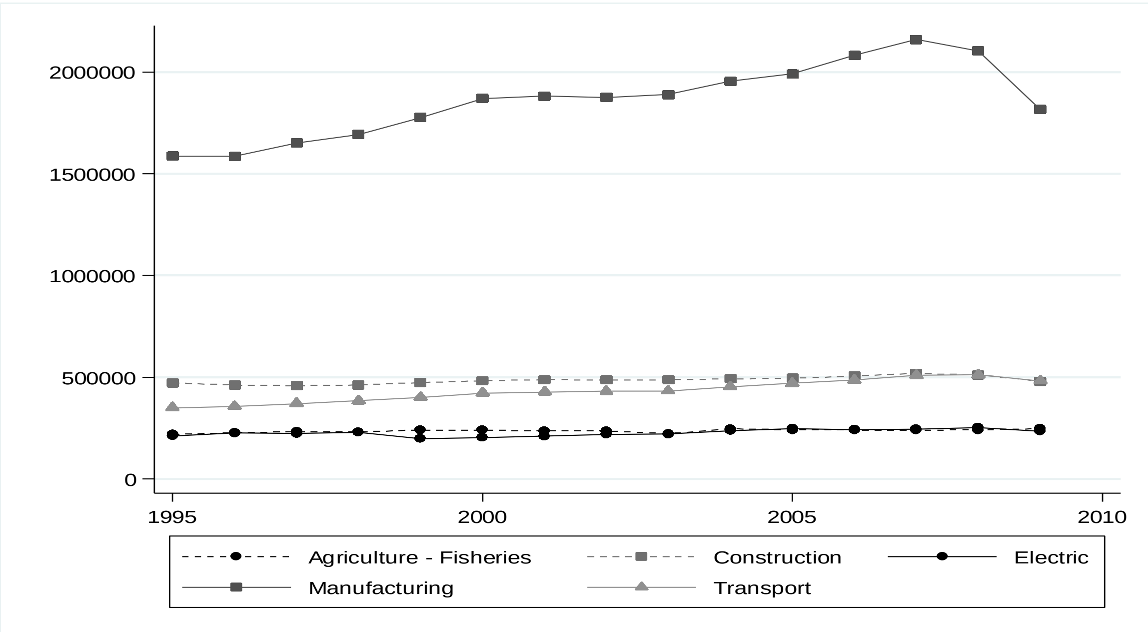
The next two figures present the trend in terms of total value added, following the same classification as before (Figures 11.a and 11.b). The highest value corresponds to the broadly defined Public Sector, followed by Real Estate and Manufacturing sector. These two sectors share a common starting level, but while the former has always an increasing trend, the latter shows a lower increasing rate and even a reduction in the last years. Even if the highest value is associated with the Public Sector, the Manufacturing sector has the highest VA level among the most emitting activities and shows an increasing trend followed by a large reduction from 2007. This confirms that Manufacturing sectors not only are very relevant with respect to energy policies but, given their contribution to national VA, have a high strategic economic role.

Figure 10.b – CO_2 emissions in EU15 by sector (ton)



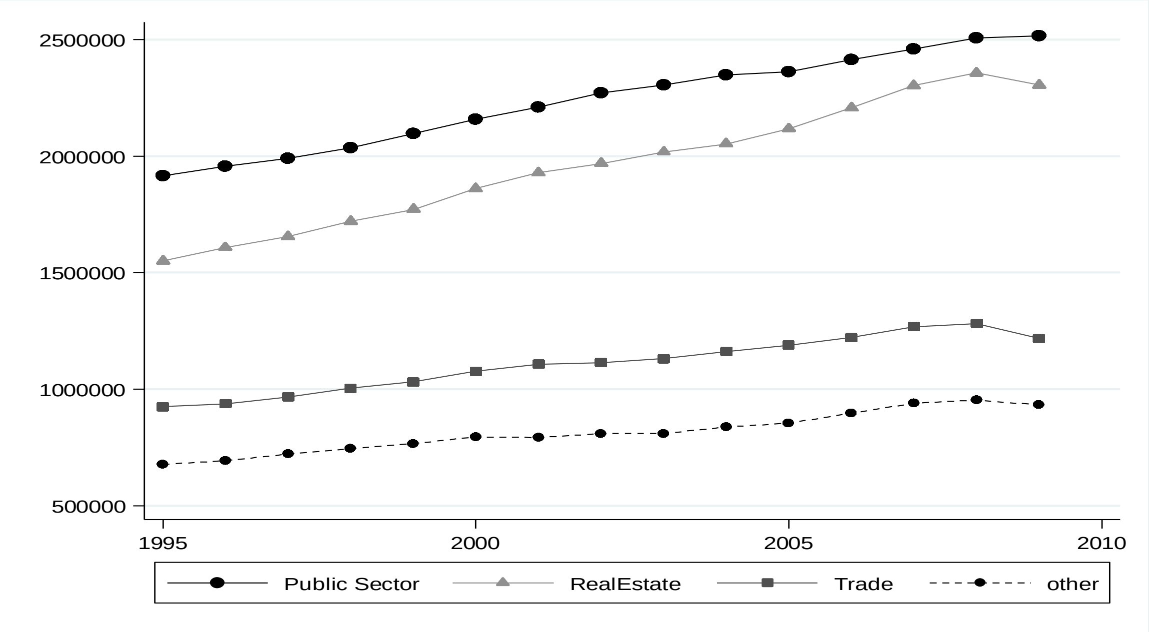
Source: Own elaboration on WIOD data.

Figure 11.a – Value added in EU15 by sector (millions USD)



Source: Own elaboration on WIOD data.

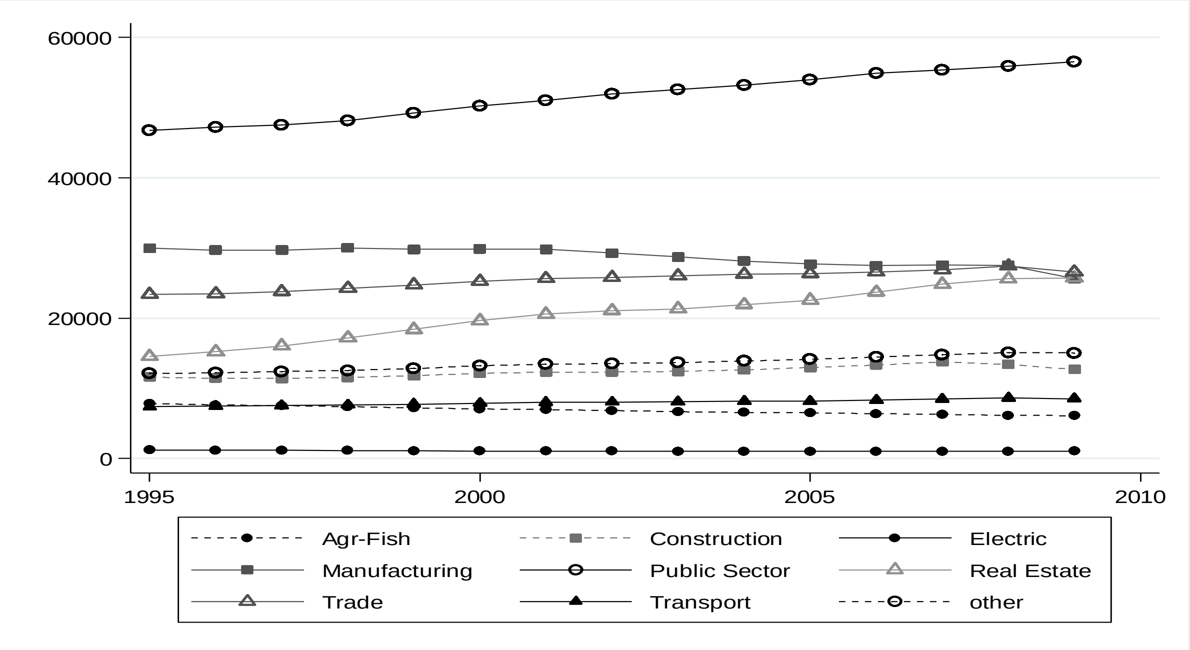
Figure 11.b – Value added in EU15 by sector (millions USD)



Source: Own elaboration on WIOD data.

When considering employment in EU15 countries (Figure 12), we find the manufacturing industry - second only to the Public Sector as number of persons employed - with a slightly decreasing trend, such that in 2009 the employment level is the same as in Trade and Real Estate activities, which are lower in the first years but have higher growth rate.

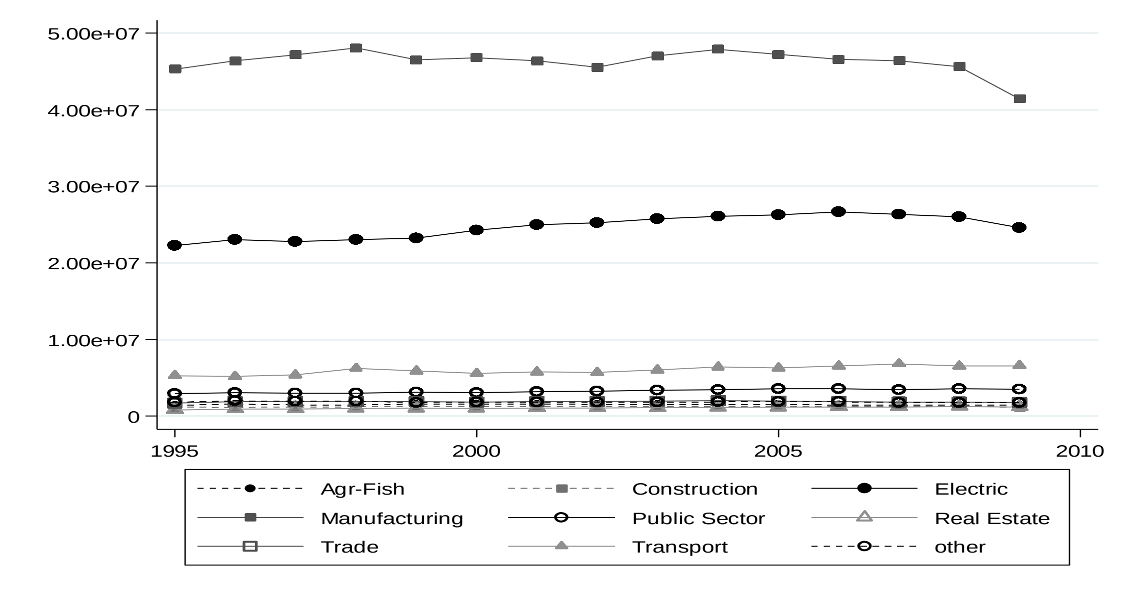
Figure 12 - Employment in EU15 by sector (number of persons engaged in 1000)



Source: Own elaboration on EU-HLFS data.

While the most relevant sectors are the Public Sector, Real Estate and Manufacturing in terms of persons engaged, the key sector is the manufacturing one when accounting for the impact of EE and climate change policies on employment. In fact, other than being crucial in terms of VA and person engaged, the manufacturing sector is also the most emission and energy intensive (Figure 10.a and 13). It is one of the main target for energy policies and, given its big share in terms of person employed, is crucial when studying the impact of green policies on employment.

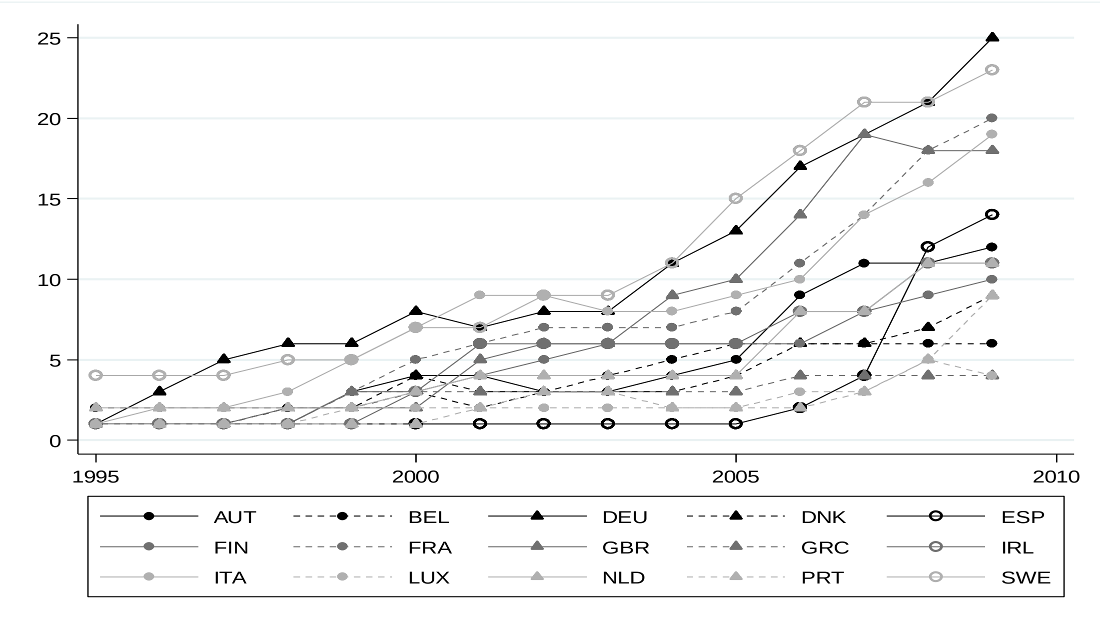
Figure 13 – Energy consumption in EU15 by sector (toe)



Source: Own elaboration on WIOD data.

Finally, Figure 14 shows how EE policies have evolved at the country level considering the EU15 by country in terms of policy stock. In general, it shows that the trend has been increasing during the entire period, particularly after 2003, which is when EU ETS Directive was enforced. In this case, the countries that put the greatest effort in promoting energy efficiency policies and measures are Germany and Sweden followed by France, Italy and Great Britain.

Figure 14 – Policy stock in EU15 by country



Source: Own elaboration on IEA data.

3.2 Econometric analysis

3.2.1 The econometric model

In order to understand the impact of country and sector specific policies and measures related to energy efficiency on the employment performance of economic sectors, it is necessary to model an inverse production function.
Starting from a simple Cobb-Douglas production function in the form:

$$Y_{ir,t} = f\left(K^{\alpha}, L^{\beta}, E^{\gamma}, T^{\delta}\right)_{ir,t} \tag{5}$$

where $\alpha, \beta, \gamma, \delta > 0$ are constant output elasticties, we assume that the output level ($Y_{ir,t}$) of each sector i, located in each country r, at time t, is a function of the amount of capital stock (K), the number of employees (L), the quantity of energy consumed during the production process (E), and finally the technological knowledge available for the production process (T) in the same dimensions i, r, t .
When an assessment of the performance of the job market at the sector-based level is conducted, starting from eq. (5) it is necessary to calculate an inverse function, allowing to retain all potential driving factors influencing the production process.
In this way, it is also possible to take into account the largest number of potential country and sector-based characteristics that may influence employment performance, without using only fixed effects to control for such heterogeneity.

Accordingly, a log linearization of eq. (5) allows obtaining the functional form:

$$lnY_{ir,t} = \alpha lnK_{ir,t} + \beta lnL_{ir,t} + \gamma lnE_{ir,t} + \delta lnT_{ir,t} \tag{6}$$

By relying on this linearized functional form it is possible to derive the econometric model necessary to estimate our employment performance function.

From eq. (6) we can easily obtain:

$$lnL_{ir,t} = \beta_0 + \beta_1 lnY_{ir,t} + \beta_2 lnK_{ir,t} + \beta_3 lnE_{ir,t} + \beta_4 lnT_{ir,t} + \varepsilon_{ir,t} \tag{7}$$

that represents how the employment level for each sector i, in each country r at time t is influenced by the whole economic dimension of the sector (represented by the output level), the capital stock, the amount of energy consumed and the technology level, plus a statistical term $\varepsilon_{ir,t}$, representing the stochastic error. In this case β_0 represents a constant term, while $\beta_1, \beta_2, \beta_3, \beta_4$ represent the linear combinations of the output elasticity values for each input with the output elasticity value of labour. The sign of each coefficient strictly depends on the elasticity relationships between factors at the sector and country level. As a general remark, we might expect that those sectors having a larger share of output will gain more than other sectors in the employment rate, ceteris paribus.
Given the object of this study, what we are interested in is to investigate if and to what extent the introduction of specific measures at the country and sector level, represented by policy instruments or by private measures for energy efficiency, play a role in influencing employment dynamics. This means that we

need to understand the effect on the change of the absolute value of employment level. Accordingly, the econometric model must be performed on differenced variables, and not by taking absolute levels. In addition to the standard inverse production function form, we need to include some further specifications referring to the specific energy efficiency policies and measures.
Hence the final general functional form to be estimated results as follows:

$$\Delta lnL_{ir,t} = \beta_0 + \beta_1 \Delta lnY_{ir,t} + \beta_2 \Delta lnK_{ir,t} + \beta_3 \Delta lnT_{ir,t} + \beta_4 \Delta lnE_{ir,t} + \beta_5 P_{ir,t-1} + s_i + c_r + y_t + \varepsilon_{ir,t} \quad (8)$$

where the term $(P_{ir,t-1})$ represents a set of different measures, both at the public and private level, and both country and sector based. In addition, we include in the econometric models three kinds of fixed effects, namely s_i, c_r, y_t, in order to account for sector, country, and time fixed effects, respectively. This allows reducing all variability related to aspects that are not taken account by the variables modeled in the estimation, in order to better isolate the real effects associated with each driving factor here investigated.

3.2.2 Methodology and indicators

The econometric analysis is carried out on a balanced panel dataset, including 27 EU countries over the time span 1995-2009, for 34 sectors.
Since the econometric estimation is carried out on the basis of differenced variables, this allows us excluding potential biases which are typical in time series analyses. Moreover, considering that the time span is longer than 10 years, potential biases due to autocorrelation of the residual terms as well as potential autoregressive forms of the dependent variable or of some regressors are likely to occur. However, the differenced representation of these variables completely eliminate these potential distortions, thus allowing us to adopt the most effective and efficient estimator for panel data, given by the panel Fixed Effects (FE) tool. The final FE panel estimator has been chosen on the basis of a Hausman test, comparing it with a random effect version of the panel estimator. Obviously, given this specific differenced functional form, the values obtained for the model fitting as represented by the R-squared values are rather low. As a robustness check for the econometric modelling choice, we have also performed a panel FE estimator on the model in eq. (7) with variables taken as levels (and not differenced). In this case all models provides R-squared values higher than 0.75 overall (as an average value of the between and within estimations), thus giving a robust enough value for this econometric specification.
Turning to the variables description, the dependent variable is represented by the annual difference of the logarithm value of total employment (number of engaged persons) level for each sector/country.
The independent variables directly derive from the dataset description as provided in Section 2. Accordingly, the value added level is provided in logarithm form with respect to the original measure based on million constant 2005 USD. The modelling approach considers the difference between the value in year t and in year t-1.
Furthermore, the differenced level of capital stock follows the PIM formulation, thus resulting in a measure of net investment flows over time discounted by the depreciation rate.
For what concerns the technology level, we have chosen as a measure of the technological capacity the stock of patents applied by each sector (where the assignment to each sector of patents is based on the methodology developed by Lybbert and Zolas, as described in Section 2), commonly adopted as a proxy of technological knowledge available for the production process.
With respect to the energy variable, we have computed some elaboration on the original values in order to better detect the role of energy efficiency in influencing employment rate changes. To this purpose, we have first computed an energy efficiency index as the ratio between the total value added of each sector and the total energy consumption for the same sector. The differenced value of this ratio that is included among the regressors in logarithm form represents gains in energy efficiency obtained from the previous to the present year by each sector in each country.

This variable might be interpreted as the indirect effect of policy measures fostering energy efficiency as the final output in terms of energy performance. Although it is not a purely specified energy efficiency policy measure, it is also necessary to consider that there are no available data on specific policy measures in energy efficiency differentiated for the industrial sectors here considered.[7] On the contrary, only energy efficiency policies at the country level are available for the entire panel dataset covering all EU27 countries and all economic sectors.

In order to partly cover this lack of information, we have computed a second index representing energy efficiency gains for the broad public sector (where postal and telecommunication sectors are accounted for a half of their energy consumption and value added, according to a standard formulation valid for all EU27 countries, considering the different weight of the public and the private component in this economic branch).

For what concerns the modelling approach of the policy measures variables, for the whole EU27 dataset the only available information is given by the IEA-Policy database, as described in Section 2, where we have captured all available information on still in force policy measures classified as energy efficiency tools at the country level. In this case we have considered all policies implemented year by year without a distinction among different instruments, since the cross-section dimension of this variable (country-based) does not match with the cross-section dimension of the whole dataset (sector-country-based). This means that we can provide general results on the impacts of country-based energy efficiency policies on changes of the employment level.

In order to provide more refined results upon the energy efficiency policy modelling side, we have built some further policy variables for a subsample of countries, namely the EU15, for which several additional data are available. The variables are the energy tax bundle, the sector-based environmental policy index, and some interactions between variables.

The energy tax bundle is expressed as the weight of energy taxation on the total energy costs weighted by energy consumption in different primary sources. The price effects in spurring innovation have been extensively analysed in economics, dating back to the seminal work by Hicks (1932) [34] who attributed to prices the role of a driving force for more efficient input substitution in which part of this process relies on innovation. The effectiveness of the price-inducement effect in the energy sector, and in particular in energy efficiency, has been tested by different contributions which generally found a significant and positive role of prices in fostering innovation dynamics in more efficient energy technologies [45; 52; 53; 56; 61]. Since we are interested in capturing the role of public policy in affecting residential end-use energy prices, we test an extended price-induced mechanism in a price-tax bundle, calculated as the ratio between the energy taxation levy on the total cost of energy consumption (by applying agent prices). In order to consider different energy commodities commonly used in the residential sector, we weight energy prices by consumptions related to each specific source as follows:

$$Tax\_bundle_{i,t} = \frac{\sum_{n=1}^{3} \left(tax_{i,t}^{n} \cdot ener\_cons_{i,t}^{n} \right)}{\sum_{n=1}^{3} \left(price_{i,t}^{n} \cdot ener\_cons_{i,t}^{n} \right)} \qquad (9)$$

where *n* indexes the energy commodity (diesel, electricity and natural gas), whereas *i* and *t* refer to countries and time, respectively. This is a measure of the market-based instrument represented by the energy taxation. Instead of taking only the tax level, we have considered the relative weight of the energy taxation on the production costs referred to energy consumed as an input in the production function. This allows better capturing the real impact of energy policies in terms of changing behaviours in production decisions.

The second additional policy variable is available only for the EU15 and only for the manufacturing sectors. It is a policy count variable built as stock value as the country-based energy efficiency policy stock variable,

[7] This approach has been followed in previous studies when emission intensity indicators have been used to proxy environmental regulation stringency [11].

but it is available with a higher degree of disaggregation since it is disentangled for the specific manufacturing sectors here considered in the analysis. It is a measure of how much each manufacturing sector is involved in environmental policies (not only referred to energy efficiency). In order to better capture the role of sector-based policies in our analytical framework, we have interacted the sector-based environmental policy variable with the country-based energy efficiency policy variable. In this way, we assume that, ceteris paribus, the policy stringency in energy efficiency in one country has a larger impact in those sectors more covered by environmental policies. This interaction proxies the relative influence of energy efficiency policies on distinguished manufacturing sectors, allowing also for a country specificity.
Relying on these additional variables available for the EU15 only, we have also considered some interaction terms in order to better design the relative influence of different aspects of the energy efficiency policy framework on employment performance.
The first interaction term is given by the product of the energy efficiency gains at the sector level with the energy tax bundle at the country level (variable 5 in Table 6).

Table 6 – Summary of energy efficiency policy variables tested in the econometric estimations

No	Acronym	Full Description	Availability	Interpretation
1	Dt of EE sect-based	Changes over year of energy efficiency measured as the ratio between energy consumption and value added at single sector level.	EU27 34 sectors	The variable measures the efforts played by the sector under investigation in reducing energy consumption with respect to a given amount of total output. The impact on employment performance is not univocally determined since it depends on substitution elasticity values between inputs in the specific production function.
2	Dt of EE in the Pub. Sec.	Changes over year of energy efficiency measured as the ratio between energy consumption and value added for the Public Sector aggregation.	EU27 Public Sector	The variable measures the efforts played by the Public Sector of each country under investigation in reducing energy consumption with respect to a given amount of total output. The expected impact on employment performance of the other industrial sectors is positive as represented by direct and indirect effects.
3	Pol. stock in EE country-based	Number of total policy measures in force at time directly oriented toward improving energy efficiency at the country level.	EU27	The variable measure the overall policy mix available in each country with the explicit purpose of reducing energy consumption with respect to the aggregated economic output. The effects on employment performance are not predictable since they depend on sector specific features.
4	Pol. stock in EE sect-based	Number of environmental policy measures in force at time t applied at sector level factored by the policy stock for energy efficiency at the country level.	EU15 14 Manufacturing sectors	The variable measures how much the country based energy efficiency policy framework may influence each sector based on its involvement in environmental protection measures.
5	Int. of EE ch. sect-based with energy tax bundle	Interaction between variable No. 1 and the energy tax bundle at the country level.	EU15 34 sectors	The variable measures how much the involvement of each sector in energy efficiency/environmental policies might be transformed into economic benefits by saving the cost of energy taxation.
6	Int. of Pol. stock in EE sect-based with energy tax bundle	Interaction between variable No. 4 and the energy tax bundle at the country level.	EU15 14 Manufacturing sectors	The variable measures how much the efficiency gains obtained by each sector might be transformed into economic benefits by saving the cost of energy taxation.

The interpretation of this variable is as follows: for those sector experiencing efficiency gains in terms of energy consumption reduction, *ceteris paribus*, the economic gains obtained, and the consequent employment impact, are greater if the sector is located in a country with a higher energy tax bundle. By considering that a high energy tax bundle means a high cost for energy consumption in the production

function, the economic savings in production costs are larger. This may allow firms in these countries to expand the production and the demand for other inputs such as labour.
The second interaction term is built as the product of the policy at sector level in environmental protection (weighted by the country-based energy efficiency policy measure) and the energy tax bundle (variable 6 in Table 6). In this case what we consider is a potential virtuous cycle given by the interaction of different policies forming the policy mix. A positive coefficient value in the econometric estimation associated with the combination of a country-based market-based instrument represented by the energy tax bundle and the specific policy efforts played at the sector level, would represent an evidence on the positive role played by a well-designed policy mix in fostering economic competitiveness of industrial sectors, here measured by the employment performance indicator.
In Table 6 we report a summary of the different driving factors tested in the econometric estimations associated with the policy influence on the employment performance related to energy efficiency interventions.

3.2.3 Econometric results

The description of results is organized as follows. First, we provide comments on the results obtained for the whole country sample, dividing results with respect to the economic aggregation considered. Accordingly, in Tables 7-8-9 we report results for the EU27, for all economic activities, for the manufacturing sectors plus the energy public utilities and the construction sector, and finally only for the manufacturing sector. For each group sectors analysed, we report different model results according to the specific energy efficiency policy variable explored (according to the details provided in Table 6) included in the econometric estimation as a single regressor or jointly with the other policy variables.
The same distinction is applied to a sub-sample of countries, the EU15, with results reported in Tables 10-11-12, recalling that for the EU15 the available policy variables are more detailed so the number of models is higher.
A final elaboration, reported in Table 13, provides further interesting results on the interaction of sector-based energy efficiency gains and sector-based energy efficiency policy with the cost of energy at the country level.
Let us start by investigating the employment performance of the whole economy in the EU27. According to Table 7, changes in the employment levels are positively related to changes in the sectoral output. This is an obvious result since output elasticity of labour as an input is positive. This means that, in the short term, given a certain level of technology (or in other terms given fixed Leontief coefficients), in order to obtain an increase in the final output, it is necessary to increase all inputs used in the production function, including labour. Accordingly, from our estimates we can state that those sectors showing a better performance in output increase are also those sectors with better employment performance.
For what concerns changes in capital stock, two contrasting effects might take place: an increase in capital intensity may displace a complementary input such as labour, leading to employment reductions; on the other hand, positive changes in capital stock reflect investment activities which can be associated to a positive sectoral dynamics conducing to employment gains. The econometric estimates reported in Table 7 suggest that the second effect prevails only for selected estimations (Columns 4 and 5 in Table 7), suggesting that capital deepening is not necessarily a vehicle of increase in employment performance. Changes in innovation activity, represented by an increase in net patents stock, are completely independent from employment performance, whatever model is performed on the whole sample of 27 countries.
More intriguingly, the coefficient value for energy efficiency gains over time is statistically robust and negative in sign. This first result reveals that, for the EU27, energy saving behaviours assumed by economic sectors associated with output gains are detrimental for employment performance. This coefficient must be interpreted as follows: for those sectors experiencing higher energy saving performances there is a reduced increase in employment changes over time. This is to say that energy saving behaviours are not necessarily responsible for a reduction in the employment rate, but only that they contribute to smooth

employment positive performance. Such result suggests that, at least in the short run, the overall effect of investments in energy efficiency in different economic sectors impacts more on the cost side than on the competitive side.
On the other hand, it is worth noting that the impact of energy efficiency gains realized in the broadly defined public sector is largely positive in terms of employment performance at the sector level, with the coefficient values in all models (Columns 2-3-5) largely higher than those (negative) obtained for the sector-specific energy efficiency variable.
This evidence suggests that that the intervention in favour of reducing energy consumption in the public sector play a significant positive role in shaping employment in the whole economy. Efficiency gains in terms of reducing energy consumption in the building sector for the provision of public services (lets think about the education and health system for instance), stimulate additional demand at the country level in several other sectors (the development and production of new energy saving materials or devices, the installation of new insulation systems or the energy building certification auditing for instance). This brings to the increasing necessity of complementary activities fostering employment rate in different sectors of economic activity. At the aggregate level, such effects can be further amplified in the medium-long run if energy efficiency translates into savings for public budgets, that can be directed for fostering economic growth and employment dynamics of economic sectors (for instance via a reduction of labour taxation or by providing incentives for employment creation).
Finally, it is worth noting that, when all 27 EU countries are analysed together, the country-based efforts in energy efficiency policy measures have no effect on the employment performance.The same results are obtained if we reduce the sector sample as described in Tables 8 and 9.
The most interesting thing is the increasing value of the coefficient related to the energy efficiency gains in the public sector when reducing the sector sample, thus revealing that the positive effects are larger in the case of the manufacturing sector, achieving a maximum value equal to 0.18 in Column 5 where all components of the empirical model are jointly included.

Table 7 - Impact on Total Employment changes over year (EU27 All sectors, 1995-2009)

	(1)	(2)	(3)	(4)	(5)
Dt of value added	0.305***	0.251***	0.305***	0.255***	0.256***
	(27.17)	(25.45)	(27.30)	(24.34)	(24.53)
Dt of capital stock	0.013	0.021	0.011	0.078**	0.075**
	(0.50)	(0.77)	(0.43)	(3.08)	(2.98)
Dt of patent stock	-0.004	-0.004	-0.004	0.003	0.003
	(-0.97)	(-0.93)	(-0.87)	(0.59)	(0.60)
Dt of EE sect-based	-0.148***		-0.155***	-0.096***	-0.102***
	(-9.25)		(-9.74)	(-8.10)	(-8.64)
Dt of EE in the Pub. Sec.		0.111***	0.133***		0.153***
		(4.51)	(5.44)		(6.83)
Pol. stock in EE country-based				-0.002	-0.003
				(-0.63)	(-0.92)
Constant	0.146***	-0.067***	0.065**	0.121***	0.029
	(8.66)	(-3.69)	(2.89)	(7.39)	(1.35)
N. Obs.	6,111	6,111	6,111	5,426	5,426
R-sq	0.13	0.12	0.14	0.12	0.13

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

The results obtained for the country sub-sample of EU15 countries allow us to obtain a more fine-grained analysis of the issues under scrutiny (Table 10-11-12).

Table 8 - Impact on Total Employment changes over year (EU27 Manufacturing Sectors, Electricity and Gas, Constructions, 1995-2009)

	(1)	(2)	(3)	(4)	(5)
Dt of value added	0.311***	0.264***	0.312***	0.264***	0.265***
	(26.77)	(25.24)	(26.89)	(23.64)	(23.82)
Dt of capital stock	-0.003	0.002	-0.006	0.069**	0.065*
	(-0.11)	(0.06)	(-0.22)	(2.58)	(2.43)
Dt of patent stock	-0.005	-0.005	-0.004	0.003	0.003
	(-1.02)	(-1.00)	(-0.91)	(0.55)	(0.55)
Dt of EE sect-based	-0.150***		-0.156***	-0.100***	-0.106***
	(-8.77)		(-9.24)	(-7.61)	(-8.09)
Dt of EE in the Pub. Sec.		0.125***	0.147***		0.165***
		(4.67)	(5.50)		(6.72)
Pol. stock in EE country-based				-0.003	-0.004
				(-0.62)	(-0.90)
Constant	0.157***	-0.070***	0.067**	0.128***	0.028
	(8.57)	(-3.53)	(2.74)	(7.14)	(1.19)
N. Obs.	5,415	5,415	5,415	4,814	4,814
R-sq	0.14	0.13	0.15	0.13	0.14

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

Firstly, results for the EU15 sub-sample mainly confirm the EU27 ones in terms of the direction of the effects on employment dynamics. However, the relative magnitude of the coefficients is different. Although it is not possible to directly compare the coefficient values obtained for the EU27 and the EU15 groups since the samples are different, it is possible to compare the relative magnitude of the sector-based energy efficiency behaviours and the energy efficiency variable related to the public sector. When looking at the EU27 it is worth noting that the impact of the public sector measure is rather higher than that associated with the sector-based efficiency gain (Column 3 Table 7). For the EU15 sample, this difference is lower (Column 3 in Table 10). In addition, contrary to the EU27 results, for the EU15 sample there is a positive and statistically significant impact of the stock of the energy efficiency public policies in force with respect to employment performance. This result is easily explained by the quality of policy data. In the new EU member states energy efficiency policies have been introduced only recently. Thus, our time span does not allow including the new environmental and energy policy settings implemented by the new EU member states, which are not covered in our dataset. On the contrary, in the case of the EU15, where energy efficiency measures have been adopted starting from the oil shocks occurred in the 70s, the time span covered by the dataset allows including long tailored past effects. Nonetheless, the relative impact of this variable is rather lower if compared with the coefficient value assumed by the energy efficiency gains in the public sector variable. In this case these two coefficients can be fully compared, since they are obtained in the same sample and they are both country-based.

Finally, it is interesting to note that for the EU15 sample the expansionary effect associated with investment in new capital stock strongly prevails with respect to labour substitution effects. Remarkably, this positive effect is linked to a (slightly significant) positive impulse of increasing technological knowledge stock, suggesting that in more advanced economies energy efficiency practices and investment are connected with technological competitiveness advancements [15].

The focus on the EU15 sample allows us to exploit additional relevant information and further qualify our results.

First, we have computed the relative role played by the first interaction term, built as the product of the energy efficiency sector-based gains and the country-based energy tax bundle.

Table 9- Impact on Total Employment changes over year (EU27 Manufacturing Sectors, 1995-2009)

	(1)	(2)	(3)	(4)	(5)
Dt of value added	0.318***	0.267***	0.318***	0.270***	0.271***
	(25.29)	(23.66)	(25.39)	(22.52)	(22.67)
Dt of capital stock	-0.016	-0.012	-0.019	0.059*	0.054
	(-0.53)	(-0.40)	(-0.63)	(2.04)	(1.89)
Dt of patent stock	-0.005	-0.005	-0.005	0.003	0.003
	(-0.99)	(-1.01)	(-0.88)	(0.48)	(0.50)
Dt of EE sect-based	-0.159***		-0.164***	-0.109***	-0.113***
	(-8.61)		(-9.05)	(-7.53)	(-7.96)
Dt of EE in the Pub. Sec.		0.137***	0.160***		0.180***
		(4.55)	(5.33)		(6.53)
Pol. stock in EE country-based				-0.001	-0.002
				(-0.27)	(-0.54)
Constant	0.169***	-0.077***	0.071**	0.138***	0.027
	(8.34)	(-3.48)	(2.59)	(6.93)	(1.05)
N. Obs.	4,721	4,721	4,721	4,202	4,202
R-sq	0.15	0.14	0.15	0.13	0.14

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

In order to reduce potential multicollinearity biases, in Columns 5-6-7 of Table 10 we have replaced the variable associated to sector-based energy efficiency performance with the interaction terms, instead of adding the interaction term to the already existing direct effect of energy efficiency performance. Whatever formulation we adopt, it is worth noting that the coefficient value for the interaction term is positive, and statistically robust. Although its relative magnitude is low, we can affirm that if the same sector in two distinguished countries obtains the same energy efficiency performance over time, the employment performance gain is higher for the sector located in the country with the higher energy tax bundle.

This result provides us with a first indication of the importance of designing a policy mix which is coherent and vertically integrated, involving the sector as well as the national levels in order to amplify the potential positive effects.

We can explain this result by considering that efficiency gains at the sector level might bring to an increase in the productivity performance of the production process, thus reducing the input intensity also for the labour input. However, at the same time, if these efficiency gains are obtained in a country where the energy bill is an important share of the total production costs, the resulting energy cost saving might have an expansionary effect on the level of economic activities at the sectoral level, which can be associated with an increase in labour demanded as input. This result is confirmed and partly reinforced for the smallest sub-samples of selected industries (Tables 11 and 12).

Furthermore, by considering the sub-sample of manufacturing sectors in the EU15 (Table 12), it is also possible to capture the effects played by sector-based environmental and energy policies, thus allowing to detect further policy impacts on employment performance. As a general comment, it is worth mentioning that all results already commented for the other variables remain unchanged, meaning that the robustness of the estimations is not biased by the introduction of these additional variables.

By looking at the additional policy variable representing sector-based environmental policies interacted with country-based energy efficiency policies (Table 13), the coefficient is statistically robust and the sign is negative according to the coefficients for the energy efficiency gains at the sector level. This allows us considering that, ceteris paribus, those manufacturing sectors facing more stringent environmental/energy policies have a relatively lower capacity to increase the employment level (Columns 1-2-3-4).

Table 10- Impact on Total Employment changes over year (EU15 Total Economy, 1995-2009)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dt of value added	0.120***	0.099***	0.120***	0.119***	0.111***	0.112***	0.111***
	(11.89)	(10.85)	(11.94)	(11.87)	(11.51)	(11.60)	(11.59)
Dt of capital stock	0.135***	0.139***	0.136***	0.134***	0.135***	0.133***	0.134***
	(5.93)	(6.09)	(5.99)	(5.92)	(5.92)	(5.84)	(5.90)
Dt of patent stock	0.025*	0.026*	0.025*	0.025*	0.024*	0.025*	0.024*
	(2.36)	(2.43)	(2.33)	(2.39)	(2.26)	(2.31)	(2.29)
Dt of EE sect-based	-0.078***		-0.077***	-0.078***			
	(-4.90)		(-4.91)	(-4.89)			
Dt of EE in the Pub. Sec.		0.077**	0.077**		0.069*		0.068*
		(2.75)	(2.76)		(2.48)		(2.45)
Pol. stock in EE country-based				0.005		0.007*	0.007*
				(1.61)		(2.25)	(2.22)
Int. of EE ch. sect-based with energy tax bundle					0.036***	0.039***	0.037***
					(3.77)	(4.24)	(4.06)
Constant	0.102***	-0.009	0.048*	0.093***	0.027	0.067***	0.017
	(7.19)	(-0.40)	(1.98)	(5.99)	(1.17)	(5.33)	(0.73)
N. Obs.	3,338	3,338	3,338	3,338	3,338	3,338	3,338
R-sq	0.10	0.09	0.10	0.10	0.10	0.10	0.10

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

Table 11 – Impact on Total Employment changes over year (EU15 Manufacturing Sector, Electricity and Gas, Constructions, 1995-2009)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dt of value added	0.122***	0.101***	0.122***	0.122***	0.114***	0.115***	0.115***
	(11.44)	(10.41)	(11.48)	(11.43)	(11.20)	(11.31)	(11.29)
Dt of capital stock	0.135***	0.139***	0.136***	0.135***	0.134***	0.132***	0.133***
	(5.72)	(5.87)	(5.77)	(5.71)	(5.68)	(5.60)	(5.65)
Dt of patent stock	0.026*	0.027*	0.026*	0.026*	0.025*	0.025*	0.025*
	(2.34)	(2.41)	(2.32)	(2.37)	(2.23)	(2.27)	(2.26)
Dt of EE sect-based	-0.081***		-0.080***	-0.081***			
	(-4.78)		(-4.76)	(-4.78)			
Dt of EE in the Pub. Sect.		0.083**	0.082**		0.073*		0.072*
		(2.75)	(2.72)		(2.43)		(2.40)
Pol. stock in EE country-based				0.005		0.008*	0.007*
				(1.48)		(2.17)	(2.13)
Int. of EE ch. sect-based with energy tax bundle					0.040***	0.043***	0.042***
					(4.12)	(4.61)	(4.41)
Constant	0.106***	-0.012	0.047	0.096***	0.031	0.074***	0.021
	(6.90)	(-0.54)	(1.80)	(5.79)	(1.22)	(5.41)	(0.81)
N. Obs.	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-sq	0.11	0.10	0.11	0.11	0.11	0.11	0.11

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

On the contrary, and in line with the results obtained for the first interaction term discussed in Tables 10-11-12, the interaction between the sector-based environmental/energy policy stringency and the country-based energy tax bundle produces a positive impulse to employment levels (Columns 5-6-7)

Table 12 – Impact on Total Employment changes over year (EU15 Manufacturing Sectors, 1995-2009)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dt of value added	0.129***	0.107***	0.130***	0.129***	0.121***	0.123***	0.123***
	(11.33)	(10.32)	(11.36)	(11.33)	(11.10)	(11.24)	(11.22)
Dt of capital stock	0.124***	0.128***	0.126***	0.124***	0.123***	0.120***	0.122***
	(4.95)	(5.08)	(5.01)	(4.94)	(4.88)	(4.78)	(4.84)
Dt of patent stock	0.027*	0.028*	0.027*	0.028*	0.026*	0.026*	0.026*
	(2.29)	(2.35)	(2.26)	(2.32)	(2.18)	(2.22)	(2.21)
Dt of EE sect-based	-0.085***		-0.084***	-0.085***			
	(-4.69)		(-4.67)	(-4.68)			
Dt of EE in the Pub. Sec.		0.093**	0.092**		0.083*		0.081*
		(2.77)	(2.74)		(2.46)		(2.42)
Pol. stock in EE country-based						0.011**	0.011**
						(2.86)	(2.82)
Int. of EE ch. sect-based with energy tax bundle					0.043***	0.047***	0.045***
					(4.05)	(4.59)	(4.39)
Constant	0.119***	-0.011	0.054	0.106***	0.037	0.083***	0.023
	(7.05)	(-0.41)	(1.84)	(5.76)	(1.29)	(5.45)	(0.81)
N. Obs.	2,590	2,590	2,590	2,590	2,590	2,590	2,590
R-sq	0.11	0.11	0.12	0.12	0.11	0.11	0.12

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

Table 13- Impact on Total Employment changes over year (EU15 Manufacturing Sector - sector-based policies, 1995-2009)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dt of value added	0.130***	0.109***	0.130***	0.122***	0.129***	0.108***	0.130***
	(11.40)	(10.44)	(11.43)	(11.19)	(11.35)	(10.39)	(11.38)
Dt of capital stock	0.126***	0.131***	0.128***	0.125***	0.125***	0.129***	0.126***
	(5.03)	(5.18)	(5.10)	(4.97)	(4.96)	(5.10)	(5.03)
Dt of patent stock	0.028*	0.029*	0.028*	0.027*	0.028*	0.029*	0.028*
	(2.35)	(2.43)	(2.33)	(2.25)	(2.38)	(2.46)	(2.36)
Dt of EE sect-based	-0.085***		-0.083***		-0.085***		-0.083***
	(-4.60)		(-4.57)		(-4.57)		(-4.55)
Dt of EE in the Pub. Sec.		0.097**	0.095**	0.087*		0.094**	0.093**
		(2.87)	(2.83)	(2.56)		(2.80)	(2.77)
Pol. stock in EE sect-based	-0.016**	-0.016**	-0.016**	-0.016**			
	(-2.50)	(-2.64)	(-2.67)	(-2.68)			
Int. of Pol. stock in EE sect-based with energy tax bundle					0.012***	0.012***	0.012***
					(3.40)	(3.39)	(3.38)
Int. of EE ch. sect-based with energy tax bundle				0.043***			
				(3.97)			
Constant	0.118***	-0.013	0.050	0.033	0.118***	-0.010	0.052
	(6.99)	(-0.49)	(1.72)	(1.18)	(7.01)	(-0.40)	(1.79)
N. Obs.	2,587	2,587	2,587	2,587	2,587	2,587	2,587
R-sq	0.12	0.11	0.12	0.12	0.12	0.11	0.12

t statistics in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01

This is a particularly interesting result in the vein of the optimal policy mix design and discussion, since the negative effects on employment levels determined by sector-specific stringency might be turned into positive impulses if a properly designed national policy setting allows discovering and emphasizing those positive dynamics. To this aim, soft instruments, such as voluntary agreements and information campaigns, can play a relevant role.
The general policy implication we can derive is a strong requirement of a coordination between different kind of policies especially if a green growth pattern and an inclusive society should be the final goal of the public policy setting.

4 Conclusions and policy implications

This research report has been structured in two parts. Firstly, we investigated the economic structure of energy efficiency sector and developed a descriptive analysis, aimed at providing a systemic mapping of the entire energy efficiency sector, considering all main issues and concerns. In doing so, the first part of the report describes the methodology used to collect, homogenize and integrate the several data sources included, which enable to systemically describe this complex system. The data coverage includes all economic sectors classified as industry and services, in accordance to the NACE classification, and the public sector. The time coverage goes from 1995 to 2009 and data are collected for all the 27 European Union countries, in order to comprehensively describe the overall European energy efficiency policy approach, given that energy and climate policies are firstly decided by the European Commission, and then adopted at national level. More specifically, selected data (on yearly basis) include the economic output at the sector level, the level of capital investment, the number of person employed, the amount of energy consumed and the propensity to innovate, which is here measured through a methodology that assign each patent presented to the European Patent Office (EPO) to the relevant economic sector.
In addition to the sectoral patent mapping, and using data from the IEA-Energy Efficiency and the IEA-Energy Efficiency in the Building Sector database, we built a database including all public policies and several instruments fostering energy efficiency (market-based, command and control, soft instrument, as voluntary approach to labelling or information and education programmes).
Beyond discrete indexes representing the existence or not of such policies, we also build a complex indicator at the country level defined as “energy tax bundle” that represent the burden of energy taxation with respect to the final energy price, weighted considering final consumption of the different primary energy sources.
Finally, for each country investigated, we build an index to account for the year-by-year increase in the energy efficiency level limited to the public sector that represents an indirect measure of the gains due to the introduction of energy efficiency intervention.
The preliminary descriptive analysis highlighted the existing gap between EU15 and the new entrants countries.
The second part of the work consisted in an econometric analysis designed to identify the main drivers explaining the occupational dynamic, with particular focus on energy efficiency measures. Taking a fixed effect panel estimator, we found several interesting results, which will be briefly summarised below.
Firstly, we found a small negative impact of specific energy efficiency measures on occupation in all the analysed economic sectors. In other words, *ceteris paribus*, in those sectors with the highest energy efficiency increase, the increase in employment level was limited (other than a reduction in occupation, this implies the inability to increase it). This is due to the role of energy inputs within the production structure given that in many economic sectors there is a complementarity rather than a substitutability relationship.
Secondly, the analysis showed the existence of a positive impact of the energy efficiency gains achieved in the public sector on the employment level of other economic sectors. In fact, considering this indicator as a measure of the national policy effort, the reasons of this positive impact is twofold. A first channel is determined by the new demand for labour needed to realise the energy efficiency interventions in the

public sector buildings (e.g., installation of audit system or insulating materials). This is mainly a short/medium term effect that occurs immediately after the implementation of EE public policies.
A second channel behind the increase occupation is based on the reduction in the public sector expenditure in energy consumption and the corresponding reduction in ordinary costs, which makes resources available to limit the fiscal burden or fostering new hiring. This channel represents a medium term effect, since the temporal lag between the time the policy is implemented and the moment when the impact becomes evident is more than one year,.
Moreover, when limiting the attention to the EU15 countries, we were able to present some additional and more specific analysis on the design of policies in terms of energy efficiency and energy taxation.
First, *ceteris paribus*, the probability of increasing the occupational levels is larger when energy efficiency promoting policies are in place. The fact that this result is statistically robust only in the EU15 is due to the longer time horizon since energy efficiency policies have been implemented in these countries and, therefore, the impact on employment - which usually is apparent in the medium rather in the short run - is stronger.
Second, the interaction between the sectoral energy efficiency gains and the burden of energy taxation at the national level has also to be noted. Considering a given increase in sectoral energy efficiency, those sectors located in countries characterised by high energy taxation show larger occupation increases than the corresponding sectors in countries where the burden of energy taxation is lower. This can be explained as follows: despite the complementarity between energy and other production inputs, the efficiency gain achieved allows to save financial resources (which is both more feasible and relevant where the cost of energy is particularly high) that can be re-invested to favour production increases, which will also have a positive effect on national occupation.
Thus, considering both the descriptive and econometric analysis, this report showed that increasing the energy efficiency at the national level can foster also gains in terms of occupation, with a medium-term horizon and excluding effects merely due to short-run fluctuations.

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6 Short biography

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Professore Associato in Politica Economica presso il Dipartimento di Economia dell'Università degli Studi Roma Tre. Precedentemente è stata Ricercatrice presso l'ENEA. Laureata in Economia presso l'Università di Roma La Sapienza, ha conseguito il Dottorato di Ricerca in Economia dell'Ambiente e dello Sviluppo presso dell'Università degli Studi Roma Tre.
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I principali interessi di ricerca riguardano l'economia e le politiche pubbliche per l'innovazione e la ricerca. Attualmente le sue attività di ricerca riguardano l'analisi della persistenza nell'innovazione, l'analisi di impatto dei sussidi pubblici alla R&S e lo studio delle determinanti e degli effetti delle innovazioni in campo ambientale ed energetico.

Elena Paglialunga
Assegnista di ricerca presso il Dipartimento di Economia dell'Università degli Studi Roma Tre. Dopo la laurea triennale in Economia presso La Sapienza Università di Roma e la laurea magistrale in Economia dell'Ambiente e dello Sviluppo presso l'Università degli Studi Roma Tre ha conseguito il Dottorato in Economia dell'Ambiente e dello Sviluppo presso il Dipartimento di Economia dell'Università degli Studi Roma Tre.
I principali interessi di ricerca riguardano l'economia ambientale con particolare attenzione all'economia dell'energia e del cambiamento climatico, il ruolo dell'innovazione e delle politiche pubbliche in ambito ambientale e lo studio di modelli applicati per l'analisi del cambiamento climatico.

Alessandro Palma
Collabora presso lo IEFE Università Bocconi in qualità di esperto di innovazione in efficienza energetica. Precedentemente è stato assegnista di ricerca presso il Dipartimento di Economia dell'Università degli Studi Roma Tre. Ha collaborato con numerosi istituti di ricerca nazionali e internazionali tra cui INEA, BC3, ETH e FAO.
Dopo la laurea magistrale in Economia dell'Ambiente e dello Sviluppo presso l'Università degli Studi Roma Tre ha conseguito il Dottorato in Economia dell'Ambiente e dello Sviluppo presso lo stesso dipartimento.
I principali interessi di ricerca riguardano l'economia ambientale e dell'energia con particolare attenzione alle dinamiche di innovazione nel settore dell'efficienza energetica.

7 Appendix

Table A1 - ISIC 2-digit codes and descriptions used in the dataset

Number #	ISIC Code	Description
1	1	Agriculture, hunting and related service activities
2	2	Forestry, logging and related service activities
3	5	Fishing, aquaculture and service activities incidental to fishing
4	10	Mining of coal and lignite; extraction of peat
5	11	Extraction of crude petroleum and natural gas (excluding surveying)
6	12	Mining of uranium and thorium ores
7	13	Mining of metal ores
8	14	Other mining and quarrying
9	15	Manufacture of food products and beverages
10	16	Manufacture of tobacco products
11	17	Manufacture of textiles
12	18	Manufacture of wearing apparel; dressing and dyeing of fur
13	19	Tanning and dressing of leather; manufacture of luggage, etc.
14	20	Manufacture of wood and of products of wood and cork, except furniture
15	21	Manufacture of paper and paper products
16	22	Publishing, printing and reproduction of recorded media
17	23	Manufacture of coke, refined petroleum products and nuclear fuel
18	24	Manufacture of chemicals and chemical products
19	25	Manufacture of rubber and plastics products
20	26	Manufacture of other non-metallic mineral products
21	27	Manufacture of basic metals
22	28	Manufacture of fabricated metal products, except machinery and equipment
23	29	Manufacture of machinery and equipment n.e.c.
24	30	Manufacture of office, accounting and computing machinery
25	31	Manufacture of electrical machinery and apparatus n.e.c.
26	32	Manufacture of radio, television and communication equipment and apparatus
27	33	Manufacture of medical, precision and optical instruments, watches and clocks
28	34	Manufacture of motor vehicles, trailers and semi-trailers
29	35	Manufacture of other transport equipment
30	36	Manufacture of furniture; manufacturing n.e.c.
31	37	Recycling
32	40	Electricity, gas, steam and hot water supply
33	41	Collection, purification and distribution of water
34	45	Construction

Table A2 - ISCO 1-digit codes and descriptions used in the dataset.

The ISCO-08 classification	
Code	Description
1	Managers
2	Professionals
3	Technicians and associate professionals
4	Clerical support workers
5	Service and sales workers
6	Skilled agricultural, forestry and fishery workers
7	Craft and related trades workers
8	Plant and machine operators, and assemblers
9	Elementary occupations
10	Armed forces occupations

Table A3 - 44x44 concordance matrix by Schmocht et al. (2003).

Field	IPC	Field	IPC	Field	IPC	Field	IPC	Field	IPC	Field	IPC
1	A01H	10	B09B	15	C06B	19	H01B	21	F16C	24	B23C
1	A21D	10	B09C	15	C06C	20	A01L	21	F16D	24	B23D
1	A23B	10	B29B	15	C06D	20	A44B	21	F16F	24	B23G
1	A23C	10	C01B	15	C08H	20	A47H	21	F16H	24	B23H
1	A23D	10	C01C	15	C09G	20	A47K	21	F16K	24	B23K
1	A23F	10	C01D	15	C09H	20	B21K	21	F16M	24	B23P
1	A23G	10	C01F	15	C09J	20	B21L	21	F23R	24	B23Q
1	A23J	10	C01G	15	C10M	20	B22F	22	A62C	24	B24B
1	A23K	10	C02F	15	C11B	20	B25B	22	B01D	24	B24C
1	A23L	10	C05B	15	C11C	20	B25C	22	B04C	24	B25D
1	A23P	10	C05C	15	C14C	20	B25F	22	B05B	24	B25J
1	C12C	10	C05D	15	C23F	20	B25G	22	B61B	24	B26F
1	C12F	10	C05F	15	C23G	20	B25H	22	B65G	24	B27B
1	C12G	10	C05G	15	D01C	20	B26B	22	B66B	24	B27C
1	C12H	10	C07B	15	F42B	20	B27G	22	B66C	24	B27F
1	C12J	10	C07C	15	F42D	20	B44C	22	B66D	24	B27J
1	C13F	10	C07F	15	G03C	20	B65F	22	B66F	24	B28D
1	C13J	10	C07G	16	D01F	20	B82B	22	C10F	24	B30B
1	C13K	10	C08B	17	A45C	20	C23D	22	C12L	24	E21C
2	A24B	10	C08C	17	B29C	20	C25D	22	F16G	25	A21C
2	A24D	10	C08F	17	B29D	20	E01D	22	F22D	25	A22B
2	A24F	10	C08G	17	B60C	20	E01F	22	F23B	25	A22C
3	D04D	10	C08J	17	B65D	20	E02C	22	F23C	25	A23N
3	D04G	10	C08K	17	B67D	20	E03B	22	F23D	25	A24C
3	D04H	10	C08L	17	E02B	20	E03C	22	F23G	25	A41H
3	D06C	10	C09B	17	F16L	20	E03D	22	F23H	25	A42C
3	D06J	10	C09C	17	H02G	20	E05B	22	F23J	25	A43D
3	D06M	10	C09D	18	B24D	20	E05C	22	F23K	25	B01F
3	D06N	10	C09K	18	B28B	20	E05D	22	F23L	25	B02B
3	D06P	10	C10B	18	B28C	20	E05F	22	F23M	25	B02C
3	D06Q	10	C10C	18	B32B	20	E05G	22	F24F	25	B03B
4	A41B	10	C10H	18	C03B	20	E06B	22	F24H	25	B03C
4	A41C	10	C10J	18	C03C	20	F01K	22	F25B	25	B03D
4	A41D	10	C10K	18	C04B	20	F15D	22	F27B	25	B05C
4	A41F	10	C12S	18	E04B	20	F16B	22	F28B	25	B05D
5	A43B	10	C25B	18	E04C	20	F16P	22	F28C	25	B06B
5	A43C	10	F17C	18	E04D	20	F16S	22	F28D	25	B07B
5	B68B	10	F17D	18	E04F	20	F16T	22	F28F	25	B07C
5	B68C	10	F25J	18	G21B	20	F17B	22	F28G	25	B08B
6	B27D	10	G21F	19	B21C	20	F22B	22	G01G	25	B21B
6	B27H	11	A01N	19	B21G	20	F22G	22	H05F	25	B22C
6	B27M	12	B27K	19	B22D	20	F24J	23	A01B	25	B26D
6	B27N	13	A61K	19	C21B	20	G21H	23	A01C	25	B31B
6	E04G	13	A61P	19	C21C	21	B23F	23	A01D	25	B31C
7	B41M	13	C07D	19	C21D	21	F01B	23	A01F	25	B31D
7	B42D	13	C07H	19	C22B	21	F01C	23	A01G	25	B31F
7	B42F	13	C07J	19	C22C	21	F01D	23	A01J	25	B41B
7	B44F	13	C07K	19	C22F	21	F03B	23	A01K	25	B41C
7	D21C	13	C12N	19	C25C	21	F03C	23	A01M	25	B41D
7	D21H	13	C12P	19	C25F	21	F03D	23	B27L	25	B41F
7	D21J	13	C12Q	19	C30B	21	F03G	24	B21D	25	B41G
9	C10G	14	C09F	19	D07B	21	F04B	24	B21F	25	B41L
9	C10L	14	C11D	19	E03F	21	F04C	24	B21H	25	B41N
9	G01V	14	D06L	19	E04H	21	F04D	24	B21J	25	B42B
10	B01J	15	A62D	19	F27D	21	F15B	24	B23B	25	B42C

Field	IPC	Field	IPC	Field	IPC	Field	IPC	Field	IPC	Field	IPC
25	B44B	27	A45D	33	B60M	37	A61M	42	F01N	44	A63F
25	B65B	27	A47G	33	B61L	37	A61N	42	F01P	44	A63G
25	B65C	27	A47J	33	F21P	37	A62B	42	F02B	44	A63H
25	B65H	27	A47L	33	F21Q	37	B01L	42	F02D	44	A63J
25	B67B	27	B01B	33	G08B	37	B04B	42	F02F	44	A63K
25	B67C	27	D06F	33	G08G	37	C12M	42	F02G	44	B43K
25	B68F	27	E06C	33	G10K	37	G01T	42	F02M	44	B43L
25	C13C	27	F23N	33	G21C	37	G21G	42	F02N	44	B44D
25	C13D	27	F24B	33	G21D	37	G21K	42	F02P	44	B62B
25	C13G	27	F24C	33	H01T	37	H05G	42	F16J	44	B68G
25	C13H	27	F24D	33	H02H	38	F15C	42	G01P	44	C06F
25	C14B	27	F25C	33	H02M	38	G01B	42	G05D	44	F23Q
25	C23C	27	F25D	33	H05C	38	G01C	42	G05G	44	G10B
25	D01B	27	H05B	34	B81B	38	G01D	43	B60F	44	G10C
25	D01D	28	B41J	34	B81C	38	G01F	43	B60V	44	G10D
25	D01G	28	B41K	34	G11C	38	G01H	43	B61C	44	G10F
25	D01H	28	B43M	34	H01C	38	G01J	43	B61D	44	G10G
25	D02G	28	G02F	34	H01F	38	G01M	43	B61F	44	G10H
25	D02H	28	G03G	34	H01G	38	G01N	43	B61G		
25	D02J	28	G05F	34	H01J	38	G01R	43	B61H		
25	D03C	28	G06C	34	H01L	38	G01S	43	B61J		
25	D03D	28	G06D	35	G09B	38	G01W	43	B61K		
25	D03J	28	G06E	35	G09C	38	G12B	43	B62C		
25	D04B	28	G06F	35	H01P	39	G01K	43	B62H		
25	D04C	28	G06G	35	H01Q	39	G01L	43	B62J		
25	D05B	28	G06J	35	H01S	39	G05B	43	B62K		
25	D05C	28	G06K	35	H02J	39	G08C	43	B62L		
25	D06B	28	G06M	35	H03B	40	G02B	43	B62M		
25	D06G	28	G06N	35	H03C	40	G02C	43	B63B		
25	D06H	28	G06T	35	H03D	40	G03B	43	B63C		
25	D21B	28	G07B	35	H03F	40	G03D	43	B63H		
25	D21D	28	G07C	35	H03G	40	G03F	43	B63J		
25	D21F	28	G07D	35	H03H	40	G09F	43	B64B		
25	D21G	28	G07F	35	H03M	41	G04B	43	B64C		
25	E01C	28	G07G	35	H04B	41	G04C	43	B64D		
25	E02D	28	G09D	35	H04J	41	G04D	43	B64F		
25	E02F	28	G09G	35	H04K	41	G04F	43	B64G		
25	E21B	28	G10L	35	H04L	41	G04G	43	E01B		
25	E21D	28	G11B	35	H04M	42	B60B	43	F02C		
25	E21F	28	H03K	35	H04Q	42	B60D	43	F02K		
25	F04F	28	H03L	35	H05K	42	B60G	43	F03H		
25	F16N	29	H02K	36	G03H	42	B60H	44	A41G		
25	F26B	29	H02N	36	H03J	42	B60J	44	A42B		
25	H05H	29	H02P	36	H04H	42	B60K	44	A44C		
26	B63G	30	H01H	36	H04N	42	B60L	44	A45B		
26	F41A	30	H01R	36	H04R	42	B60N	44	A45F		
26	F41B	30	H02B	36	H04S	42	B60P	44	A46B		
26	F41C	31	H01M	37	A61B	42	B60Q	44	A46D		
26	F41F	32	F21H	37	A61C	42	B60R	44	A47B		
26	F41G	32	F21K	37	A61D	42	B60S	44	A47C		
26	F41H	32	F21L	37	A61F	42	B60T	44	A47D		
26	F41J	32	F21M	37	A61G	42	B62D	44	A47F		
26	F42C	32	F21S	37	A61H	42	E01H	44	A63B		
26	G21J	32	F21V	37	A61J	42	F01L	44	A63C		
27	A21B	32	H01K	37	A61L	42	F01M	44	A63D		

Source: Schmocht et al. (2003), pp. 67-68.

Table A4 - List of 44 NACE codes used by Schmocht et al. (2003)

Field no	NACE	Description
1	15	Food, beverages
2	16	Tobacco products
3	17	Textiles
4	18	Wearing apparel
5	19	Leather articles
6	20	Wood products
7	21	Paper
8	22	Publishing, printing
9	23	Petroleum products, nuclear fuel
10	24.1	Basic chemical
11	24.2	Pesticides, agro-chemical products
12	24.3	Paints, varnishes
13	24.4	Pharmaceuticals
14	24.5	Soaps, detergents, toilet preparations
15	24.6	Other chemicals
16	24.7	Man-made fibres
17	25	Rubber and plastics products
18	26	Non-metallic mineral products
19	27	Basic metals
20	28	Fabricated metal products
21	29.1	Energy machinery
22	29.2	Non-specific purpose machinery
23	29.3	Agricultural and forestry machinery
24	29.4	Machine-tools
25	29.5	Special purpose machinery
26	29.6	Weapons and ammunition
27	29.7	Domestic appliances
28	30	Office machinery and computers
29	31.1	Electric motors, generators, transformers
30	31.2, 31.3	Electric distribution, control, wire, cable
31	31.4	Accumulators, battery
32	31.5	Lightening equipment
33	31.6	Other electrical equipment
34	32.1	Electronic components
35	32.2	Signal transmission, telecommunications
36	32.3	Television and radio receivers, audiovisual electronics
37	33.1	Medical equipment
38	33.2	Measuring instruments
39	33.3	Industrial process control equipment
40	33.4	Optical instruments
41	33.5	Watches, clocks
42	34	Motor vehicles
43	35	Other transport equipment
44	36	Furniture, consumer goods

Source: Schmocht et al. (2003), pp. 63.