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Autor/es: M.Teresa Sanchis Llopis

Filiación/es académica/s: Universidad de Valencia

Dirección electrónica de contacto: m.teresa.sanchis@uv.es

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Spillovers from electricity in the Spanish most progressive decade, 1958-1970

Spain, 1958-1970

M. Teresa Sanchis Llopis
University of Valencia and
Figuerola Institute of History and Social Sciences
e-mail: m.teresa.sanchis@uv.es

Abstract

Following the growth accounting approach introduced by Oliner and Sichel (2000) for the General Purpose Technologies, this paper analyzes the impact of electricity in Spanish economic growth in 1958-1970. Spain represent the case of a follower country that could display the benefits of electricity only some decades later that it was introduced in the country and four decades later than it had its biggest impact in the U.S. The analytical framework has been modified to distinguish between two spillover effects: one derived from the consumption of electrical utilities, the other derived from the electrical capital deepening. The results obtained confirm that electricity played a significant role in Spain through the three channels identified in the literature for quantifying the contribution of a GPT. The impact is higher than that estimated for other follower countries in 1920's, but lower than the estimated impact for the U.S in the 1920's.

Keywords: Electricity, GPT, Growth Accounting, Spain

1. Introduction

A GPT is defined as a "technology that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many Hicksian and technological complementarities" (Lipsey, 1998). The way this kind of technologies develop and disseminate their effects over the economy will affect the pace at which the growth process evolves. It is a well-established fact in the literature on growth accounting that their impact on overall productivity growth used to be negligible at its starting and that the whole realization of its potential could be delayed several decades. Steam, electricity and information and communications technology (ICT) are considered the most common examples of this kind of technologies.

As much as the dissemination of the beneficial effects of the new technologies on the pioneering countries takes a long time to be realized, even more it could be the case in the follower countries. If technological change is considered not to be exogenous, but an endogenous response to the economic conditions of the innovator country[1], it could be difficult for the follower countries to catch-up with the technology of the leader, because it has been invented to cope its specific requirements. Nowadays there is a concern about the lower impact that the ICT technologies are having in Europe compared to the big impact they have just reached in the U.S.[2] The follower countries has to deal with institutional and economic policy changes in order to remove the obstacles to develop the new technologies, but even done, there seems to be no guarantee that the follower countries could take advantage of the new technologies with the same scope they have been in the leader country.

[1] This is an idea very present in Economic History that was introduced by Gerchenkron (1962). Habakkuk (1962) also makes reference to the importance of factor endowments in explaining the U.S. economy growth. Acemoglu and Zilibotti (2001) insist in the idea of how technological change is guided by the needs of the innovative country.

[2] The acceleration in American productivity growth since 1995 is explained by the increasing use of ICT equipment (Oliner and Sichel, 2000; Jorgenson and Stiroh, 2001). For Europe, Timmer, Ypma and van Ark (2003).

This paper analyzes the case of Spain, a follower country that could take a great advantage of the use of electricity only some decades later that it was introduced in the country and four decades later than its biggest impact in the U.S. The period analyzed is 1958-1970. One question that could immediately arise to the readers is what contribution could make this particular exploration to the discussion about electricity when it seems to be located out of the period taking in the literature to analyze the role of electrification in economic growth.

As it had happened in the U.S. in the 1920s, the 1950s and 1960s represent for Spain its "most progressive era". It was the moment to seize the opportunity to incorporate and develop the technologies of the Second Industrial Revolution. It is for this reason that it makes sense to calculate the contribution of electrification to Spanish economic growth some decades later of the introduction of this new source of energy and some decades later than it has been usually estimated for the U.S and other European countries. It is also a common fact in the literature about the Golden Age in Europe to assume that during those decades the European countries caught-up with the U.S. by assimilating and developing the technologies developed in this leader country in the interwar period. Although it was not the case of electricity, it was the case for other industries that after the IIWW could use a more efficiently produced and distributed electricity and to take full advantages of the challenges related with their specific technologies.

As in other European countries, the introduction of electricity in Spain took place relatively soon, in the last decades of the XIXth century. Its diffusion throughout the exiguous industrial sector was relatively rapid. Before the Civil War, most of Horse Power used in the exiguous manufacturing sector was generated by electricity. The reason is that electricity let to remove one of the main obstacles for their industrialization, such it was the shortage of coal to produce steam power. However the early birth of electricity in Spain, the Spanish economy was not mature enough to take full advantage of the incremental innovations in other industries that this new technology could propel. In spite to have enjoyed high rates of GDP growth between1920-1929, industry in 1935 still represented only 20 % of overall GDP. Meanwhile between 1954 and 1975 the share of the industrial sector increased in 15 % points, from 20 to 35 %.

The growth accounting approach is one of the ways followed in the empirical literature to estimate the impact of this kind of technologies. This approach usually considers that the productivity effects coming from a GPT operate through three channels. The first one is the "multifactor productivity" coming directly from the industry or industries producing the new technology. The second is the "capital deepening effect" in the whole economy that consists in the increase of the capital stock by means of investing in capital goods that embody the new technology.

The third is the "spillover effect" that is made up of all those benefits in terms of multifactor productivity that experience the industries by using the new technology. This last effect could act in different manners, such as changes in the organization of the firms, savings in the consumption of intermediate inputs, product and process innovations propelled by the new technology, etc. In this paper we will distinguish between two kinds of spillover effects: one is similar to that estimated by the below referenced papers, and the other one operates through the savings in the consumption of electricity by unit of output.

This growth accounting framework has been applied by Crafts (2004) to study the impact of steam power in British economic growth during the Industrial Revolution. According with his estimations, steam has its biggest impact on productivity growth in the second half of the XIXth century, in the decades of railways and steamships development. Given the relevance of steam power in British Industrial Revolution, its estimated impact on output and productivity growth was quite modest, it hardly represented 17% of GDP growth in the peak years of 1870-1900. This figure represents a low bound estimation since no TFP spillovers have been added.

The same exercise has been applied by Oliner and Sichel (2000) to ICTs in the U.S. economy since 1974-2000, the peak contribution was achieved in 1996-2000 when alone the impact of ICTs added 2.43 percentage points of U.S. GDP, representing nearly 58 % of total GDP growth. This estimation is also a low bound figure because these authors do not report any estimate of TFP spillovers from ICTs. Jalava and Pohjola (2008) realize a similar exercise for Finland in 1990-2004 and find that the contribution of ICTs to GDP growth was 77%, and that most of the contribution came from multifactor productivity in the ICTs sector (42.6 %), followed by spillovers from this sector to the rest of the economy (36.8 %) and capital deepening (20 %). These results outline the importance that diverse authors have conceded to the GPTs to explain the long run sources of economic growth and even, when the “spillover effects” can be retrieved, it is possible to appreciate its significance for the GPTs displaying its full potential.

With regard to electricity results are less conclusive. Jalava and Pohjola (2008) find that the contribution of electricity to Finnish GDP growth was quite weak in 1920-1938, only of 11 %, and that the spillover effects were insignificant in those years. Meanwhile Crafts (2002) estimated that the impact of electricity in the U.S. economic growth in the same decade, 1919-1929, was high and around 70 % of the same came from the spillover effects.

The results obtained in this research confirm that electricity played a significant role in the period in which industrialization in Spain made a great leap forward. The impact of electricity worked favorably through the three channels identified in the literature for quantifying the contribution of a GPT. And although the general contribution of electricity to GDP growth (25%) was quite modest compared with the recent estimation for the ICTs contribution on the U.S. or in Finland, it is higher than the other impacts estimated for electricity impact and leaves room for the spillover effects to work.

The rest of the paper is organized as follows. Section 2 presents a descriptive description of the transformation of the Spanish economy in 1958-1970. In section 3 describes the changes operated in the functioning of the electrical sector after the Civil War that let to increase the installed capacity and the efficiency of the sector. Section 4 presents the analytical framework, with the specification of the two kinds of spillover effects, and the discussion of the main results. Section 5 collects the conclusions. Meanwhile the details about the process of data construction are described in Appendix 1.

2. Output and productivity growth in 1950-1975 from a historical perspective

According to the computations of long run sources of output growth by Prados de la Escosura and Rosés (2009), in 1952-1974 output and productivity grew at 6.38% and 3.83%, respectively, which implies that around 61 % per cent of output growth came from TFP. This historical break in productivity growth during the third quarter of the century was heavily though not exclusively concentrated in the manufacturing sector. Sectoral productivity growth estimates for the period 1958-1975 reveals that manufacturing made a contribution approximately of 75% to global TFP growth and transportation, communications and public utilities (electricity, gas, water and other energies) a contribution of 24.65%. Other positive contribution came from agriculture, which alone accounted for 11.5% due to its still high share in Value Added (21 %), despite its relatively low productivity growth. Meanwhile, a significant part of overall productivity growth was offset by the negative contribution of construction and some branches of the services sector (-13%).

Having in mind these results, our analysis proceeded to ask whether there were common forces at work that propelled the economy beyond the specific technological change of any particular industry and help to understand the broadly based productivity surge in 1958-1975. Sanchis (2006)[3] shows that for 1958-1975, the five industries that recorded the largest increases in productivity were responsible for half of total productivity growth in spite of they only represented 15% of total Value Added. The group of leading industries included "the machinery and equipment industry", "electricity, gas and water", "transport equipment" and "the rubber and plastics industry". We can therefore consider that technological change was linked to the use of electrical machinery and appliances, to the motor vehicle and other related industries and to new communications (telephone and television)[4]. The image that could emerge from these results would be that of a "mushroom process" between industries, in which the opportunities for particular industries to experience rapid TFP growth depended on their technological deficit with regards to the most advanced countries in embodying the most relevant technologies of the Second Industrial Revolution[5]. Despite the high

[3] Sanchis (2006) exploits sectoral growth accounting methodology in a similar way to Jorgenson, Gollop and Fraumeni (1987) in order to measure the contribution of intermediate inputs, capital, labour and productivity to the increase in total output for 25 productive branches.

[4] During the 1960s, several sectors were simultaneously leading the Spanish "catching-up" process. Spain incorporated some of the technologies of the Second Industrial Revolution that have been developed in the leading country the United States since the beginning of the XX[th] century.

[5] Harberger (1998) made this analogy for describing the economic growth process: “yeast-like” process against “mushroom” process. A “yeast process” means that the productivity growth expands uniformly under a common fermenting agency, whereas a “mushroom process” reflects efficiency improvements or

concentration of the transformation, one can still observe that 77% of total Value Added industries experienced positive productivity increases.

In Figure 1 the degree of concentration of productivity growth for total output is represented against the concentration in Value Added in a way similar to a Lorenz curve. The cumulative sum of total Value Added has been represented on the x-axis and the cumulative sum of productivity growth on the y-axis. The first vertical line marks the point where the rising curve crosses 100% on the vertical axis. This can be interpreted in the following way: productivity growth in around 50% of industries (measured by their share in Value Added) was equal to the productivity increase for the economy as a whole[6]. In addition, there are other industries producing a further 22 % of total Value Added whom positive contribution to productivity is offset by yet another 28% of industries with negative productivity growth. The second vertical line marks the maximum point of the curve. In this case, about 72% of industries enjoyed positive productivity increases during 1958-1975, meanwhile the remaining 28% recorded negative productivity growth. The negative contribution came from "hotels and restaurants", "railroad transport" and "construction"[7]. The picture that emerges is a "sun-rise" diagram, following the analogy of Harberger (1998), which reveals an economy experiencing a phase of general productivity growth and modernization.

In Figure 2 we have plotted only the industrial branches and excluded agriculture and services. The more plain slope of the Lorenz-type curve makes the contrast between the "pro-mushroom" findings for the economy as a whole (Figure 1) and the "pro-yeast" for

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innovations stemming from different causes that used to be highly localized and idiosyncratic to particular industries and even to individual firms.

[6] It's interesting to comment that from the point in the graph that represents 46% of total Value Added and accumulated TFP growth of 4.18 to next point which represent 67% of VA and 4.70 of accumulated TFP we find the agriculture sector which alone still represented 21% of total VA. This means that it is difficult to stablished exactly in wich point the horizontal line cross the curve, but we estimated that it is approximately around 50% Value Added.

[7] It is difficult to accept that "construction" lost out during the years of rapid growth. This may be due to certain difficulties to measure Value Added in this activity.

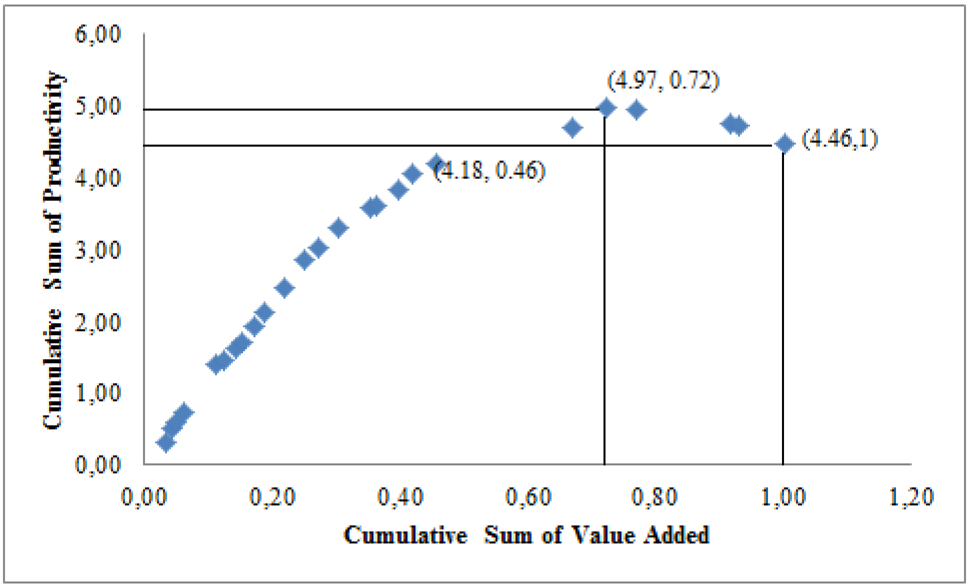
the industrial sector alone (Figure 2) immediately apparent. In contrast with Figure 1, in this diagram all the industrial branches experience a positive productivity growth in 1958-1975. Evidently the industrial productivity surge could reflect broad, generic developments impinging widely upon all manufacturing activities.

What is striking in this period of technological progress is its broad base, both within and outside manufacturing. Technologies just developed in the most advanced countries in electric utilities, chemicals, communications, electrical machinery and transport widespread during this period in Spain. If anything characterizes the advances in all these sectors is their interrelation, as shown by Field (2003, 2004) for the 1920's and 1930's in the U.S. There is no shortage of examples, such as the interconnection between large scale car fabrication, road building, the new layout and asphalt of cities and the development of increasingly cheap rubber and oil refining industries. Another interesting example is the increasingly widespread use of assembly lines using electricity in factories with the expansion of "machinery and equipment industries", which are at the same time, related to large scale electricity generation and supply and the new corporate organisation techniques.

Among this wide set of interconnections between the technologies of the Second Industrial Revolution, electricity and their externatilities over other industries is one of the most outstanding examples, particularly in Spain where the increased flow of electricity let to overcome one of the main obstacles to the Spanish economy development, its traditional shortage of energy. In Spain the big push for industrialization since the middle of the fifties until the first oil shock was hand by hand

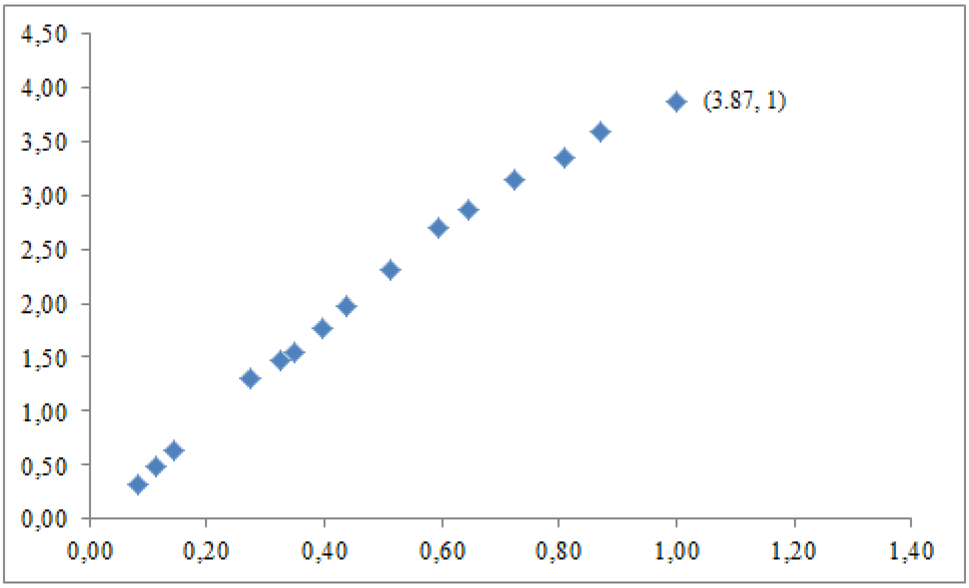
Figure 1

Harberger-type diagram for Total Output, 1958-1975
(Cum. % Productivity Growth vs. Cum. % VA)



SOURCE: Industry productivity calculations in Sanchis (2006).

Figure 2
Harberger-type diagram for Manufacturing Industries, 1958-1975
(Cum. % Productivity Growth vs. Cum. % VA)



SOURCE: Elaborated from industry productivity computations in Sanchis (2006).

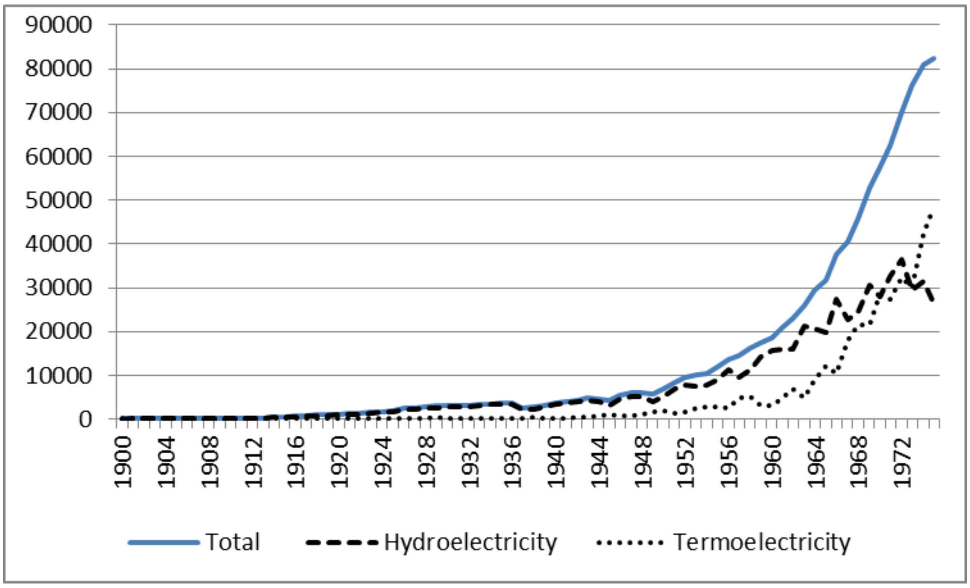
with the expansion of production of electricity at big scale and with the articulation of an integrated network for the delivery of electrical utilities all around the country. The increased supply of electricity at lower real prices let to boom the flow of production in all kind of industries. The conditions of working improved not only for the big plants but even for the small factories and craft mills. It changed the factory design and organization. It made possible the use of better machines and made plant expansion easier. Consequently the electricity using industries were able to benefit of high rates of multifactor productivity growth.

3. The evolution of electricity production

Electrification in Spain started around 1880, at the same time than in other European countries. This process experienced a noticeable advance in the 1920s, with annual growth rates of 10.4 per cent, but it was partly interrupted by the Civil War and the post war years of deep isolation and autarkic economic policy. It was not until the second half of 1940s when it was picked up again with renewed enthusiasm. Since 1945 to 1975 the electricity productive capacity multiplied by a factor of 19, reaching an annual growth rate of 10.5 per cent in 1945-1975 and Spain assisted to the consolidation of electricity as one of the main power sources in the economy.

Before the Civil War (1936-1939) the electrical industry was made up of private firms that were scarcely regulated by the state. At the beginning, there were basically small size firms based on the use of coal, but with the improvements in the long-distance electricity transport, the use of hydroelectricity became more relevant. The establishment of large generating plants through the 1910s and 1920s, which were transporting electrical power over long distances, altered the configuration of the market towards more oligopolistic positions.

Figure 3
Electricity Production (in 1000 kWh)



SOURCE: Carreras (2005), *Estadísticas Históricas de España*.

Gradually, as the large scale firms were increasing their market share, the state started to regulate different aspects related with the delivery of electricity to the consumers. One of them was the establishment of the electrical rates. Electricity rates were fixed by the state in 1919 with the main purpose to protect the consumers against possible abusive practices by the big firms.

The other area where the state tried to regulate was in the development of a unified network for the distribution of electrical utilities. The central dispatching network represented the will of both the state and the private firms. It was the way to improve the efficiency of the overall electrical system and to take full advantage of the production of electrical power at large scale. Both the government and the private producers were aware that a unified network could report advantages in terms of ensuring the delivery of low cost energy to a large number of users. Without connection to a central dispatching office, the particular companies were forced to maintain an excess of capacity in order to deal with demand at rush hours. This fact increased notably their capital costs, reduced their profit rates and discouraged new investment plans. The setting of connections between the different areas and producers and the centralized management of all resources available in the network could facilitate the delivery of electricity anywhere at any moment without maintaining idle resources. As a result, production costs and consumption prices would bring down.

As David (1991) states, the transformation of industrial processes by electric power technology was "a long-delayed and far from automatic process". Its development was not simply a matter of technology, but it also required political and institutional changes to enable supply-side improvements that propelled the final phase of the electrification process. However, the integration and extension of power transmission over expanded territories was part of the overall process of electrification that exceeded the individual interest of any particular private firm (Millward, 2006). And it is in this point where we can find one important factor in the explanation of the protracted delay in electrification in Spain since 1936 to the second half of the 1940s.

The government and the private firms did not reach any agreement about this issue. When the Civil War broke out in 1936, there was not still any project in progress, in spite of the interests for both parts and all the favorable reports.The war interrupted the expansion of a sector that had shown a great advance in terms of output and productivity in the 1920s. In fact, before the Civil War around 80 per cent of the Horse Power used in the industrial sector had been generated by electricity, mainly of hydroelectrical origin. But more specifically, the war interrupted the progress towards the construction of an integrated and unified network that could operate more efficiently.

The electrical industry emerged relatively unscathed from the Civil War. Even so, until 1943 the production elements were sufficient to meet the demands of the market. But from 1943 onwards it was forced to impose frequent shuts off in the supply of electricity[8]. As several authors have shown, in the decade following the Civil War the interruption in the installation of new productive capacity could not be attributed to the shortage of demand, but to a lack of incentives to invest. In fact, demand not only recovered its long term secular trend after the Civil War, but also initiated a new upward trend since the middle of the forties.

The historiography has sought in the economic policy practiced by the new State one of the major causes of these shortages (Sudrià, 1987). The policies of import substitution carried on to reduce energy dependence from abroad forced the use of expensive domestic coal. And moreover, the alignment of Franco with Germany caused the reprisals of the Allies that lead to daily cuts in oil supply. Hence, hidroelectricity became the only source of power free of restrictions and this fact provoked a substitution effect in favor of electricity and against the more expensive uses of domestic coal or rationed petrol.

In spite of the high increase in electricity demand, the supply remained stagnant. Several factors explain the lack of incentives to invest by private firms[9]. One of them is the increase in the real costs of production. Electric companies had to withstand with the low rate prices, fixed by the government at 1933 levels, and the increasing costs of equipment and materials. The government decided to fix the electricity rates at the

[8] The first shuts off due to supply shortages took place in 1944 and they used to be frequent between 1944 and 1950. The worst years were 1945 and 1949, when the deficit was over 20 per cent of demand (Sudrià, 2001).

[9] Sudrià (1990, 1994, 1997) Gómez-Mendoza, Sudrià and Pueyo (2007); Barciela, López, Melgarejo y Miranda (2001), Pueyo (2007).

prewar levels in order not to charge the consumers with excessive costs, meanwhile the costs of equipment and intermediate inputs increased both because of general inflation and rationed inputs markets.

Moreover, the companies that initiated plans to repair or to extent their facilities met with problems arising from the general restrictions imposed by the government over foreign trade or over domestic markets. The imports of equipment and other essential materials were restricted due to the lack of foreign currencies. The low quality of the intermediate products made in Spain adversely affected the efficiency of the power plants. Additionally, there was a hostile attitude of the Franco's government with regards to foreign investment. These restrictions to the imports of intermediate and capital goods relaxed progressively after 1951, and more intensely after 1959 with the Stabilization Plan. Since then the economic policy changed towards a more permissive attitude in favor of trade liberalization (González, 1979; Viñas et al, 1979) and other foreign capital.[10]

Another factor that explains the dramatic fall in the investment in new plants was the conflict between the government and the private firms[11]. The Franco's government did not express any particular interest with regard to the electricity sector until the frequent shuts off of electricity became a problem for its industrialization plans in 1944. Then, the shortage in the provision of electricity was interpreted by the Franco's government as a signal of the inability of the private firms to meet the new demands and hence the state manifested its interest to intervene the sector throughout

[10] One of the main items of the American Aid in 1953 were the imports of electrical material used to repair existing equipment and to build new power stations (Calvo, 2001).

[11] According to Pueyo, J. (2007), documents relative to the INI's foundation (Instituto Nacional de Industria) reveal two positions about how to address the relationship between the INI and the electrical industry. One position considered that the private firms should be submitted to the guidelines of the INI. The other one was more permissive and sought the collaboration between public and private firms. Meanwhile the government did not define totally which would be its position, the collaborative strategy seemed to lose weight. And hence the private firms distrusted the intentions of the government with regards to the sector.

the installation of new public electricity companies and the management of the regime of shuts off. These intentions were considered by the private firms to interfere their own interests and provoked their reluctance to invest unless the conflict was solved. The private firms feared that if they left in public hands the control of the network they would lose the control over their own investments and markets. As a result, in august 1944 they funded a new employer's organization, UNESA, to defend the private management of the sector.

Finally, the state and UNESA arrived to a deal. The private firms asked the government to respect their private interests and then they would accept the entry of public firms in the industry and would commit to manage and develop a unified electrical network. As long as the state was delimiting its own initiatives and it was giving believable guarantees of not interfering in the private interests, the private firms recovered the trust and were more liable to invest.

By means of this agreement, the settlement of new electrical companies by the industrial public holding (INI) was subordinate to the interests of the private initiative. The public sector would build new power stations, fundamentally of thermal origin, because in this area it would not compete with the private initiative (Buesa, 1986)[12]. With regard to the management of the unit of dispatchment, UNESA committed to manage the unified network but following the guidelines issued by the state. It was not until 1953 when really the central dispatching office, RECA, started to work[13]. Its mission was to connect all the producer centers to the network and to redistribute the excess of production between the different areas in order to achieve an optimal use of the full capacity of production available in the country.

[12] Notwithstanding, the public sector did not only build thermal power stations to supply electricity to the INI's firms, but also arrived to compete with the private firms with the construction of an hydroelectric plant, ENHER.
[13] Díaz Morlán (2006), pp. 314-316, y Gómez Mendoza (2000), pp. 69-84.

The establishment of new electrical rates was also a central point in the frictions between the state and the private firms. Electrical rates had stayed practically at the same level since 1933 and the private managers had complained repeatedly to the authorities for the low rates levels. Its revision was considered necessary in order to encourage the construction of new private plants and the widening of the existing ones. The new rates (TTU) were approved in 1951 and they went into effect in 1953. These new rates fixed a maximum price level that covered the average cost of production and an overcharge devoted to help funding the construction of new power stations and to subsidize the new thermoelectricity power stations whose production costs were higher than in the hydroelectricity plants. Additionally, there was also established a set of fiscal benefits and subsidies for stimulating private investment.

By this way, although most of the private companies did not ask for the fiscal benefits to enlarge or to build new facilities, they welcomed the public aids for laying new electricity lines (Buesa, 1986). Therefore, changes in the regulation of the electricity sector provoked a strong investment cycle since the middle of the 1940s and the installed capacity was multiplied by more than 10 between 1945 and 1970 (Figure 1). In the period 1952-1959 investment in the whole sector grew at an annual rate of 11.7. As a result, the production of electricity was multiplied by a factor of 19 in 1945-1970.

Additionally, the electrical industry registered the highest increase in total factor productivity of the economy as a whole, with an annual rate of growth of 6.81 in 1958-1975 in comparison with 4.46 of the total economy (Sanchis, 2006). In those years, the Spanish electricity firms could purchase abroad the equipment for the generation of electricity, embodying the best state of the technology in their plants. Additionally, changes in the organization of the system reduced the amount of losses in the network and reported a substantial increase in the efficiency of the overall electrical system operated. As a result, production was expanded to such an extent that not represented any constraint in the economic development of the two decades previous to the oil shock. Henceforth, the increase in productivity was reported to rest of the economy by means of a decrease in the real cost of electricity, as can be observed in Table 1.

Table 1
Average Electricity Rates (en cents of peseta/kWh)

	Nominal (current cents)		Real (cents. 1952)	
	Domestic Uses	Industrial Uses	Domestic Uses	Industrial Uses
Jannuary 1953	39,73	39,73	39,73	39,73
August 1958	82,05	89,28	48,81	57,52
August 1969	86,54	102,47	28,36	33,58
December 1970	94,50	113,09	29,09	34,81

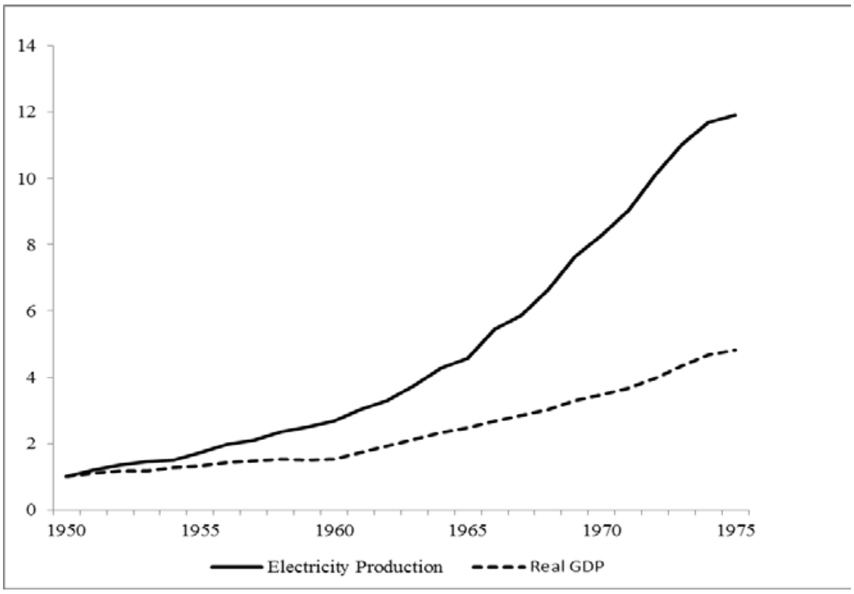
Source: Calcultations by Sudrià and Pueyo (2007) with information about electrical rates from (*Bolletin Oficial del Estado*). Nominal figures deflated by GDP at factor cost deflactor calculated by Prados de la Escosura (2003), base 1952.

The investment in new equipment, most of them electrically propelled, improved the way the electricity was used in the different industries. Even though some industries reduced the consumption of electricity by unit of output produced, in general this period was still characterized by increases in the production of electricity more than proportional to the increase in GDP.

Figure 4

Evolution of Real GDP and Electricity Production

(Index number, 1950=100)



Source: Real GDP (Prados de la Escosura, 2003); Electricity Production (Carreras, 2003).

4. Analytical Framework: The electricity as a General Purpose Technology

In this section we apply a growth accounting approach in order to analyse the role of electricity as a General Purpose Technology (GPT) in the consolidation of Spanish industrialization. The empirical literature applying the growth accounting approach usually considers that the productivity effects coming from a GPT operate through three channels. The first one is the "multifactor productivity" coming directly from the industry or industries producing the new technology. The second is the "capital deepening effect" in the whole economy that consist in the increase in capital intensity by means the investment in the capital goods that embody the new technology. And the third is the "spillover effect" that consists in all those benefits in terms of multifactor productivity that experience the industries by using the new technology. This last effect could act in different manners, such as changes in the organization of the firms, savings in the consumption of intermediate inputs, or product and process innovations propelled by the new technology.

4.1. The methodology

In this section we examine the electricity's impact as a proximate source of GDP per capita growth, by following the methodology introduced by Oliner and Sichel (2000) for evaluating the contribution of ICT to American productivity growth in the nineties[14]. As Crafts (2004) has outlined, this type of growth accounting addresses the question "how much did the new technology contribute to growth?" This methodology departs from the Standard Cobb-Douglas production function:

$$\Delta A / A = \Delta Y / Y - s_k \Delta K / K - s_l \Delta L / L \qquad [1]$$

where Y, K and L represent total output, capital input and labour input and s_k and s_l are the income shares of capital and labour respectively, and A is the Solow residual, also called "Total Factor Productivity". Oliner and Sichel (2000) take into account the developments in the new growth economics and the models that embodied the hypothesis of endogenous innovation. These kind of models let them to identify the contribution of technological change in the growth accounting framework by developing a straightforward generalization of equation 1 that splits up capital and the residual in different varieties. Specifically, they identified the contribution of innovations in ICT to the growth of labour productivity as coming through three types of ICT capital-deepening (computer hardware, software and communication equipment) weighted by the shares of these types of capital in income and through TFP growth in ICT production weighted by its share in gross output.

[14] Afterwards, this methodology has been used by the economic historians for analyzing the contribution of Steam Power Technologies to the British Industrial Revolution(Crafts, 2004a and 2004b) or to the climacteric (Crafts and Mills, 2004). For Spanish railroads see Herranz Loncan (2006).

We apply this methodology to distinguish the contribution of electrification to productivity growth stemming from electrical capital deepening and from technological progress linked to electrification. Thus following Oliner and Sichel (2000) the growth accounting equation could be rewritten in order to separate the role played by electricity to overall output growth:

$$\begin{aligned}\Delta(Y/L)(Y/L) &= s_{non-elec}\Delta(K_{non-elec}/L)(K_{non-elec}/L) + s_{Kelec}\Delta(K_{elec}/L)(K_{elec}/L) \\ &+ \gamma(\Delta A/A)_{melec} + \phi(\Delta A/A)_{non-melec}\end{aligned} \qquad [2]$$

In equation 2 the specific contribution of electricity to overall labour productivity growth is measured throughout two components[15]: the electrical capital inputs (K_{elec}) and electrical industry specific productivity advance (A_{melec}). At the same time, with regard to the electrical capital we have decided to distinguish between two kinds of capital: that part of the overall stock of capital that is made up of "electrical machinery and equipment" ($K_{elec\text{-}mach}$) and that capital devoted to increase the capacity of production of the electric power stations ($K_{elec\text{-}structures}$). The reasons for including this second kind of capital stock is that an economy does not be able to increase the use of electrical machinery without increasing at the same time the capacity of generating electrical power. The subscript *"non-elec"* indicates other capital excluded "electrical capital".

In Equation 2 the same split up is made within the TFP. Likewise, two kinds of productivity improvements linked to the process of electrification are distinguished. By the one hand, there is a piece of overall TFP growth that comes from innovations in the

[15] We take this decomposition from Crafts (2002) estimation of electricity impact in U.S. 1920's economic growth. For example for steam power Crafts(2004) distinguish different types of steam consuming machines (stationary steam engines, railroads and steamships); Oliner and Sichel (2000) distinguish different types of ICT machines (hardware, software and communications equipment).

“electrical machinery and equipment”. By the other hand, there is that part of TFP growth that comes from improvements in productivity in the generation and distribution of electrical power. Both kinds of productivity increase are respectively weighted by the share of each industry in total output. Where ϕ and γ represent the share of the gross output of these sectors in Total Value Added, that is the well-know “Domar weight” usually used in the literature of Growth Accounting at the industry level[16].

$$\begin{aligned}\Delta(Y/L)/(Y/L) &= s_{k\cdot non-elec}\Delta(K_{non\cdot elec}/L)/(K_{non-elec}/L) + s_{elec-struct}\Delta(K_{elec-estruc}/L)/(K_{elec-struct}/L) \\ &+ s_{elec-mach}\Delta(K_{elec-mach}/L)(K_{elec-mach}/L) + \gamma(\Delta A/A)_{elec-struct} + \lambda(\Delta A/A)_{elec-mach} + \phi(\Delta A/A)_{non-elec}\end{aligned} \quad [3]$$

Thus electricity is allowed to have impacts on growth both through an embodied capital-deepening effect as well as through the orthodox TFP growth. Unfortunately, the components of Equation 3 specifically devoted to calculate the effect of electrification on productivity growth could represent a lower bound estimate of the real impact of the new technology, as they do not identify the spillovers from electricity to the rest of the economy. Until now, the growth accounting studies usually fail to quantify the indirect TFP spillovers, due to the measurement problems involved in addressing this question[17].

In the next section it is developed a new way to measure one kind of spillover effect coming from electricity. It consists in separating from the last component of Equation 3 that part of TFP growth which comes from the increases in productivity in

[16] (Domar, 1961). The “Domar weight” is the rate between the total output of a particular industry and Value Added of the global economy. These weights do not sum to unity. For an algebraic justification of this procedure see Hulten (1978). This aggregation procedure is very common in the growth accounting literature (Jorgenson, Gollop and Fraumeni (1987), Jorgenson and Stiroh (2000)…). With this aggregation procedure Domar tries to reflect the different output concepts used at aggregate and industry level. For any particular industry, gross output considerably exceeds value added, and therefore the sum of gross output across industries exceeds the sum of value added. Weighting as suggested by Domar implies that economy-wide TFP growth can grow faster than the sum of particular industries' productivities as productivity gains in any particular industry are magnified as they work their way through the production process when they are consumed by other industries as intermediate inputs.

[17] Oliner and Sichel (2000), pp. 16-20, and Crafts (2004), pp. 339-340.

particular industries strictly related with the consumption of electricity. Taking into account the Domar's weighting used to aggregate the individual industries productivities, Total Factor Productivity could break down as follow:

$$\Delta A/A = \gamma\,(\Delta A/A)_{elec\text{-}struc} + \lambda(\Delta A/A)_{elec\text{-}mach} + \phi_1(\Delta A/A)_{spillover\ from\ elec\ utilities}$$
$$+\ \phi_2(\Delta A/A)_{spillover\ from\ elec\ capital} + \phi_3(\Delta A/A)_{other\ non\text{-}elec} \qquad [4]$$

Where $\gamma(\Delta A/A)_{elec\text{-}struc}$ represents the "electric utilities industry" contribution to overall TFP growth, $\lambda(\Delta A/A)_{elec\text{-}mach}$ represents the specific contribution of "electric machinery and equipment industry" and $\phi_1(\Delta A/A)_{spillover\ from\ elec}$ represent that part of productivity growth in the other industries that comes from the consumption of more efficiently produced or used electricity. This effect is what we identify as "electric utilities spillover effect".

Finally, the term $\phi_2(\Delta A/A)_{spillover\ from\ elec\ capital}$ represent any kind of improvements in other industries productivity that comes from the use of new electric capital goods and it will be identified as "spillover from the use of electrical capital goods". This kind of spillover has been introduced following the approach developed by Javala and Pohjola (2008). The ways to obtain both spillover effects are explained in the next section.

4.2. The Estimation of the Spillover Effects

In order to obtain an accurate measure of industry specific productivity growth and to measure the "spillover effect" from the consumption of electric utilities, productivity growth at the industry level has been estimated. As explained by Hulten (1978), growth accounting at the industry level differs from growth accounting at the aggregate level in that the output produced by other industries can be used as inputs in a given industry.

Jorgenson, Gollop and Fraumeni (1987) splits out the output growth at the industry level into the sum of the contributions of intermediate, capital and labour inputs and productivity growth. This way of proceeding let us to take into account changes in the quality of factors (capital and labour) and also in the quality and quantity of the intermediate inputs. We consider as "spillover effect from electric utilities" any saving in intermediate inputs consumption that causes a positive effect on the industry specific productivity growth. This "spillover effect" could come from any improvement in productivity in the supplier industries.

Following, Jorgengson *et al* (1987) methodology, the productivity measurement which underlies the disaggregated approach is a homogeneous production function *(F)* for each of the *n* industrial sectors. The production function for the *i*th industry gives the quantity of output, $Z_{i,}$ as a function of the primary inputs, capital services (K_i) and labour services (L_i), intermediate inputs (X_i) and the level of technology (t):

$$Z_i = f_i(K_i, L_i, X_i, t) \qquad i = 1....n \qquad [5]$$

where all inputs are measured as service flows rather than stocks. Under the assumptions of constant returns to scale and the exhaustion of the value of output by the value of inputs, the growth accounting equation for each sector is,

$$d\ln A_i = d\ln Z_i - v_{k_i} d\ln K_i - v_{l_i} dnL_i - v_{M_i} \ln X_i \qquad [6]$$

where v is the average share of the subscripted input in the i sector and A_i is industry productivity. The augmentation factor A_i is conceptually analogous to the TFP concept used in aggregate accounts. We refer to this term as "industry productivity" to distinguish it from TFP, which is estimated from the value added concept. The shares of intermediate (v^i_X) inputs in the value of the output take into account the variety of intermediate inputs used in the production of any particular industry i. The shares of the individual intermediate (v^i_{Xj}) can be defined in the values of the corresponding aggregates by,

$$v^i_{Xj} = \frac{p^i_{Xj} X_{ji}}{p^i_X X_i} \qquad (i,j=1\ldots n) \qquad [7]$$

Where X_{ij} is the set of n intermediate inputs from the jth sector and p^i_X denote the prices of intermediate inputs. Under constant returns to scale the elasticities and the value shares for all three inputs (K, L, X) add up to unity, so that the value of output is equal to the value of the inputs.

This formulation has the ability to capture the impact on output of efficiency improvement in the production of intermediate inputs. An improvement in the quality of the input could be reflected in a reduction in the quantity consumed or in a drop in the relative price of the input. In both cases, the net effect would be a reduction in the share of that input (v_{xj}) or/and in a reduction in (X_i/X), and hence an improvement in the productivity of the consuming industry. This effect has been estimated specifically for the consumption of electric utilities. For this purpose we have separately deflated output and intermediate inputs consumption (for more details see Appendix 1). Hence the "spillover effect from the electric utilities" can be represented as following:

$$\phi_1(\Delta A/A)_{spilt-elec-utilities} = (-1)\phi_i \sum_i v^i_{elec-utilities} \Delta\left[\frac{x^i_{elec-utilities} \cdot p^i_{elec-utilities}}{P^i \cdot X_i}\right] \quad [5]$$

Where γ_i refers to the Domar's weight for industry *i* and $v_{elec\text{-}utilities}$ represents the share in each industry of the consumption of electric utilities. The term is multiplied by (-1) because the consumption of intermediate inputs enter with negative sign for the computations of industry productivity.

Some authors outline that the arrival of a new technology can generate an acceleration in the rate of growth of overall productivity. Those industries that use the new technology can increase their productivity investing in those capital goods that embody the new technology. An exogenous increase in the rate of investment will increase the rate of growth of productivity as best-practice machinery replaces older vintages. Additionally, technological breakthroughs present profit opportunities that require new investment and thus induce an increase in capital formation. David and Wright (1999) have shown that large spillovers could arise from the widespread use of electricity in the U.S. manufacturing industry in the 1920's.

Jalava and Pohjola (2008) propone to estimate econometrically the relationship between investment in capital goods related with the new technology and the multifactorial productivity growth of specific industries and associate this relationship with the "spillover effect" derived from the use of new equipment, as reflected in Equation 6.[18] The estimated β coefficient is used to measure the importance of the new

[18] Unfortunaly, Jalava and Pohjola(2008) do not have date of this kind for the electricity and estimate it only for ICT technologies in Norway in 1990-2004.

capital spillover effect in each industry that and finally are aggregated by using the Domar's shares:

$$\Delta \ln A_{it} = \beta \Delta \ln K_{i,t-nonelec} + u_{it} \qquad [6]$$

4.3. The empirical results

Table 2 summarizes the results of implementing the growth accounting framework as represented in Equation 3. This equation has been modified to break down the multifactor productivity spillovers arising from the consumption of electric utilities and the investment in electrical machinery, as shown in Equation 4. Hence, the contribution of electricity to overall economic growth is broken down in three effects: "electric specific productivity growth" (arrow 1), "capital-deepening" (arrow 2) and the "spillover effects" over particular industries (arrow 3).

The average rate of productivity growth for the period 1958-1975 is 6.81 per cent for "electric utilities industry" and 5.86 per cent for the "electric machinery and equipment industry". The Domar's shares are 0.04 and 0.1, respectively. Multiplying both components, we find that the contribution in terms of TFP is 0.27 for the "electric utilities industry" and 0.58 for the "electric machinery and equipment industry", which summarizes a total "electricity productivity effect" of 0.85. This means that jointly both industries make a contribution of 18 % to aggregate TFP growth (4.62).

Table 2

Contributions to GDP per capita in the Business Sector, 1958-1975
(% per year)

	1958-1974	
1.1. Productivity contribution of Electric Machinery Industry	0.58	
Productivity Growth in Electric Machinery	5.86	
Output Share (Domar' contribution)	0.1	
1.2.Productivity Electric Utilities Industry Contribution	0.27	
Productivity Growth in Electric Utilities	6.81	
Output Share (Domar's contribution)	0.04	
1. Total global TFP Effect (1.1+1.2)		0.85
2.1. Electric Machinery and Equipment Capital Deepening	0.15	
Machinery and equipment Capital Stock Growth per capita	7.67	
Income share	0.02	
2.2.Electricity Production and distribution Capital Deepening	0.12	
Capital Stock Growth in Electricity Utilities per capita	7.94	
Income share	0.015	
2. Total Capital Deepening Effect (2.1+2.2)		0.27
3. Spillover Effect from electricity		0.34
Spillover from electric utilities	0.20	
Spillover from electric capital	0.14	
Overall Electricity Contribution to GDPpc (1+2+3)		1.46
GDP per capita		5.81
% Electricity over GDPpc		25.00

SOURCE: See the text.

The specific "capital deepening" effect of electricity is estimated as in Crafts (2002) by dividing electrical capital into two components: electric utilities capital stock and the total stock of electrical capital goods. "Electric Machinery and Equipment Capital Deepening" (row 2.1) refers to the increase of this kind of capital for the economy as a whole. The capital-deepening effect takes into account the stimulus in machinery and equipment investment. Most sectors of the economy invested in new electric machinery and equipment and, as it has been shown in the previous section, the percentage of machinery driven by electricity was between 90 to 95 per cent between

1958 and 1975. Prados de la Escosura and Rosés (2010) capital stock estimations give an average annual rate of growth of total machinery and equipment of 7.67 per cent between 1958 and 1975[19].

The income share of "electric machinery and equipment" capital stock is calculated as follows. First, we take "total capital income share" from Prados de la Escosura and Roses(2006) who correct by the compensation to employees and obtain an average share of 0.22 per cent for the period 1958-1975; second, we multiply this figure by the "share of machinery and equipment" in total capital, that runs from 9.07 % in 1958 to 11.32 % in 1975 according to Prados de la Escosura and Roses (2010) figures; and third, we have taken into account that electrical driven machines are in average 95 % of total machinery and equipment as reflected in the industrial survey *Estadísticas de la Producción Industrial* published by the Servicio Sindical de Estadística. Finally, the estimated income share of "electrical machinery and equipment" is 0.02, which gives a contribution to overall GDP per capita growth of "electrical machinery and equipment" capital stock of 0.153 (see *row 2.1*).

The "income share of electric structures" is calculated as follows. The capital stock in infrastructures devoted to the production and distribution of electricity has been measured through the increase in the capacity installed for the generation of electric utilities that, according to the figures published by the Ministry of Industry and UNESA, increased at 9 % per annum in 1958-1975, which in per capita terms represents a growth rate of 7.94 %. The capital income share of the "electric utilities industry" which is 0.032 of total capital share according with Input-Output Tables information and then we have multiplied it by the share of infrastructure in the capital of

[19] This is not the most accurate way to measure the volume of electrical machinery and equipment capital because we don't have hedonic prices, as do Oliner and Sichel (2002) to deflate ICT investment, and hence we can't take into account the improvements in quality that this kind of machinery could incorporate. We should consider it as a low bound approximation to the increase in the stock of electrical machinery and equipment.

this sector according to the Industry Ministry figures on technical production coefficients[20]. The final contribution of the increase in the stock of capital invested in power generating infrastructures is of 0.12, which summed up to 0.15 coming from the increase in electric machinery stock, gives a "total capital-deepening effect" of 0.27.

The "spillover effect from electric utilities" is calculated taken into account the consumption of electric utilities made by the different branches. The intermediate consumptions have been drawn from the Spanish Input-Output tables of 1958 and 1970 that have been aggregated according to 1970 Spanish National Accounts classification. See Appendix 1 for detailed information about sources and method [21]. We are specifically interested in the services offered by the electricity sector to the 23 business sector, which include agriculture, 15 industrial branches, construction and 7 service branches. These electricity services will depend on the increase in the quantity of electric utilities consumed by any branch and on the change of the electric utilities value share in any particular industry. The "electric utilities spillover effect" measures the contribution to overall TFP growth made by any industry by means of its particular electricity saving by unit of output produced. As can be observed in arrow 3 the contribution of this effect to overall TFP and hence to GDP per capita growth is 0.20. The resulting "spillover effect from electric utilities" is quite similar to the "capital-deepening effect".

Table 3 and 4 present a detailed explanation of how the last effect is calculated. Column 1 in Table 3 presents the growth rate of consumption of electric utilities by unit

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[20] In a survey of the Ministry of Industry (1980), "Los coeficientes técnicos de capital-producto y capital-empleo en diferentes sectores de la economía española", one can find the share of the different compontents of capital in different industries.

[21] Agriculture; energy, not including electricity; electricity, gas and water; metal and non-metallic; mining; primary transformation of metals; non-metallic minerals industry; chemical industries; industrial machinery and equipment; transport equipment; food and tobacco products; textile mills products; clothing and footwear; lumber, wood and furniture; paper products and printing; rubber and plastic; miscellaneous manufacturing; construction; trade; hotels, restaurants and bars; railroad transport; land transport; sea transport; air transport; communications; financial institutions.

of output for any particular industry. In *column 3* is shown the contribution of electricity to specific industry productivity growth, taking into account the share of electricity over total intermediate consumption (*column 2*). Since the intermediate consumption component enters with negative sign for computing the industry productivity (Equation 6), the contribution in *column 3* has been multiplied by (-1). A negative sign in the rate of growth of “electric utilities consumption” (*column 1*) means a positive effect over the industry productivity growth (*column 3*).

As can be observed in Table 3, not all the industrial branches behaved in the same way. Some industries experienced a contraction in the consumption of electric utilites for unit of output, meanwhile other industries intensified the consumption of this input.
As should be expected, most of the industrial activities and all the service sector activities benefited by the use of cheaper electric utilities and by the use of technologies that let them to make a more efficient use of this input. During those years electrification in Spain advanced with the high investments in power generation capacity but also with the improvement and expansion of the transmission and distribution system. This fact made electrical power available without restrictions and a lower real cost rates.

However it is interesting to observe that among those industries that increased the consumption of electricity by unit of output are those industries with more scope for introducing the large scale production technologies of the Second Industrial Revolution, such were the production of cars, machines, or even the processing of food and tobacco, or apparel and shoes making. It was since the second half of the 1950s, and more specifically in the 1960s, when Spain began the transition to this kind of technologies. One can guess that the change toward technologies more intensive in the use of capital was complemented by a more intensive use of electricity. And the advances in the "electric utilities industry" by increasing the supply at lower cost and prices, removed previous obstacles to the development of this kind of industries. Finally, last column of Table 4 summarizes the overall contribution of the "spillover effect from electric utilities" to aggregated TFP growth. As it can observed the positive contributions overcome the negative ones, with a net positive contribution of 0.20.

The last one is the "spillover effect from electrical machinery and equipment". To estimate this effect we have estimated an Ordinary Least Square regression between industry productivity growth and the average changes in electrical machinery stock for a set of manufacturing industries and wholesale and retail trade, transportation. The estimated coefficient β is 0.55 for 1964-1970. This estimated effect is quite poor since it gives an R-square of 0.2. The spillover from electrical capital is calculated multiplying 0.55 by the average growth of electrical capital in each industry and, finally the sum up all these components, we have aggregated using the Domar's share of the industry in total Value Added. The final "spillover" derived from the incorporation of new electrical equipment is 0.14.

Table 3

Spillovers Effects from Electricity. Contribution to Industry Productivity

	(1) Growth Elec Utilities Consumption ($X_{elec.\ i}/X$)	(2) Share of Electric Utilities (v_i)	(3) Contribut. to Industry TFP (-1)*(1)*(2)	(4) Growth of Industry TFP
Agriculture. forestry and fishing	3.02	0.02	-0.05	0.96
Energy. unless electricity	-6.07	0.06	0.35	7.98
Electricity. gas and wáter	-11.21	0.23	2.55	9.78
Metal and non-metallic mining	-3.08	0.15	0.46	5.92
Primary transformation of metals	-2.14	0.03	0.07	1.96
Nonmetallic minerals industry	-0.20	0.09	0.02	6.35
Chemical industries	-3.92	0.05	0.18	4.09
Industrial machinery and equipment	1.86	0.02	-0.03	5.74
Transport equipment	2.19	0.01	-0.02	1.86
Food and tobacco products	1.24	0.01	-0.01	2.02
Textil Mill Products	3.97	0.02	-0.06	2.32
Apparel and show	5.90	0.00	-0.02	4.51
Lumber. wood and furnitures	0.05	0.01	-0.00	6.44
Paper products. printing and publishing	-1.25	0.04	0.05	5.78
Rubber and plastic	-4.46	0.03	0.14	7.36
Miscellaneous manufacturing	-3.54	0.02	0.06	1.21
Construction	-0.66	0.01	0.01	-2.34
Trade.	-0.36	0.03	0.01	-2.70
Hotels. restaurants and bars	-1.72	0.05	0.09	-1.46
Railroad transport	-0.65	0.08	0.05	-1.79
Land transport	-7.96	0.02	0.18	5.30
Sea transport	-19.20	0.01	0.26	3.36
Air transport	-24.60	0.04	1.08	10.43
Communications	-4.75	0.15	0.69	0.57

Source: See the text for details.

To sum up, according to the growth accounting approach, electricity's overall contribution to GDP per capita growth was 1.46 percentage points per year in 1958-1970, of which 0.85 points came from specific TFP growth in the industries producing the new technology, 0.27 points came from capital-deepening for the production and the introduction of the new technology and 0.34 represented spillover effect. This spillover effect has been broken in two part, 0.20 points correspond to the savings in the consumption of electric utilities and 0.14 points to the acceleration of productivity in non-electrical industries which could be related with the investment in new electrical equipment. The shares of each effect in the overall contribution of electricity are: 58% for TFP in the new technology industries, 18 % from electrical capital deepening, 14 % from spillovers from the "electrical utilities" and 10 % from "capital spillovers".

Our results contrast widely with those obtained by Crafts (2002) for the United States in 1919-1929, the "most progressive era" in which the consolidation of electricity was hand by hand with the dissemination of the Second Industrial Revolution technologies (Field, 2003). Crafts found a great room for the contribution resulted from spillovers, around 70 % of total electricity contribution, meanwhile our estimation gives a lower bound for the spillovers, that are around 24 % of total contribution. More recently Jalava and Pohjola (2008) have made the same exercise for Finland in the 1900-1913 and 1920-1938, but without estimating the spillover effects. They find that in those decades of consolidation of the electrification process, the contribution to overall GDP growth was of 18 %. These results are quite similar to ours. If did not sum up the spillover effects, the contribution of the "capital effect" plus the "TFP effect" would be only 19 %.

Since these authors do not estimate the contribution of the electricity spillover effects, it is difficult to set a reliable comparison. However, they analyze the "spillover effect from ICT capital" for Finland in 1990-2004. This contribution derived from ICT capital deepening (16 %), ICT industries productivity growth (59 %) and the spillover effects from ICT (25 %).[22] These results are more close to the results that we have obtain for electricity in Spain in 1958-1970 with regard to the relative importance of the sources of the growth contributions.

[22] Computations made from Table 3 of Jalava and Pohjola (2008).

Table 4
Spillovers Effects from Electricity. Contribution to Aggregate TFP

	Contribution Electricity to industry TFP	*Domar aggregation*	*Contribution to overall TFP*
Agriculture, forestry and fishing	-0.05	0.40	-0.019
Energy, unless electricity	0.35	0.05	0.016
Electricity, gas and wáter	2.54	0.05	0.125
Metal and non-metallic mining	0.46	0.01	0.006
Primary transformation of metals	0.07	0.13	0.009
Nonmetallic minerals industry	0.02	0.04	0.001
Chemical industries	0.18	0.09	0.017
Industrial machinery and equipment	-0.03	0.12	-0.004
Transport equipment	-0.02	0.09	-0.002
Food and tobacco products	-0.01	0.31	-0.002
Textil Mill Products	-0.06	0.12	-0.007
Apparel and show	-0.02	0.09	-0.002
Lumber, wood and furnitures	0.00	0.05	0.000
Paper products, printing and publishing	0.05	0.05	0.002
Rubber and plastic	0.14	0.03	0.004
Miscellaneous manufacturing	0.06	0.03	0.002
Construction	0.01	0.16	0.001
Trade,	0.01	0.19	0.002
Hotels, restaurants and bars	0.09	0.09	0.008
Railroad transport	0.05	0.02	0.001
Land transport	0.18	0.08	0.015
Sea transport	0.26	0.02	0.005
Air transport	1.08	0.01	0.011
Communications	0.69	0.01	0.010
Spillovers Contribution to TFP			0.20

Source: See the text for details.

In the two decades in which a more wide, efficient and integrated electrical network was established in Spain, the economy had more scope to develop the technologies of the Second Industrial Revolution, most of them related with a more efficient use of electricity and electrical machinery. It was then when electrification could manifest its character of General Purpose Technology, with a contribution to GDP per capita growth of 25 %.

5. Conclusions

In this paper one specific question is posed: How much did electrification contribute to the Spanish economic growth in "its particular most progressive era"? As it had happened in the U.S. in the 1920s, the 1950s and 1960s represent for Spain the moment to seize the opportunity to incorporate and develop the technologies of the Second Industrial Revolution. Additionally, it is a common fact in the literature about the Golden Age in Europe to assume that during those decades the European countries make an effort to catch-up with the U.S. by assimilating and developing the technologies developed in this leader country in the interwar period.

As in other European countries, and even do the backwardness of the country, the introduction of electricity in Spain took place relatively soon, in the last decades of the XIXth century. Its diffusion throughout the exiguous industrial sector was relatively rapid. Before the Civil War, most of Horse Power used in the exiguous manufacturing sector was generated by electricity. The reason is that electricity let to remove one of the main obstacles for their industrialization, such it was the shortage of coal to produce steam power. However the early birth of electricity in Spain, the Spanish economy was not mature enough to take full advantage of the incremental innovations in other industries that this new technology could propel. In spite to have enjoyed high rates of GDP growth between 1920-1929, industry still represented only 20 % of overall Value Added.

The expansion of the installed capacity of the electricity sector was interrupted by the Civil War and by the economic policy of the first years of the Franco's dictatorship. Only the settlement of new agreements between the new regime and the large private firms create the conditions to invigorate the investment in new plants and to organize a centralized network for the distribution of electricity around the country. Between 1945-1970, the capacity installed in the sector multiplied by a factor of 19. The expansion of electricity production let to cope with the increasing demand coming from an industrial sector that had started a continuous expansion and diversification.

It was also in the fifties, and especially in the sixties, after the openness inaugurated by the 1959 Stabilization Plan, that the machinery and equipment industry developed and experienced high rates of multifactor productivity growth. The expansion of this industry was highly depended of the arrival of capital and technology from abroad (Cubel and Sanchis, 2007).

We have estimated that the general contribution of electricity to GDP per capita growth was the order of 25 %. When we break down this figure in contributions arising throughout three different sources: multifactor productivity growth inside the industries producing the new technology, capital deepening related with electricity and spillovers from the new industries towards the rest of the economy, we find a similar picture to those obtained by other authors for the impact of ICT in the last two decades. First, our results show that multifactor productivity growth inside "electrical utilities industry" and the "electrical machinery and equipment" industries made the biggest contribution of electricity to overall GDP per capita growth. At least 58 % of the overall contribution of electricity came from this source.

Second, to the extent that these sectors producing the new technology could provide an increasing flow of electric utilities and capital goods, and to the extent that they could make it more efficiently, the new technology could disseminate its productivity gains all over the economy. Between 1958 and 1970, the relative price of machinery and equipment with regard to the GDP deflator decreased in a 45 %[23]. As a consequence, investment in new capital goods boomed in those decades, the investment rate in this kind of goods doubled in those years from a rate of 2.3 % over GDP to 5.7 % in 1970. At least 95 % of this investment was in electrical capital goods. Hence, we find that 18 % of the contribution of electricity to GDP per capita growth came from capital deepening in specific capital goods and infrastructures related with electricity.

Finally, one of the main contributions of this piece of research to the literature about the impact of electricity, is to have calculated two kinds of spillover effects related with the use of this technology. We have done that by splitting down those parts of the multifactorial productivity growth in specific industries that could arise both, from the consumption of electric utilities, and, from general improvements in efficiency related with investment in electrical capital goods. Taking into account that the relative price of electric utilities with regards to the GDP deflator decreased around 40 %, we find two kinds of industries. By one hand, there are those industries that reduced their consumption by unit of output and, by the other hand, there are those that intensified the consumption of electricity making in those decades the transition towards technologies more intensive in capital. In general, we find that the contribution of the "spillover effect from electric utilities consumption" represents at least 14 % of total electricity contribution. Furthermore, the "spillover effect coming from capital deepening" in electrical capital goods was the order of 10%, although the computations with regard to this effect are quite rude.

[23] Here it is interesting to highlight that Spain could be some sort of special case because an important part of the decrease could be explained by openness to international trade (Cubel and Sanchis, 2007). This means to abandon rationed markets and to open the door to new competitors. But in any case openness brought the opportunity to access to capital goods on the border of technology frontier and at the same time encouraged investment in the domestic capital industries to cope with the arrival of new competitors.

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Appendix 1. Variables and data sources

Labour inputs

The appropriate measure of labour input is the flow of services emanating from this factor which can be considered proportional to the hours of work. An accurate measure of labour services would require taking into account as many attributes of the labour force as possible in order to capture its heterogeneity and improvements in workers' skills. Differences in the services offered by any labour category are a consequence of their differences in marginal productivity and can be reflected in differences in labour compensation per hour in any employment category. These differences in marginal labour productivity by workers are obtained through a process of education or qualification in the workplace. Therefore if we take into account as many attributes of the labour force as possible we can better capture the changes in labour force quality and in turn. the contribution of labour input to growth.

For developing this measure of labour input we have used the publication *Salarios* of the Spanish Instituto Nacional de Estadística (INE) which contains information on hours worked and average labour compensation per hour for fourteen industrial branches. construction and three services branches. In this survey data wages are classified in two employment categories. skilled and unskilled workers. with at least five salary levels in each category. We have crossed the wage survey information with total employment data collected by Alcaide(2003). With the data on the average labour cost for each category. we have calculated the v^i in order to measure how changes in the quality of employment affected the productivity growth in any particular industry.

Capital input: data sources and method

Data on capital stock at sectoral level are taken from the *El stock de capital en España y su distribución territorial* (2005) database published by *Fundación BBVA*. The advantage of this source is that it provides estimates of both net capital stock and gross investment for different sectors and it estimates different depreciation rates for every sector[24]. The main difficulty in constructing "input capital" at a sectoral level for the Spanish economy is that we cannot break down the aggregate capital stock into its components at a sectoral level and reconstruct the individual progress over time of every kind of capital by industry. For this reason the growth of "capital input" is assumed to be proportional to the growth of the aggregate capital stock for every sector. This assumption implies not taking into account differences in economic obsolescence of assets directly related with rapid technological change that could significantly influence the evolution of capital services.

Intermediate inputs: method and data sources

Intermediate inputs are treated in the same way as labour inputs. Data on intermediate inputs consumption are taken from several Spanish Input-Output Tables (1958. 1962. 1970 and 1975). In order to operate with successive Input-Output tables each table has been deflated. The Intermediate input quantity indexes by sector of origin

[24] Agriculture; fisheries; energy products; metal mining; primary metals; non-metallic mineral mining; chemicals and allied products; fabricated metal products; agricultural and industrial machinery; electrical machinery; transportation equipment; food and kindred products; tobacco manufactures; textile mill products; apparel and other textile products; printing, publishing and other paper products; rubber and plastic products; lumber, wood products and furniture; construction; hotels and restaurants; transportation; communications; finance and insurance; other services.

have been constructed by deflating the intermediate inputs consumed by one sector by a specific producer price index for this sector. This was achieved by using the Tornqvist index, which is commonly used to measure volume changes for productivity measurement purposes[25].

Data appendix

Intermediate Inputs Deflators

The objective has been to build a price index weighted by the share of national and imported inputs in the intermediate and final consumptions of each sector. The result is an average weighted price for each cell in the input-output table.

This appreciation is interesting as the Spanish economy progressively opened up over the period under analysis. This affected the composition of intermediate inputs. with an increasing participation of imports.

The series of domestic prices used as deflators for domestic consumption of goods and services are the following:

- Agriculture: The *Indice de precios percibido por los agricultores*. published by the Ministry of Agriculture. equivalent to the producer prices at which the tables are valued.
- Industry: *Indice de Precios al por Mayor* at 1955 base (IPM-55). In Sanchis (2000). equivalences have been established between branches of CNE-70 and IPM-55.
- Construction and services: It has been difficult to obtain appropriate deflators. For this reason we use the Value Added deflators. This means accepting that their prices vary in a similar way to their respective value added. The hypothesis is reasonable for more labour intensive services in which the value added is the most important component of overall cost. But for services like transport and communications where the composition of input consumption and costs is more complex. this deflator is less suitable.
- Import prices: An import price index had to be produced using two kinds of import series: imports in values and imports in physical quantities. The data used are the series of values and quantities of imports summarised by the *Instituto Nacional de Estadística* in its *Anuarios Estadísticos*. over several years. The original source is the *Estadística del Comercio Exterior de España de la Dirección General de Aduanas*.

The deflating procedure was conducted as follows: 1) After establishing the composition of intermediate and final consumption between domestic and imported goods. We obtain a different deflator for all the cells in the tables. 2) This deflator is built as a Tornqvist index which is commonly used to measure volume changes for productivity measurement purposes. The Tornqvist index is a discrete-time approximation to a Divisia index which takes into account share changes over time. When the production possibilities being analysed can be represented by a homogeneous

[25] The Tornqvist index is a discrete-time approximation to a Divisia index which takes into account share changes over time. When the production possibilities being analysed can be represented by a homogeneous translog function, as is the case, the Tornqvist index provides an accurate measure of the underlying theoretical volume index.

translog function. as is the case. the Tornqvist index provides an accurate measure of the underlying theoretical volume index. In Sanchis (2000 and 2005) the input-output tables are aggregated at the same level and expressed at current and constant prices.

Output: Sources and coverage

Constructing data for sectorial productivity growth requires output to be correctly valued. Jorgenson suggests the concept of valuation from the producer's point of view. This concept is half-way between the national accounting concepts of valuation at market prices and valuation at factor cost. The value of output at market prices includes taxes paid by producers and excludes any subsidies they receive. Output value at factor costs excludes these taxes and includes subsidies but intermediate inputs include taxes paid by producers for each input. Thus valuation from the producers' point of view is the best way to integrate output and input data into productivity measures at sectorial level.

In general output value has been taken from Input-Output Tables. The level of aggregation and the classification of activities are different in all the tables (1958, 1962, 1970 and 1975) and therefore correspondences between tables must be established first. In some cases it is easy to find some inconsistencies between two consecutive tables with respect to the input and output growth rates. For this reason control totals for output value are made. We checked the output growth derived from Input-Output Tables with Value Added growth by sector from the Spanish National Accounts.