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Research article

Economic resilience in the short-run: A dynamic macroeconomic approach

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Abstract: We analyzed the dynamics of the relatively elusive concept of economic resilience. Resilience and its two distinctive components, adaptability and resistance to shocks, are concepts that conveniently characterize the structure of economies in the long-run. In studying resilience, we established a relationship between the short-run and long-run dynamics, or from a macroeconomic perspective, between transitional dynamics and long-run growth. The loss or gain of systemic resilience is usually gradual and, to a large extent, reversible: over time, resilience may fluctuate. We extended previous analyses by studying the resilience of an economic system over several short-run periods corresponding to the distinct phases of the business cycle. We articulated these periods in a backward sequence of overlapping long-run periods that allowed us to compute the adaptability and resistance indexes, even if they were originally designed to measure resilience in the long-term. Unlike other studies that measured it using flow variables such as (un)employment or income, we used capital stock to measure the attributes of adaptability and resistance. The dynamics of aggregate capital reflect much better the evolution of the size and complexity of the economy and also allowed us to subdivide adaptability into its depreciation and investment components. Our case study was the Spanish economy during the period 1964–2016, encompassing different subperiods of expansion, slowdown, and crisis. We identified a reference point of perfect resilience, and found that the most resilient subperiod corresponds to the years of expansion 1994–2007. The least resistent subperiod is 1974–1985, showing strong slowdown and crisis. The least adaptable subperiod is 1986–1991. Adaptability was mostly stable during expansions and recessions, and was perfect during the most resilient subperiod. The depreciation effect mimicked the adaptability pattern better than investment. Resistance did not show a clear pro- or counter-cyclical pattern.

Keywords: adaptability; capital stock; depreciation; investment; resilience; resistance

JEL Codes: E22, E32, O11, O52

1. Introduction

An important property of nonlinear dynamic systems, with which economists are often quite uncomfortable, is that small shocks can be magnified, leading to qualitatively unexpected behavior at macroscopic levels. Ecological and other dynamic natural systems are highly nonlinear and sometimes even complex systems. It is in this context that resilience is so important, because once it is lost, the system is no longer capable of absorbing turbulences without suffering fundamental changes that may imply a jump to new states and domains of stability (Holling, 1973; Pimm, 1984).

Today, the concept of resilience plays also an important role in the field of social sciences (Hanley, 1998; Martin and Sunley, 2015). Economics in particular, in the wake of the Great Recession, began to show a growing interest in the subject, an interest that has been renewed as a result of the Covid-19 crisis. The areas of economics most involved in the study of resilience are environmental economics, economic geography, and regional economics. These do not belong to mainstream economics, but they are important subdisciplines where the expansion of the frontier of knowledge requires the cooperation of specialists from different areas of research. In other words, they call for multidisciplinarity, exactly what is needed for the study of resilience.

There are a wide variety of definitions of resilience, but most are complementary and not mutually exclusive. One meaning of resilience close to the analytical requirements of economic theory is the capacity of an ecosystem to respond to a natural perturbation, to an anthropogenic disturbance, or to any destabilizing influence, by maintaining the previous state, resisting damages, and, if necessary, recovering quickly from them. Thus, once introduced in the social sciences, the concept of resilience was adjusted and its meaning broadened to include the ability of a system to maintain services, to adapt in the face of adverse economic conditions, to absorb supply and demand shocks without suffering complete degradation or failure, and to resist changes.

Economic resilience has been defined in different ways since the concept was adopted in economics from previous studies in the context of natural sciences. In our opinion, the extrapolation that best fits economic systems is the one that defines it by splitting the concept between the capacity of an economy to withstand absorbing shocks and the capacity to recover from them (Dasgupta, 1995; Levin et al., 1998). Given the variety and magnitude of the shocks it may suffer, it is important that the economic system does not cross the threshold of structural stability, maintaining its dynamic properties during and after the shocks (Liu et al., 2007; Ehrlich et al., 2012).

Regarding the areas of economics concerned with the study of resilience, the usual question that researchers try to answer is about the ability of an economic system to respond to some particular natural or human-made negative shock. But, what is meant by *to respond to*? According to Hill et al. (2008), it is the extent to which an economy is able to maintain a pre-existing path or state. This could be interpreted as the ability of the system to return to its previous trajectory or to avoid being thrown out of its trajectory. The latter would require avoiding or withstanding the shock with little or no adverse impact. Moreover, given the purposeful nature of economic behavior, resilience can also be viewed as the capacity of a system to continuously develop along a preferred expected trajectory, while remaining within social and physical boundaries (Becker, 2014). In any case, resilience is not treated as an absolute feature of systems but a relative one. Comparing the resilience of different systems requires sharing a similar background and defining the same variables to measure deviations from their corresponding expected trajectories. The same is true for comparing the resilience of one system over time. It is necessary to choose the variables assuming that the domain of stability remains constant, and then measure the deviations from the expected trajectory in different subperiods.

According to Martin (2012), there are three main perspectives to address the concept of resilience: engineering, based on the existence of a unique dynamic equilibrium path; ecological, which admits the existence of multiple equilibria; and adaptive, founded in complex adaptive systems theory. The definition of economic resilience that we use in this paper does correspond to the first of the three perspectives. Consequently, we use a concept of resilience grounded in physics and mathematics that shows a strong connection with the elements of modern dynamic macroeconomics and the theory of economic growth. These developments in economic theory emphasize the relationship between short-run and long-run dynamics, i.e., between transitional dynamics and long-run growth.

Resilience was originally introduced in relation to disasters. Consequently, most of the recent studies, like Briguglio et al. (2008), Simmie and Martin (2010), Fingleton et al. (2012), Hallegate (2014), or Caldera-Sánchez et al. (2016), focused on isolated and negative exogenous shocks and analyzed the reaction of the system in terms of the economic performance. However, an economy (aggregate, regional, etc.) is regularly affected by a large number of shocks and disturbances of many types (supply shocks or demand shocks, recessionary or expansive) and of different intensities. It is in this more general context where resilience should be evaluated.

Unfortunately, there is no specific theory of economic resilience. There is no universally accepted definition. There is no widely accepted methodology for how to empirically implement and measure the concept. Moreover, the question of what explains the resilience of an economy remains to be addressed in depth. Most empirical works suggest the use of data on aggregate output and employment analyzing the levels and the rates of growth of these variables during recession and post-recession periods. They primarily focused on identifying an isolated negative shock and studying the reaction of the economy by inspecting the evolution of employment during the subsequent crisis period. Our methodological approach is different. We first identify different periods of economic expansion and crisis based on the evolution of the rate of growth of gross value added. We do not identify specific shocks but rather analyze the consequences of the shocks. We do not focus on a particular shock to see how the economy reacts to that isolated shock. We assume that the economy experiences continuous impacts from a wide variety of disturbances that overlap over time. By considering the set of shocks that affect the economy at different times over a period, we implicitly cover both negative and positive shocks, monetary and fiscal, financial and technological, even trade and, of course, international and domestic.

The concept of economic resilience is largely shared with others: resilience as a combination of two attributes of economic systems, resistance and adaptability, with these or similar names. However, a first difference arises from the way in which the concept is operationalized: the resilience of a small territory against that of a broader territory, or resilience by comparing the short-run trajectory affected by disturbances with the long-run trajectory that behaves as if it had withstood or absorbed all impacts. A second difference comes from the way the indexes for resistance and adaptability are defined and what they try to capture: the consequences of an isolated negative shock during the subsequent crisis period, or the reaction to the whole set of shocks that affect the economy at different times over any period of crisis or expansion. A third difference is the variable to which the indexes are going to be applied: employment-output-productivity or capital(s). In short, the method for measuring economic resilience is a matter of choice: the choice of the variable to be inspected and the choice of the index to be used as a tool.

From the scientific literature on ecology, we know that the measurement of resilience in deterministic systems can be computed directly from the equations describing the relevant population dynamics; that is, the number of organisms in the ecosystem and how it evolves. However, in the study of economic systems, the equivalent of such a population is not the human population, unless we want to carry out a demographic study, nor does it seem appropriate to associate the size of the system and its fluctuations with changes in employment levels or its rate of growth. The capital stock and its varieties reflect better than employment or income the size and complexity of the economic system. In this paper, we focus on capital stock, which is a predetermined variable, making our study of resilience more coherent with those that populate ecology literature. The study of resilience, resistance, and adaptability turns around the cumulative productive factors on which economic growth depends. Using capital stock as the reference variable, we identify two representative trajectories of the economy, one referring to the short-run which, at any moment, is affected by any kind of disturbance, and another referring to the long-run that behaves as if it had withstood or absorbed all impacts.

Taking a step forward, and in accordance with the lessons from Batabyal (1998), we can define an economic system as resilient provided that the state variable that represents it avoids and recovers quickly from shocks by staying during the transition as close as possible to the balanced growth path (BGP). We assume that there is a unique BGP throughout the entire time period analyzed because we consider the dynamic economic system to be structurally stable and also dynamically stable. The true configuration of the economic system is not simple or linear, but by assuming its structural stability, complex dynamics can be avoided, and by simplifying the magnitude of feedbacks and nonlinearities, the case of multiple equilibria is ruled out. In our conceptual framework, the short-run equilibrium path may fluctuate because of the multiple and repeated shocks experienced by the economy, but our long-run BGP is an exponential monotonic trajectory. The assumption of a single BGP with a single constant growth rate is based on the stylized fact that the structure of the economy remains stable over long periods.

Recently, Escribá-Pérez et al. (2024) revisited the concept of economic resilience using the insights and outcomes of endogenous growth models as a reference and opening a novel pathway for studying the properties of resistance and adaptability in economic systems. They proposed studying resilience by inspecting the dynamics of capital, or the combined dynamics of different types of capital, that determine the growth of the economy in the long-run, independent of other influences received in the short-run. In their article, the authors defined two new complementary indexes to measure separately the attributes of adaptability and resistance of economic systems. Using these measures, they made a rough assessment of the economy's relative degree of resilience. In addition, they also provided a sophisticated method for decomposing the adaptability index into a depreciation effect and an investment effect. However, all these new statistical tools were customized for measuring the different attributes and components of resilience in the long-run. The proposed indexes were designed to make calculations with all the data in the sample series over a long period of time. Consequently, the image they provided was a static image, which summarized in a single figure the relationship between the short- and long-term trajectories of the relevant variable. This is so because authors argue that resilience, resistance, and adaptability are timeless categorical attributes of the economic system.

The big challenge we face in this paper is to transform the conceptual framework and the indexes that measure economic resilience and its various components, so that they can be properly used to study these same properties throughout each of the short phases of the business cycle. Although we are going to measure in the short-run, this new measurement should continue to be based on the relationship between the transient behavior and the asymptotic behavior of the economic system, which is constantly exposed to shocks of different nature and intensity. This makes the problem of measuring economic resilience in dynamic terms a rather difficult one. Given the complexity of the indexes, and the fact that they are designed to generate stationary measures, adapting them to a dynamic context, such as studying the cyclical evolution of the economy, is neither straightforward nor immediate. However, the expectation of a richer characterization makes it a priority to incorporate dynamic computational aspects into the analysis. Only in this way can it be possible to empirically implement the study of the dynamic evolution of resistance and adaptability, and put it into practice with the data available for the Spanish economy. To this end, it is essential to completely rethink the mechanics of the aforementioned indexes: we articulate the subperiods in a backward sequence of overlapping long-run periods that, when subtracted from each other, give us the values corresponding to short periods of time without sacrificing the fundamental relationship between the current evolution of the capital stock and its evolution throughout the BGP.

The paper is organized as follows: In Section 2, we provide a brief quantitative description of the Spanish cyclical behavior, identifying the phases of the different business cycles this economy has transited between 1964 and 2016. In Section 3, we adapt the resilience indexes defined in Escribá-Pérez et al. (2024) for their study in the long-run to a dynamic context in order to explore the dimensions of adaptability and resistance, as well as the depreciation and investment effects, throughout the different phases of the cycle. In Section 4, we apply the new indexes to the Spanish data using the available series of economic/short-run and statistic/long-run capital stock. The results arising from our computations for the study of resilience in terms of adaptability and resistance, over the different phases of expansion and recession, are graphically illustrated and discussed. We provide a causal explanation for the results focusing on the processes that directly influence the dynamics of the capital stock. Section 5 provides some policy implications and concludes the article.

2. An overview of the Spanish business cycle

Since the preferences represented by utility functions are subjective, and although it may not be an accurate measure of well-being, scholars always look at per capita income as the relevant variable that measures the performance of the economy. More specifically, what is taken as representative of economic performance is the evolution of per capita income over time and, therefore, its growth rate. But this is a non-predetermined flow variable, and what ultimately concerns us are the dynamics of state variables. In the context of endogenous growth models, according to which the economy grows during the transition but also in the long-run, the basis for economic growth lies in the accumulation of one or more types of capital. It is the dynamics of these stocks that determines the progress of output, per capita income, and welfare. This is the reason why, in this section, we study the business cycle by analyzing only the variables of output and capital stock.

In order to analyze economic resilience in the short-run, we have defined the different subperiods of analysis according to the evolution of the Spanish business cycle. Figure 1 shows with a solid line the evolution of the growth rate of output measured by the gross value added (GVA) of the non-financial business sector. Throughout the period analyzed, 1964–2016, factors such as economic liberalization, energy crises, integration into the European Union, and the Great Recession have conditioned the evolution of Spanish output. Table 1 shows the average growth rates for the different subperiods.

The first column of this table shows the average annual growth rate for the subperiod 1964–1973, a phase of economic expansion and development. Following the implementation of the 1959 Stabilization Plan, Spain experienced a period of accelerated growth. During the years under review, GVA grew at an average annual rate of over 6%. The 1973 oil crisis marked the end of the expansionary period. GVA growth slowed down significantly, with an average annual growth rate of less than 2% in this subperiod (1974–1985). This slowdown can be explained, on the one hand, by the uncertainty generated by the political transition to democracy, together with the rise in unemployment and high inflation, which led to the implementation of the stabilization measures of the Moncloa Pacts in 1977. On the other hand, because of the consequences of the second oil shock in 1979 and the structural reforms, especially the strong process of industrial reconversion in the first half of the 1980s. Figure 1 shows the decline in the growth rate of output, which turned negative at the end of the 1970s and the beginning of the 1980s.

Spain's entry into the European Economic Community in 1986 marked a change in the low growth trend of the previous period. The good expectations associated with economic integration, together with the stimulation of domestic demand and liberalization measures, led to one of the strongest periods of growth in the Spanish economy. This period of expansion lasted until 2007, although it was interrupted by the exchange rate crisis of the early 1990s. Thus, within this period of strong growth, we will consider three subperiods: two expansionary phases corresponding to the years 1986–1991 and 1994–2007, with average growth rates of 3.69% and 3.43%, respectively, and a recessionary phase corresponding to the years 1992–1993, with an average annual rate of −0.52%.

The strong growth of the last expansionary phase came to an abrupt halt with the outbreak of the financial crisis in 2008. The Spanish economy was hit severely, with output growth of −5% in 2009. During the Great Recession (2008–2013), the economy suffered not only from the consequences of the global financial crisis, but also from the sovereign debt crisis, which contributed to an average annual growth rate of −2.03% during this subperiod. The Spanish economy began to recover in 2014. This last subperiod corresponds to a phase of expansion that lasts until the crisis caused by the Covid-19 pandemic. Due to data unavailability, we only include the first three years of this expansionary phase in our analysis, during which the average annual growth rate of output reached 3.60%.

In addition to the evolution of output, Figure 1 and Table 1 also show the growth rates of long-run capital (statistical measure of capital) and short-run capital (economic measure of capital). As discussed above, capital is a variable that approximates the size and complexity of the economic system as a whole. Although capital depends on investment and depreciation decisions, which can fluctuate pro-cyclically or counter-cyclically, the evolution of capital does not show strong fluctuations like flow variables such as income or (un)employment. In fact, as can be seen in Table 1, capital grows in all subperiods, albeit more strongly during expansions. It is interesting to note the difference in the intensity of this positive growth of the two capital stocks. The growth of economic capital is much higher than that of statistical capital during expansions and much lower during recessions. The exception is the expansionary subperiod (1994–2007), when there was a boom in investment in information and communication technologies (ICT), which changed production methods and significantly increased obsolescence.[1]

[1] The last subperiod is also an exception, but this may be because the entire expansionary phase of the cycle is not considered due to unavailability of capital data.

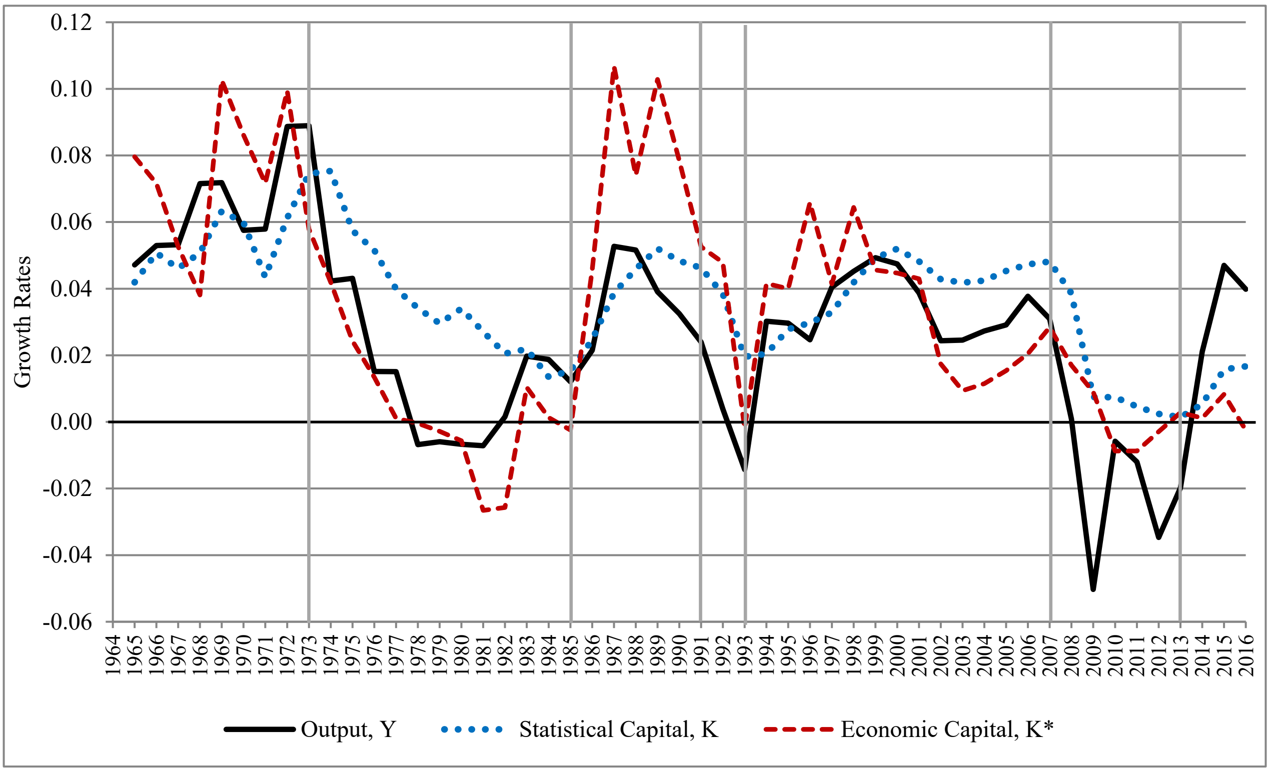

Figure 1. Output (GVA), statistical capital, and economic capital growth rates. Spanish non-financial business sector. Source: Our own elaboration from National Accounts and Escribá-Pérez et al. (2018, 2022).

Table 1. Spanish non-financial business sector growth rates. Values in percentages.

	Subperiods							Whole period
	1964–1973	1974–1985	1986–1991	1992–1993	1994–2007	2008–2013	2014–2016	1964–2016
Output ($\widehat{Y}$)	6.55	1.18	3.69	−0.52	3.43	−2.03	3.60	2.71
Statistical Capital ($\widehat{K}$)	5.46	3.50	4.26	2.90	4.07	1.03	1.26	3.65
Economic Capital ($\widehat{K^*}$)	7.33	0.24	7.67	2.29	3.49	0.14	0.23	3.27

Source: Our own elaboration from National Accounts and Escribá-Pérez et al. (2018, 2022).

Figure 2 shows the evolution of K^*/K over time, allowing visualization of the changes in the relationship between short-run and long-run capital. Thus, values greater than unity indicate that short-run capital is higher than long-run capital, and values less than unity indicate the opposite. In the first subperiod, corresponding to the first expansion phase of the business cycle, economic capital is higher than statistical capital, with the ratio being greater than one and with an increasing trend over the subperiod. In the second subperiod (1974–1985), corresponding to a phase of slowdown in production, there is a change in the trend of the capital ratio: the gap between short-run and long-run capital narrows until 1977. From this year onward, statistical capital, or long-term capital, is higher than economic capital, and this difference begins to increase until the end of the subperiod. In 1986, with the beginning of the new expansion phase, there is a change in trend again: the ratio between the two capitals is still below one, but the gap begins to narrow, although it is interrupted in the crisis subperiod of 1992–1993. In the following expansion subperiod (1994–2007), marked by a surge in ICT investment, the capital ratio increases until the end of the 1990s. Then the trend changes, with the difference between the two capitals decreasing and increasing again from 2003 until the end of the sample.

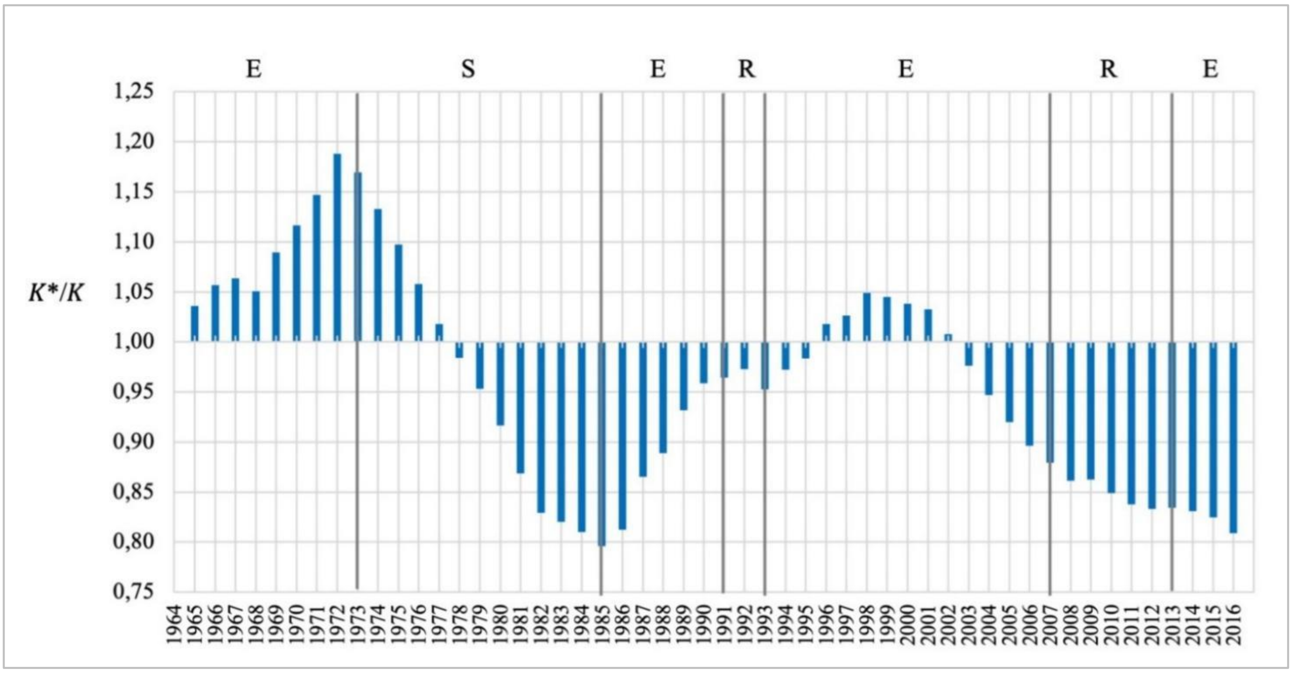

Figure 2. Relationship between economic capital and statistical capital in the different phases of the Spanish business cycle. E: expansion, S: slowdown, R: recession. Source: Our own elaboration from Escribá-Pérez et al. (2018, 2022).

3. Measuring resilience: The dynamic indexes of resistance, adaptability, and the investment and depreciation effects

Our conceptualization of resilience is derived from the literature that studies plant and animal ecosystems and their subsequent extensions to the whole of the natural sciences and demography. When studying the resilience of biological systems, the evolution of their spatial scale, mass, and diversity is monitored. This gives rise to our interest in monitoring capital in a broad sense. In our opinion, from an economic point of view, the best alternative for the area occupied by an ecosystem and the resident species, which represent its biomass and biodiversity, is not territory, human population, or employment, but capital, or the sum of all the cumulative productive factors on which economic growth is based. The analogy with biological systems can be established as follows: the size and composition of capital as substitutes for biomass and biodiversity.

Then, we argue for the use of the dynamics of capital because the dimension, the composition, or any other quasi-permanent feature of an economic system is better represented by a state variable like capital stock than by a flow like labor input or the unemployment rate. Flow variables do not play any role in our indexes because our measure of resilience is obtained by comparing two trajectories of capital stock, one in the short-run that currently captures the effect of impacts and another in the long-run that behaves as if it had withstood and/or absorbed all impacts.

As previously stated, in the face of exogenous shocks, economic resilience is a combination of the ability of the system to adapt and recover quickly its original size and structural shape, and the ability to resist the shocks themselves and avoid being pushed out of its previous equilibrium path. Consequently, the two attributes at the core of the concept of economic resilience are the capacity for adaptation-absorption and the resistance ability to stay close to a benchmark long-run trajectory. Since we are pursuing the measurement of resilience in the short-run during each phase of the business cycle, we need to be able to measure adaptability and resistance in each of these phases of the business cycle. Given the underlying strategy of our approach, these measurements should be based on the relationship between the transient behavior and the asymptotic behavior of the capital stock. We take the behavior of the capital stock as a reliable indicator of the behavior of the economic system, which is constantly exposed to shocks of different nature and intensity. This makes the problem of measuring economic resilience in dynamic terms a rather difficult one. However, the expectation of a richer characterization makes it a priority to adapt the methodology and undertake a resilience study that incorporates dynamic computational aspects into the analysis. To this end, it is essential to completely rethink the mechanics of the aforementioned indexes: we build a backward sequence of overlapping long-run periods that, when subtracted from each other, give us the values corresponding to short periods of time without sacrificing the fundamental relationship between the current evolution of the capital stock and its evolution throughout the BGP.

To measure adaptability and resistance in dynamic terms, we consider two capital stock series:

$$K_t = I_t^G + (1 - \delta_t)K_{t-1} \tag{1}$$

$$K_t^* = I_t^G + (1 - \delta_t^*)K_{t-1}^* \tag{2}$$

where I_t^G is the series for gross investment and the rates δ_t and δ_t^* measure, respectively, statistical and economic depreciation (Escribá-Pérez et al., 2023). The first equation, or statistical measurement of capital, represents the level of capital stock throughout the long-run BGP, which is growing at a constant rate $\bar{\gamma}_K$. The second equation, or economic measurement of capital, represents the capital stock along the transition in the short-run, which grows at a variable rate γ_{K_t}.

$$K_t = K_{t_0} \cdot \prod_{\tau=t_0}^{t} (1 + \bar{\gamma}_K) \tag{3}$$

$$K_t^* = K_{t_0}^* \cdot \prod_{\tau=t_0}^{t} (1 + \gamma_{K_\tau^*}) \tag{4}$$

Assuming that the two series of capital share the same initial value, the case of absolute or perfect resilience does correspond to the case in which $\gamma_{K_t^*} = \bar{\gamma}_K \; \forall t$. However, when as a consequence of shocks (positive or negative, supply or demand) the capital stock moves from the long-run path, there is imperfect resilience, and we can differentiate between the economy's adaptive capacity and resistance to these shocks.

First, we have the index of adaptability.

$$AID_t = \frac{1}{(1+n)}\frac{1}{(t-t_0)}\sum_{\tau=t_0}^{t}\left(\gamma_{K_\tau^*} - \bar{\gamma}_K\right) \tag{5}$$

where $n \in [0,\infty]$ stands for the number of times the K_t^* series encounters the K_t series, crossing or bouncing on it, not counting the initial period in which they are equal by assumption.

Then, we can define a dynamic index of adaptability that allows us to analyze the evolution of this important attribute of economic systems over the successive subperiods into which the full sample has been divided.

$$AID_{dynamic}^{t_F - t_I} = \left(\frac{t_F - t_0}{t_F - t_I}\cdot\frac{1+n_F}{1+n_F-n_I}\right)AID_{t_F} - \left(\frac{t_I - t_0}{t_F - t_I}\cdot\frac{1+n_I}{1+n_F-n_I}\right)AID_{t_I} \tag{6}$$

where t_0 denotes the initial moment of the full sample period, t_I the initial moment of the subperiod we are interested in studying, and t_F the final moment of that subperiod. On the other hand, n_I refers to the number of times that the K_t^* series meets the K_t series from moment t_0 until the moment when the selected subperiod begins, and n_F is the number of times that the two series encounter each other from moment t_0 until the end of that subperiod.

Second, we have the index of resistance, which approaches the variance of the difference $\ln K_r^* - \ln K_r, \forall\ t_0 \le r \le t$.

$$RID_t = \frac{1}{(t-t_0)}\sum_{s=t_0}^{t}\left(\sum_{\tau=t_0}^{s}\left(\gamma_{K_\tau^*} - \bar{\gamma}_K\right) - \frac{1}{(r-t_0)}\sum_{s=t_0}^{r}\left(\sum_{\tau=t_0}^{s}\left(\gamma_{K_\tau^*} - \bar{\gamma}_K\right)\right)\right)^2 \tag{7}$$

Then, we can define a dynamic index of resistance that allows us to analyze the evolution of this second attribute of economic systems over the successive subperiods of the full sample.

$$RID_{dynamic}^{t_F - t_I} = \left(\frac{t_F - t_0}{t_F - t_I}\right)RID_{t_F} - \left(\frac{t_I - t_0}{t_F - t_I}\right)RID_{t_I} \approx Variance\left\{\sum_{\tau=t_I}^{r}\left(\gamma_{K_\tau^*} - \bar{\gamma}_K\right)\right\}_{t_I \le r \le t_F} \tag{8}$$

Finally, we can decompose adaptability into investment and depreciation effects. Actually, what drives adaptability is the sum of the two effects. Sometimes depreciation predominates, but other times, investment does. In any case, the adaptability of the system in terms of a measure based on the rates of growth of capital stock depends on the speed with which old capital is dropped and new capital is incorporated. Using Equations (1) and (2), it is possible to decompose the adaptability index of Equation (5) into two distinct parts: the depreciation effect, which depends on the difference between the statistic depreciation rate δ_t and the economic depreciation rate δ_t^*, and the investment effect, which is related to the two ways of defining the investment rate, one with respect to the short-run economic capital stock $i_t^* = I_t^G/K_{t-1}^*$, and the other with respect to the long-run statistic capital stock $i_t = I_t^G/K_{t-1}$. That is, $AID_t = DEP_t + INV_t$, where

$$DEP_t = \left(\frac{1}{1+n}\right)\left(\frac{1}{T}\sum_{s=1}^{T}\delta_s - \frac{1}{(t-t_0)}\sum_{\tau=t_0}^{t}\delta_\tau^*\right) \tag{9}$$

$$INV_t = \left(\frac{1}{1+n}\right)\left(\frac{1}{(t-t_0)}\sum_{\tau=t_0}^{t} i_\tau^* - \frac{1}{T}\sum_{s=1}^{T} i_s\right) \tag{10}$$

Then, we can define the dynamic depreciation and investment effects over the successive subperiods into which the full sample has been divided as follows.

$$DEP_{dynamic}^{t_F-t_I} = \left(\frac{t_F-t_0}{t_F-t_I}\cdot\frac{1+n_F}{1+n_F-n_I}\right)DEP_{t_F} - \left(\frac{t_I-t_0}{t_F-t_I}\cdot\frac{1+n_I}{1+n_F-n_I}\right)DEP_{t_I} \tag{11}$$

$$INV_{dynamic}^{t_F-t_I} = \left(\frac{t_F-t_0}{t_F-t_I}\cdot\frac{1+n_F}{1+n_F-n_I}\right)INV_{t_F} - \left(\frac{t_I-t_0}{t_F-t_I}\cdot\frac{1+n_I}{1+n_F-n_I}\right)INV_{t_I} \tag{12}$$

where t_0, t_I, t_F, n_I, and n_F represent the same numbers as defined above.

The way we implement the indexes to study adaptability and resistance over a sequence of shorter time periods is based on the prior calculation of the indexes using overlapping long sampling periods. Therefore, when we analyze consecutive short periods, there is no risk of altering the long-term nature of the reference indexes. In addition, each index is calculated by comparing the rates of growth along the transition path with that of the BGP. The values in each subperiod are period-specific. The properties of resistance and adaptability are therefore specific to each period analyzed, so that greater or lesser resistance to shocks in one period may be accompanied by either greater or lesser adaptability in the same period, and without having immediate consequences on the intensities with which resistance and adaptability are experienced in a different period, including consecutive ones.

4. The indexes in action: Results and interpretation

The ideal indexes of resilience, resistance, and adaptability should be computed by combining different categories of capital. However, what should be used as a good indicator of capital (a combination of private and public physical capital, human capital, and natural capital, as it provides a better description of the size and composition of the economic system) is one thing, and what we can use in an empirical exercise, given the availability of quantitative data and the difficulty of combining them into a single capital index, is quite another. In this section, we show the results obtained by computing the dynamic indexes just introduced in Section 3 with the available data on physical capital stocks of the Spanish economy. The full sample period 1964–2016 has been divided according to the subperiods identified in Section 2. Thus, Table 2 provides the numerical values of each of the indexes for the full sample and for each subperiod. Next, Figures 3 to 6 provide a graphical image of the results, organizing the information from Table 2 in different ways to facilitate visual interpretation.

Table 2. Resilience indexes: Adaptability, its splitting into two effects, and resistance. Spanish non-financial business sector.

	Adaptability index	Investment effect	Depreciation effect	Resistance index
Whole period: 1964–2016	−0.00095	0.00103	−0.00198	0.01654
Subperiods				
1964–1973 (Expansion)	0.03683	0.00060	0.03623	0.01111
1974–1985 (Slowdown)	−0.01713	−0.00110	−0.01603	0.02190
1986–1991 (Expansion)	0.04464	0.02344	0.02120	0.00815
1992–1993 (Recession)	−0.03694	−0.01172	−0.02521	0.00074
1994–2007 (Expansion)	−0.00063	0.00347	−0.00409	0.00152
2008–2013 (Recession)	−0.03736	−0.01219	−0.02517	0.00554
2014–2016 (Expansion)	−0.03297	0.00752	−0.04049	0.00114

Source: Our own elaboration.

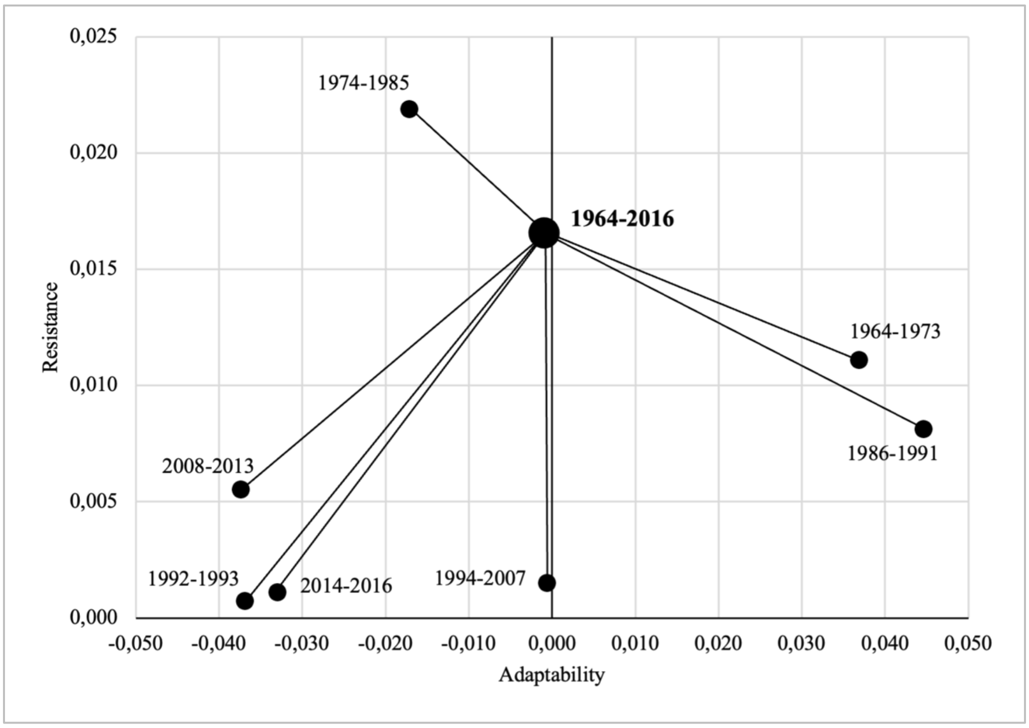

Figure 3. Comparative results with respect to the average for the entire period. Source: Our own elaboration.

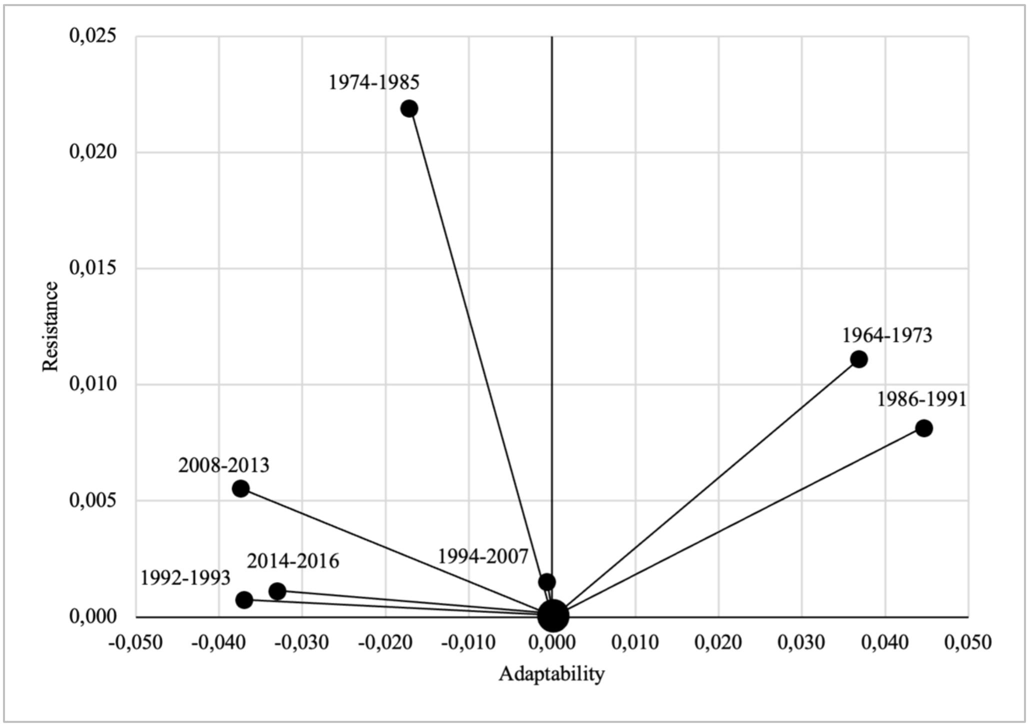

Figure 4. Comparative results with respect to the ideal "Perfect Resilience". Source: Our own elaboration.

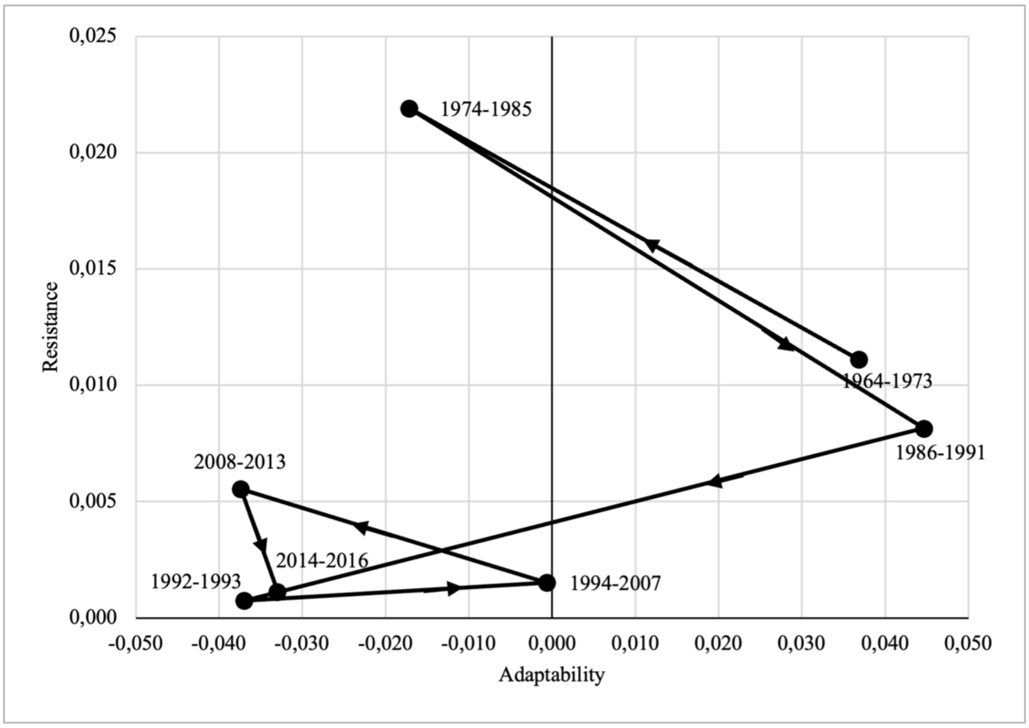

Figure 5. Dynamic evolution of the adaptability and resistance indexes. Source: Our own elaboration.

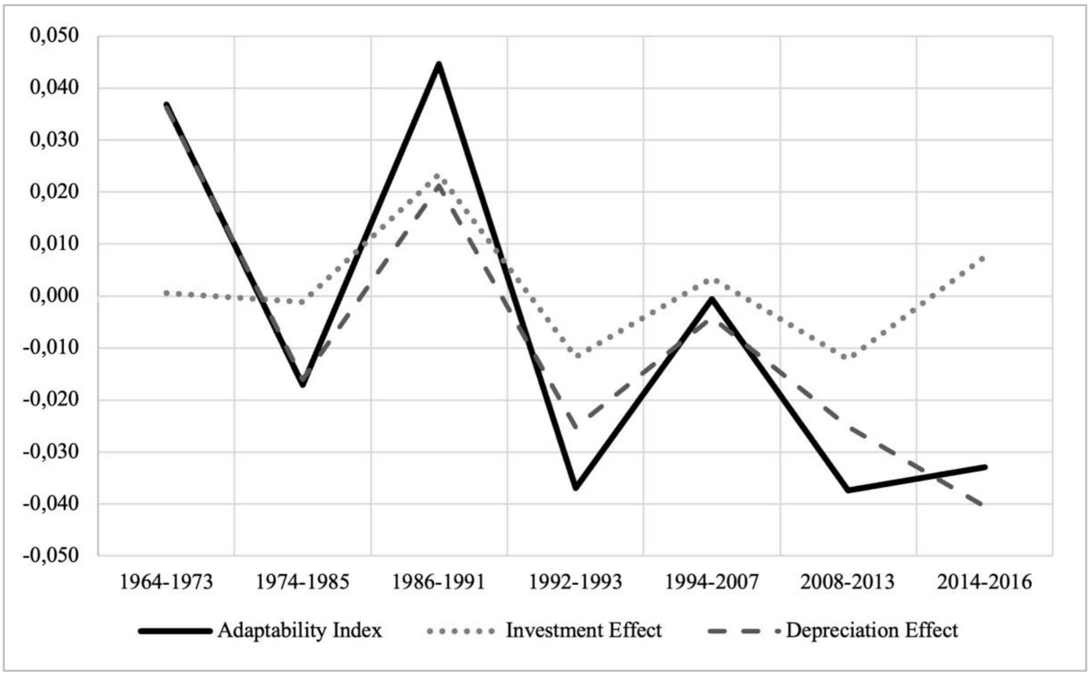

Figure 6. Dynamic evolution of the adaptability index and depreciation and investment effects. Source: Our own elaboration.

In Figure 3, we observe that the Spanish economy, on average, adapts very well to shocks, since adaptability is nearly perfect in the full period between 1964 and 2016, but resistance is far from perfect. With respect to this mean, all subperiods show better resistance except for the years between 1974 and 1985 (crisis), and all subperiods have a worse adaptability score except for the years between 1994 and 2007 (expansion).

In Figure 4, we compare the performance of each subperiod with the point (0,0) of perfect resilience, i.e., perfect adaptability and resistance. The most resilient subperiod of the Spanish economy corresponds to the years of expansion from 1994 to 2007. The remaining subperiods offer mixed results: slightly or moderately imperfect resistance, but much more imperfect adaptability to shocks in either case.

Figure 5 shows a dynamic line connecting the sequence of consecutive subperiods, which are distributed in space according to their adaptability and resistance scores. The transition from the expansion period between 1964 and 1973 to the recession period between 1974 and 1985 entails an increase in adaptability but a decrease in resistance, so no definitive conclusion about the change in resilience can be drawn. As discussed in Section 3, adaptability can be broken down into two underlying effects: investment and depreciation. Table 2 and Figure 6 show the computed values and graphical evolution of the adaptability index and its components. During the transition between the two subperiods, the depreciation effect, with a higher absolute value, appears as the dominant driver of the change in the adaptability index. There is a sharp increase in economic depreciation caused by the acceleration of obsolescence, which in turn was caused by the oil price shocks and the substitution of capital goods triggered by industrial restructuring. This strong economic depreciation, together with increased investment in new capital goods, resulted in the substitution of existing equipment with newer technologies, which ultimately improved the economy's adaptability. Accompanying these changes, shock resistance declined, shown with a variance value that reaches the highest level among all subperiods between 1964 and 2016.

The next movement, from the second subperiod (1974–1985) to the third (1986–1991), which corresponds to an expansion phase, reverses the previous adjustment, bringing the economy almost back to its initial position. The decline in adaptability observed during this transition is equally influenced by both the investment and depreciation effects, which show positive and similar absolute values that add up to each other. Economic expansion stimulated investment, which was reinforced by positive expectations linked to Spain's entry into the European Economic Community (EEC) and liberalizing reforms. Firms invested in new equipment but simultaneously increased maintenance expenditures on existing capital goods, a decision primarily driven by the aim to raise capacity utilization. This expanded the use of older equipment, reducing the economic depreciation rate. Consequently, although investment increased, the lack of substantial substitution of old capital led to a deterioration in adaptability. During this expansionary period, resistance to shocks increased, counteracting the worse adaptability.

A new movement then takes the economy into the short recession of 1992–1993, with a slight increase in adaptability and a substantial increase in resistance, leading to an overall improvement in resilience. This recession was marked by a major loss of economic capital due to the collapse of many small and medium-sized enterprises during the exchange rate crisis, along with scarce acquisition of new equipment. The investment effect shows a small absolute value and contributes significantly to improving adaptability, but the depreciation effect largely offsets this improvement with a larger absolute value. Both values are negative and, when added, adaptability remains substantially unchanged compared to the previous period. The variability recorded in the resistance index was reduced by one-tenth.

The subsequent transition into the long expansion period of 1994–2007 reflects now a truly important improvement in adaptability. This phase is characterized by robust economic growth and a boom in investment, including research and development (R&D) and ICT. Significant changes in production methods led to higher depreciation due to obsolescence, with firms substituting outdated equipment for more advanced technologies. Both the value of the investment effect and the depreciation effect are close to zero and of opposite sign, and consequently the adaptability in this period is perfect. The variance computed in the resistance index shows, compared to the previous period, a slight worsening of the Spanish economy's ability to withstand shocks. Even so, the index value is still within the range of smaller values.

The transition into the Great Recession period (2008–2013) shows a clear deterioration in resilience, as both adaptability and resistance decline. This drop in adaptability, largely driven by the depreciation effect, can be attributed to a sharp decline in demand and credit constraints that limited new investment in capital goods. Consequently, the capital stock aged without being replaced. In this case, the value of the investment and depreciation effects are both of the same sign, with the absolute value of the latter being twice the absolute value of the former. This quantifies the large loss of adaptability observed. The variability recorded in the resistance index increased reflecting the lower capacity of the Spanish economy to resist shocks.

Finally, in the transition to the subsequent recovery period (2014–2016), the Spanish economy shows a slight improvement in how well it adapts to shocks, along with a noticeable increase in its resistance. The resumption of economic growth led to more investment in the productive sector, but also to a larger capital substitution, meaning higher economic depreciation rates. The numerical value of the investment effect is small in absolute terms, which could be behind a significant improvement in adaptability, but it is offset by the negative contribution of the depreciation effect. In any case, the combined results of resistance and adaptability suggest that, as the economic expansion continues, the resilience of the Spanish economy is likely to keep increasing.

Figure 6, as support for the dynamic evolution we have just described, illustrates more clearly the cyclical trajectory of the strength of the Spanish economy to adapt to shocks. This figure also shows how the relative contributions of investment and depreciation effects have evolved throughout the phases of the business cycle. The peaks and troughs in the Spanish adaptability index align with periods of expansion and recession, respectively. However, what matters here is the absolute value of the index. The economy shows greater adaptability to shocks when the index is close to zero. If the absolute value of the index increases, this means that the adaptive capacity weakens. We cannot identify a clear trend in adaptability over the entire sample period. Moreover, the figure confirms that the dynamic evolution of adaptability is mainly driven by the effect of depreciation, and not so much by the effect of investment. It is worth remembering that a value close to zero of the adaptability index may be the result of the sum of two zeros or the sum of two similar values, big or small in absolute terms, but of opposite sign. Figure 6 shows a fluctuating inversion effect, but unlike the depreciation effect, it does not move far from the zero axis.

5. Conclusions

In the study of economic resilience, we can identify at least four key levels of interest for research. First, the concept itself, which is characterized by two main features: resistance and adaptability. Additionally, adaptability can be further broken down into two effects: investment and depreciation. Second, the measurement instrument, which involves recognizing the relevant variables and developing tools such as an index. Third, the measurement process itself, which allows us to characterize the resilience, resistance, and adaptability of the economic system over a given long period of time and over a sequence of consecutive shorter time periods. Finally, once we have a detailed description of the system's resilience properties, we may be interested in understanding the underlying economic causes that explain the results we achieved in the previous stages. However, there is still some ambiguity about what is meant by economic resilience, how it should be conceptualized and measured, what its determinants are, and how it links to long-run growth patterns.

We have made novel contributions to the first three areas. This paper addresses the problem of resilience measurement both at the methodological level and at the empirical level. In studying resilience, we establish a relationship between the short-run and long-run dynamics, or from a macroeconomic point of view, between transitional dynamics and long-run growth. Our approach is aggregate, and we do not analyze sectoral heterogeneities. In particular, we focused on the non-financial business sector of the economy and our capital is the stock of private and productive physical capital. Of course, there are sectors in some economies, such as tourism in the case of Spain, that constitute an important subsystem within the overall economy and would likely require a more specific analysis. However, we cannot perform this exercise for two reasons: because the subsector is not perfectly identified and bounded in national accounts, and because the data needed to conduct a resilience study as disruptive as the one we propose are not currently available.

The resilience of the economy is assessed based on its ability to stay as close as possible to a hypothetical balanced growth path. But it should not be confused with convergence, which is a dynamic property of dynamic systems, since resilience is a structural characteristic, absolute or relative, of the dynamic system. We are not considering an economy that is initially outside the steady state to study how it approaches or moves away. What we have done is to identify two representative trajectories of the economy, one referring to the short-run that is a consequence of initial conditions and successive disturbances, and another referring to the long-run that supposedly has withstood or absorbed all the impacts. Then, we compare these two trajectories and conclude about the structural properties of adaptability and resistance of the system, because these are the two key dimensions of resilience. Accordingly, we do not consider resilience as a one-piece property of economic systems, but rather as a combination of two attributes, and we study quantitatively each of them in isolation before attempting to merge them qualitatively into a single statement. Furthermore, adaptability can be partitioned into a depreciation component and an investment component.

The idiosyncrasy of our approach is that we concentrate on capital and not on employment levels, unemployment rates, or income. Our proposal is based on the comparison between the evolution of capital stock during the transition trajectory and along the balanced growth path. We advocate for the use of this state variable by establishing an association with biological systems: the size and composition of capital as analogues of biomass and biodiversity. In fact, employment tends to overreact more than capital to marginal changes in the economic environment, while capital is a more structural variable that can better capture the material support of economic activity.

In this article, we adapt the resilience indexes defined in Escribá-Pérez et al. (2024) to a dynamic context in order to explore the dimensions of adaptability and resistance, as well as the depreciation and investment effects, throughout the different phases of the cycle. It is quite reasonable to ask: How has resilience evolved over time?, and What are the results reported by indexes in different and successive subperiods? It has been necessary to rethink the mechanics of the aforementioned indexes and implement them by articulating a backward sequence of overlapping long-run periods. In doing so, we find that indexes that were conceived for the calculation of some long-term properties of the economic system, and that require the use of large data samples, can be used to determine the properties of the economic system in short periods of time without sacrificing the fundamental relationship between the current evolution of the capital stock and its evolution throughout the BGP.

Our empirical case study is the Spanish economy during the period between 1964–2016, encompassing different subperiods of expansion, slowdown, and recession. To this end, we have first provided a brief quantitative description of the phases of the different business cycles through which the economy has transited over the course of these more than fifty years. Although we cannot establish a quantitative cardinal for resilience by studying resistance and adaptability in isolation, they can be used to establish ordinal comparisons and, in some cases, conclude about the evolution of resilience. The results show that the absolute value of the adaptability index is mostly stable during expansions and recessions, but Spanish economy adaptability improves during the 1974–1985 period of slowdown and crisis, and is almost perfect during the 1994–2007 expansion. The depreciation effect mimics the adaptability pattern better than the investment effect. On the other hand, the resistance index does not show a clear pro- or counter-cyclical pattern. Spanish economy resistance is particularly weak during the 1974–1985 crisis period, and improves substantially after the 1986–1991 expansion period.

Additionally, we have taken a step further by providing a causal explanation for the results, focusing exclusively on the processes that directly influence the dynamics of the capital stock, while deeper causes, such as institutional, socioeconomic, and political factors, have not been explored in detail and are left for future research. In our opinion, firms improve the economy's adaptability and resilience when they can efficiently substitute capital goods in response to shocks. This has several implications for economic policy. First, it is essential to facilitate and accelerate these substitution processes by promoting new investment and replacing old capital. Second, fiscal incentives should be strengthened to encourage the incorporation of advanced technologies, including tax deductions within the corporate tax system for R&D, adoption, and diffusion. Third, policymakers should reduce costs and frictions that hinder the replacement of obsolete capital, either by removing regulatory or bureaucratic barriers or by implementing reforms to enhance credit availability. Finally, capital adjustment is more effective when accompanied by a dynamic entrepreneurial class and a skilled workforce. Thus, investment in specific human capital for managers and entrepreneurs, active labor market policies, vocational training aligned with industry needs, and digital retraining programs are also key components of an overall strategy.

Author Contributions

Credit author statement: María-José Murgui-García: Conceptualization; Methodology; Formal analysis; Investigation; Data curation; Writing-original draft; Writing-review&editing; Visualization; Supervision; Funding acquisition. Jose-Ramon Ruiz-Tamarit: Conceptualization; Methodology; Formal analysis; Investigation; Data curation; Writing-original draft; Writing-review&editing; Visualization; Supervision; Funding acquisition.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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