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ARTICLE

Natural and cyclical unemployment: A stochastic frontier decomposition and economic policy implications

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Abstract

This work splits effective unemployment into two components: natural unemployment, and cyclical unemployment. For that purpose, an estimation of the stochastic cost frontier is performed. The study is focused on the 17 autonomous communities in Spain over the period 1982–2012. Results evidence greater importance of the natural component as the principal determinant of effective unemployment. When comparing these results with those obtained applying univariate filters, the distribution in the components of the effective unemployment changes, increasing the importance of cyclical unemployment. This result indicates that the policymakers should have a greater power to implement aggregate demand policies.

KEYWORDS
decomposition of unemployment, labor market, stochastic frontiers, unemployment rate

JEL CLASSIFICATION
E24, J08, J64, R23

1 | INTRODUCTION

The Spanish labor market over the past few decades has been characterized by having generated exceptionally high unemployment rates when compared to those seen elsewhere in Europe (Bentolila & Jimeno, 2003; Jaumotte, 2011). The explanations, as to the reasons, behind such high and persistent levels of unemployment, have been set out in many academic papers.[1] A further issue which has been the subject of much inquiry in the literature (Bande & Karanassou, 2013; Bande et al., 2008; Jimeno & Bentolila, 1998; Porras & Martín-Román, 2019; Romero-Ávila & Usabiaga, 2008) is the enormous disparity between unemployment rates in the various regions of Spain and their persistence over time.

The objective of this paper is to put forward a methodological proposal to divide the actual unemployment rate into two components: the natural unemployment rate and the cyclical unemployment rate. This issue is extensively addressed in the literature based on the macroeconomics of the labor market, but in a very different way as done in this piece of research. Here, we assume that cyclical unemployment cannot take negative values since it is difficult to imagine in a world with more unemployed persons than the sum of structural and frictional unemployment, even when the economy is booming. That would be the case when the natural rate of unemployment (NRU, hereinafter) is considered to be the same as the notion of nonaccelerating inflation rate of unemployment (NAIRU). We do not follow this path in this paper. Instead, we make use of a composed error model econometric method to ensure that the nonnegative cyclical unemployment assumption is satisfied. To sum up, the main aim of this paper is to estimate the NRU with the stochastic frontier (SF, hereinafter) technique and then to compare it with some of the most popular procedures to do it, such as the Hodrick–Prescott (HP, hereinafter) and Baxter–King (BK, hereinafter) filters or the quadratic-trend (QT, hereinafter) regression.

This paper contributes to the unemployment rate decomposition literature.In the same vein, we might assert that we align ourselves with the compartmentalization view of the macroeconomics of the labor market. According to Karanassou et al. (2007, 2010), this is only one of the competing theories to explain aggregate labor markets functioning, together with the "chain reaction theory (CRT) or prolonged adjustment view" and the "hysteresis hypothesis." By assuming the unemployment compartmentalization standpoint, we would be adopting some of the economic principles usually linked to a "frictionless equilibrium" in the labor market (Karanassou et al., 2007). However, the concept of NRU is far from being a clear-cut notion even within the compartmentalization literature (Rogerson, 1997). As we will discuss in greater detail later, our approach fits well with the some of definitions of the NRU enumerated by Rogerson (1997). At the same time, HP filtering is considered by Rogerson (1997) as another conceivable definition of what the NRU actually is. In this way, we think that this article not only provides a fresh estimate of the NRU to an already extensive literature but clarifies our own NRU concept. Hence, the comparison between our SF estimation of the NRU and those of the HP, BK, and QT could be thought of as an appraisal of different conceptions of the NRU within the compartmentalization hypothesis.

With regard to the innovation and the value added to the paper, first we should point out that the literature on SF estimation of the NRU is quite scarce compared to other sorts of NRU estimates. After the seminal work by Hofler and Murphy (1989), there are only a few additional references. To the best of our knowledge, only the works of Warren (1991), Bodman (1999) or, more recently,

[1] The exceptional works of Blanchard and Wolfers (2000) and Blanchard (2006) highlight the role played by labor institutions during high unemployment rates at the face of adverse macroeconomic shocks. Another study that provides information on the topic under discussion is the work of Nickell et al. (2005).

Aysun et al. (2014) and Cuéllar-Martín et al. (2019) could be deemed to be closely related to this article. Furthermore, and as a second innovative element, here we develop a theoretical framework to justify our empirical approach of modeling the NRU as a lower envelope by using the SF estimation (i.e., a cost frontier in the usual terminology). In addition, we offer, for the first time as far as we know, a systematic statistical comparison of the SF estimates of the NRU with the much more standard estimates by means of time-series filtering techniques. That contrast between different econometric procedures could serve as an assessment tool for making informed decisions. It is worth mentioning that such an assessment should be carried out not in terms of goodness of prediction because in the end the NRU concept is unobservable, but in terms of economic policy implications we will explain it below.

To carry out the empirical strategy, the present work takes advantage of the spatial and temporal variability of regional unemployment rates in Spain. We make use of a database that provides information on the 17 autonomous communities in Spain for the period between 1982 and 2012.[2] Regarding the main results obtained, our methodological proposal reduces the weight of the natural component of unemployment in favor of the cyclical, as compared to the NRU estimates using time-series filtering techniques. These results might have significant potential implications for economic policy as they could provide a greater scope of action for policymakers seeking to control unemployment. More precisely, our results seem to suggest that the scope for Keynesian economic policy measures (i.e., aggregate demand stimulus policies) is greater than previously considered, as a consequence of the larger scale of cyclical unemployment.

The remainder of the work is organized as follows. Section 2 outlines the theories on unemployment compartmentalization and reviews the literature on unemployment decomposition. Section 3 shows a formal model connecting our conceptual framework to our empirical strategy. Section 4 sets out the methodological aspects, both in terms of the SF analysis used in the decomposition as well as the univariate filters employed in the subsequent comparison. Section 5 details the database used and provides a brief explanation of the variables applied in the study. Section 6 offers the main results obtained when decomposing unemployment through the SF. Section 7 compares SF estimates with the decompositions obtained from the univariate filters. Section 8 sets out certain economic policy implications. Finally, Section 9 sums up the main conclusions of the present work.

2 | UNEMPLOYMENT COMPOSITION: THEORIES AND FACTS

2.1 | Theories on unemployment compartmentalization

As Karanassou et al. (2007, 2010) state, there are three fundamental views of the labor market regarding the movements in unemployment: (1) the frictionless equilibrium view, (2) the hysteresis view, and (3) the chain reaction theory, or prolonged adjustment view. Besides other implications for the aggregate labor market modeling or the macroeconomic policy, that distinction entails a conception of how the actual unemployment rate might be broken down into different components, which is the main aim of this piece of research.

In the first place, the "*frictionless equilibrium view*" establishes a clear-cut distinction between two types of unemployment: natural and cyclical unemployment. Within this hypothesis, the

[2] Spanish autonomous communities correspond to the second level (NUTS-2) of the Nomenclature of Territorial Units for statistics. For further information concerning the concept of NUTS, see http://ec.europa.eu/eurostat/web/nuts/overview.

former is assumed to be a long-run equilibrium concept, giving rise to the notion of NRU, whereas the latter is associated with short-run fluctuations. This, in turn, leads to the idea of compartmentalization, which suggests that the unemployment rate can be decomposed into its two constituent components by means of econometric procedures. This interpretation of the macroeconomics of the labor markets has been defended on the grounds of the analysis of the role of shocks and institutions (see, among others, Blanchard & Wolfers, 2000; Layard et al., 1991), of the structuralist theory of unemployment (see, for instance, Phelps, 1994; Phelps & Zoega, 2001), or from a purely institutionalist standpoint (e.g., Nickell et al., 2005); see Blanchard (2006) for an assessment of this literature.

Second, and fairly opposed to the previous hypothesis, the "*hysteresis view*" affirms that all the short-run fluctuations automatically turn into long-run changes in the unemployment rate (Blanchard & Summers, 1986, 1987; Røed, 1997; León-Ledesma, 2002; Raurich et al., 2006). In this way, transitory business cycle shocks bring about permanent variations in the unemployment rate. Hence, according to this theory, it is not possible to distinguish long-run equilibrium from cyclical fluctuations. In practical terms, this theory implies that the unemployment rate in a specific period of the time strongly depends on its past values. From an econometric viewpoint, the above would correspond to an unemployment rate being characterized by not following a "random walk." That is, with the presence of a unit root in such a series, with a value of the autoregressive parameter equal to unity.

Third, the "*prolonged adjustment view*" or "*chain reaction theory*" of unemployment establishes that the labor market adjusts only slowly to external shocks. There are several reasons for this sluggish adjustment, among them we could highlight the following: (1) employment adjustment costs (e.g., firing and hiring costs; see, for instance, Cabo & Martín-Román, 2019, for a recent formal model on that); (2) wage staggering (Ascari, 2003; Karanassou & Sala, 2012); (3) price stickiness (Andersen, 1998); or (4) labor force participation adjustment (see Martín-Román et al., 2020, for a fresh analysis with a regional economics perspective). This hypothesis might be thought of as an intermediate case between the "*frictionless equilibrium view*" and the "*hysteresis* view." Moreover, this theory addresses the idea of "frictional growth," a phenomenon that encloses the interplay of lagged endogenous variables (frictions) and growing exogenous variables (growth drivers). Thus, when the exogenous variables have nonzero long-run growth rates (e.g., capital accumulation, population growth) unemployment does not gravitate towards its NRU. The CRT was originally developed by Karanassou and Snower (1996, 1997, 1998). In the same vein, see also Karanassou et al. (2003, 2004, 2006, 2007, 2010).

On the basis of the aforementioned reasons, there is currently some debate on whether or not compartmentalization is an appropriate stylized representation of the aggregate labor market. In this sense, Karanassou et al. (2007) state that compartmentalizing the unemployment rate into its natural and cyclical components does not fit with the European (or even the United States) experience since the 1980s, providing theoretical arguments for their point: in a frictionless world, even allowing for imperfect competition in goods and labor markets, the short-run and long-run are separated from each other. Thus, temporary labor demand shocks generate short-run variations in unemployment, while in the long run the NRU responds to changes in the capital stock, the labor force, or the technological level. If, on the contrary, one assume that labor market decisions are characterized by prolonged adjustments (see, for instance, Kunz, 2009), then the compartmentalization of the natural and cyclical unemployment rates vanishes and is only valid under rather restrictive assumptions. Furthermore, Karanassou et al. (2010) or Bande and Karanassou (2013) maintain that under the phenomenon of "frictional growth," that is, the interplay of growing variables with labor market lagged adjustment processes, the effective natural rate does not

converge towards the NRU and, therefore, the latter cannot be regarded as a reference point for policy recommendations.

At this point, we should make clear, however, that the approach proposed in this paper assumes the compartmentalization of unemployment into its natural and cyclical components. Put differently, it might be said that we align ourselves with the "*frictionless equilibrium view*" to a great extent. Although the "hysteresis" and the CRT views have challenged the "*frictionless equilibrium view*" in recent years, we still feel that the latter is still a widespread view. In the same vein, a recent paper by Blanchard (2018) questions the concept of NRU itself.[3] He analyses critically the notion of NRU from both macroeconomic and microeconomic grounds. Nevertheless, and despite this criticism, Blanchard finally states that: "Policymakers should keep the natural rate hypothesis as their null hypothesis, but also keep an open mind and put some weight on the alternatives." Therefore, in our view, this statement reinforces the methodological approach followed here.

Furthermore, we find several motives to keep on using this interpretation on the aggregate labor market functioning. For example, all that literature analyzing the so-called gap version of Okun's law precisely correlates the cyclical component of the unemployment rate with the business cycle, measured usually by means of the cyclical component of the GDP time series too. This approach tacitly assumes the compartmentalization view and has produced, and still is producing, a great amount of academic work; see, for instance, Lee (2000), Freeman (2000), Cuaresma (2003), Adanu (2005), Perman and Tavera (2005), Apergis and Rezitis (2003), Villaverde and Maza (2007, 2009), Marinkov and Geldenhuys (2007), Moosa (2008), Herwartz and Niebuhr (2011), Ball et al. (2013), or Bande and Martín-Román (2018). Therefore, it could be affirmed that the compartmentalization view is implicitly adopted in this extensive research field. Second, and despite the challenging approaches of the hysteresis and prolonged adjustment theories, the compartmentalization view is still inherent in many of the works modeling the macroeconomics of the labor markets by preeminent scholars nowadays. Some current examples of this strand of research are Daly et al. (2012) and Diamond (2013). Hence, although this second motive might be considered as an "argument from authority," we still feel it is a valid reason.[4] The third argument in favor of following the compartmentalization view has to do with the regional economics perspective of this paper. Thus, it has been quite common to make the use of the compartmentalization hypothesis when analyzing the aggregate regional labor market. Some outstanding examples of this literature are Marston (1985), Partridge and Rickman (1997), López-Bazo et al. (2005), and Cracolici et al. (2007). Again, an extensive strand of research is adopting implicitly the approach followed here (as in the case of the first argument). A final reason is related to economic policy objectives. In the aforementioned paper, Blanchard (2018) also states that: "the general advice must be that central banks should keep the natural rate hypothesis (…) as their baseline."

In any case, and despite asserting that our paper follows the mainstream view of unemployment compartmentalization, there will be several features that distinguish our approach from those other more standard empirical methodologies (e.g., filter decompositions) described in a later subsection. The most remarkable difference is that we elaborate a formal framework in which cyclical unemployment cannot be associated with negative values and, even more importantly, we employ an econometric technique to guarantee that such an assumption is fulfilled. More specifically, we apply a composed error model to break down the unemployment rate. The SF

[3] It is worth mentioning though that Blanchard uses the concepts of NRU and NAIRU interchangeably, which is not the case in this paper (see the next subsection).

[4] We also acknowledge here that long ago, many prominent scholars criticized the usefulness of this theoretical tool, the monographic issue of the *Journal of Economic Perspectives*, vol. 11, issue (1), Winter 1997, is a good example.

methodology has been already used previously with this purpose. Thus, the seminal work by Hofler and Murphy (1989) established the basic foundations to perform aggregate unemployment breakdown by means of this technique. Then, the studies of Warren (1991), Bodman (1999), and more recently Aysun et al. (2014) have followed this path. In a later subsection, we will review this literature in more detail.

2.2 | A reflection on the concept of NRU

As is obvious from the previous discussion, the NRU plays a key role in this research. However, that concept is far from being a crystal-clear idea, rather it is a polyhedral notion that has been used differently by different authors during the 1980s and the 1990s. Following Rogerson (1997), among these alternative definitions of the term, we could find (1) the average rate of unemployment (Blanchard & Fischer, 1989), (2) the equilibrium rate of unemployment (Blanchard & Fischer, 1989; Johnson & Layard, 1986), (3) the unemployment in the long run (Johnson & Layard, 1986), (4) the normal unemployment rate that results when workers and firms correctly perceive the levels and rates of change of price and wages (Hall & Lilien, 1986), (5) the steady-state rate of unemployment (Mankiw, 1994), (6) the lowest sustainable rate of unemployment (Auerbach & Kotlikoff, 1995), (7) the trend component of unemployment generated by the HP filter[5] (Rogerson, 1997), (8) the efficient rate of unemployment (Clark et al., 1979), and (9) the unemployment at full employment (Hahn, 1980).

Although it could seem tempting to paraphrase Solow (1986): *"*(…) it is not clear what we are talking about when we talk about the natural rate," we really believe that the underlying issue is that, frequently, different economists are talking about different clear-cut concepts. In this paper, we aligned ourselves with some of the aforementioned views on the NRU. We deem that our concept of the NRU fits well with definitions (6) "lowest sustainable rate of unemployment" and (8) "efficient rate of unemployment" and, to some extent, with definition (9) "unemployment at full employment," if we assume that full employment is that level associated to the best scenario regarding the state of the business cycle. Moreover, it is worth stressing that in this paper our main objective is to compare and contrast the estimates of the NRU attained with the SF technique with those of the definition (7) "trend component of unemployment generated by the HP filter." As a matter of fact, the list provided by Rogerson (1997) is rather useful to position our paper in the literature. From our standpoint, this piece of research might be thought of as a methodological proposal to estimate the concept of NRU understood as an "efficient rate of unemployment" and then to compare such an estimate with that of the definition (7) or with those obtained by using other types of time-series filters.

At this point, one important clarification should be made concerning the terms NRU and NAIRU. Although the two concepts are frequently used indistinctly, there are several differences that call into question that the NRU and the NAIRU are truly equivalent concepts. Following the work of Espinosa-Vega and Russell (1997), the two notions stem from quite different schools of economic thought. Moreover, Tobin (1997) maintains that "the NAIRU and the NRU are not synonyms." The NAIRU in relation to the macroeconomic level, in a nutshell, relates observed unemployment to inflation. Should the effective unemployment rate exceeds the NAIRU, then the inflation rate ought to fall and vice versa. In contrast, following Grant (2002), the NRU is

[5] Actually, Rogerson (1997) attributes this definition to Christiano. Allegedly, this definition was given in a private conversation between the two of them.

an equilibrium unemployment rate which is mainly determined by the institutional and demographic characteristics of the economy.

For the purposes of the present work, what is important is to realize that the concept of NAIRU is linked to a cyclical unemployment rate that could take negative values at certain periods (those in which the inflation rate rises). After all, a relatively simple estimation of the NAIRU is the intersection of an expectations-augmented Phillips curve with the "X" axis, with the effective unemployment rate being either higher or lower than the said value. Hence, the notion of NAIRU proves extremely useful in order to understand inflationary pressures in macroeconomic models. Nonetheless, if we considered the NAIRU as the sum of frictional and structural unemployment (as some textbooks do), that would be equivalent to stating that such sum should be greater than effective unemployment during periods of increasing inflation. Therefore, it is easy to understand why the NAIRU is an influential macroeconomic notion. But taking a more labor-economic-oriented perspective, it is a bit complicated to conceive a labor market in which there are less unemployed persons than the sum of those unemployed workers as a consequence of structural reasons plus those unemployed individuals as a consequence of imperfect information (frictional unemployment). Put differently, if we think of a more or less conventional labor market, it is difficult to imagine a situation in which there are "negative" unemployed workers by cyclical motives, which would be the case when the NAIRU is higher than the actual unemployment rate. This is so because unemployment is always a positive number in labor market modeling. To sum up, we recognize the value of the NAIRU as an abstraction to interpret the inflation rate movements in macroeconomic models, but we do not follow that path here. Instead, we focus on the NRU idea and suppose that all the components making up that unemployment rate have to be positive numbers. To ensure this last assumption, we make use of the SF technique. This is our methodological approach, which will be assessed by comparing our estimates with the more standard procedures to break down unemployment explained in the next subsection.

2.3 | Empirical strategies to decompose the unemployment rate

Decomposing the unemployment rate into its different types is a recurring theme in economic literature, for which a range of different methods have been used.[6] One common option when obtaining the components of effective unemployment is to use univariate statistical filters to split the unemployment rate into various elements. Two of the most widely used filters are undoubtedly the HP filter (Hodrick & Prescott, 1997) and the BK filter (Baxter & King, 1999). These filters are usually accompanied by decomposition through the QT decomposition, most probably due to the simplicity of its application.

The HP filter has often been used when estimating Okun's law in an effort to extract the natural component and the cyclical component from effective unemployment (Adanu, 2005; Apergis & Rezitis, 2003; Ball et al., 2013; Perman & Tavera, 2005; Villaverde & Maza, 2007, 2009). The QT decomposition has also been widely used in economic literature related to Okun's law, most likely because it offers very similar results to the HP filter (Adanu, 2005; Villaverde & Maza, 2007, 2009). Finally, there are also various studies in which the BK filter has been used in the same context as the two previous ones (Apergis & Rezitis, 2003; Freeman, 2000; Villaverde & Maza, 2009). The economic literature has also drawn on another set of "more complex" econometric techniques in an attempt to obtain the various components of effective unemployment. Prominent among

[6] The work of Bean (1994) provides a comprehensive review of the topic in hand.

these are the models based on the Phillips curve to estimate the natural component of effective unemployment (Apergis, 2005; Blomqvist, 1988; Hahn, 1996), techniques based on the Kalman filter (Moosa, 1997; Mocan, 1999; Salemi, 1999), or estimations based on structural autoregressive vectors (King & Morley, 2007).

However, few studies have been found which use the SF approach to decompose the effective rate of unemployment. One of the pioneering works in this sense is Warren (1991) which uses frontier estimation to obtain the frictional component of the unemployment rate. Warren (1991) takes matching models in the labor market as a starting point. With this background, he applies an approach based on a model of employment growth when the economy is in the steady state to derive the expression of the unemployment rate in the steady state.[7] At a second stage, and by applying an ordinary least squares model, Warren (1991) obtains the mean unemployment rate for the U.S. manufacturing industry between April 1969 and December 1979. An SF of production is subsequently applied to determine frictional unemployment in the manufacturing industry. Finally, by subtracting both estimated rates a measure of inefficiency for the said labor market is derived.

Another study carried out along the same line is that of Bodman (1999) who takes the theoretical model set out in Warren (1991) as a starting point. The main differences emerge from the regional perspective (the analysis is carried out for all the states in Australia) and from how the inefficiency term of the error is modeled, which is estimated following the proposal of Battese and Coelli (1995). Having obtained frictional unemployment and the inefficiency of the error term, Bodman (1999) finds a positive effect on the inefficiency of Labor Party administration in most of the states analyzed.

One study more closely aligned to the approach adopted in the present research is that of Hofler and Murphy (1989). These authors draw on a database of unemployment rates containing both transversal and temporal information for the United States, considering that there is a lower envelope function which the authors link to the notion of the frictional unemployment rate. They model frictional unemployment using deterministic components such as the SF in its cost version (a lower frontier), and the distance from that lower frontier to effective unemployment which they term "*excess supply unemployment*" in the labor market.[8] At a second stage, they find that it is the variables related to social transfers, the size of the youth labor force, female participation rates, educational attainment, and net migration rate, which account for both the level of frictional unemployment in each state as well as the changes to occur between 1960 and 1979.

Finally, in the research carried out by Aysun et al. (2014) elements from the three previous studies are combined, using the modeling of one upper and one lower SF to decompose the unemployment rate into its various components. On the one hand, they use a model and a method that are similar to that used in Warren (1991) to extract the frictional component of unemployment. They also apply a cost SF to ascertain the structural component of the unemployment rate as was done in Hofler and Murphy (1989), using a specification of the expectations-augmented Phillips curve.

[7] It is precisely the use of information concerning vacancies which means that in the present work we are unable to apply Warren's approach (1991). It is a well-known fact that information concerning vacancies in Spain is extremely poor.

[8] The model put forward in Hofler and Murphy (1989) to illustrate frictional unemployment corresponds to the following equation: $U_{tj} = \underbrace{\beta_0 + \beta_1 t + \beta_2 t^2 + w_{tj} + \vartheta_{tj}}_{F_{tj}}$. where U_{tj} refers to the unemployment rate during period t and state j, F_{tj} encompasses the components of frictional unemployment and ϑ_{tj} reflects excess supply. The lower SF (cost frontier) approach is used to separate w_{tj} from ϑ_{tj} and to find the lower frontier which corresponds to the frictional component of unemployment.

The authors thus obtain a measure of structural unemployment which is always lower than the effective component.

3 | THEORETICAL FRAMEWORK

3.1 | The model

In this section, we elaborate a theoretical model in order to link our conceptual setting with our methodological approach. As this model is totally instrumental in grasping the basic underlying idea in this paper, it will be constructed as the simplest model possible. To fix ideas, we define the three types of unemployment we are going to model in the same way as basic economics textbooks do (see, for instance, Krugman et al., 2011): Frictional unemployment (U^F) is unemployment due to the time workers spend in a job search; structural unemployment (U^{ST}) is unemployment that results when there are more people seeking jobs in a labor market than there are jobs available at the current wage; cyclical unemployment (U^C) is a deviation in the actual rate of unemployment from the natural rate due to downturns in the business cycle. For the sake of simplicity, we begin with a constant labor force (i.e., it does not depend on any variable, particularly it does not depend on the real wage rate):

$$L^S = \bar{L} = 100. \tag{1}$$

The previous assumption normalizes the size of the labor force and allows us to pass from unemployed persons to the unemployment rate straightforwardly. Then we use a quite standard upward sloping aggregate effective labor supply in the employment (N) and real wage (W) space:

$$N^S = \rho_1 W - \rho_0. \tag{2}$$

These two graphical devices are displayed in Figure 1. The difference between L^S and N^S highlights the fact that not all active workers are immediately available for work. As the market real wage increases, it exceeds the "dynamic" reservation wage (or that of the job-search theory) of a higher number of workers, with the latter more willing to accept the jobs they find. As a result, the distance between L^S and N^S is lower for higher salaries. The said horizontal difference between the two curves is what we will call later frictional unemployment (U^F).

To complete the system, the aggregate labor demand is also linear. However, this function will depend on the state of the business cycle (y). We will assume that if the cycle is booming the aggregate labor demand will shift outwards in a parallel way and the opposite is true when the business cycle is in a slowdown or a bust. Put in other words, and again for the sake of simplicity, we suppose that the state of the business cycle affects the position of the labor demand but not its slope. In more formal terms:

$$N^D(y) = \pi_0(y) - \pi_1 W. \tag{3}$$

With these three basic relationships, it is rather straightforward to decompose total unemployment into three main categories, following in this sense the compartmentalization hypothesis. To illustrate this, let us first assume that the state of the business cycle is at its maximum level ($y^{\max}$), which in turn entails that the labor demand reaches its maximum level too (i.e., it is

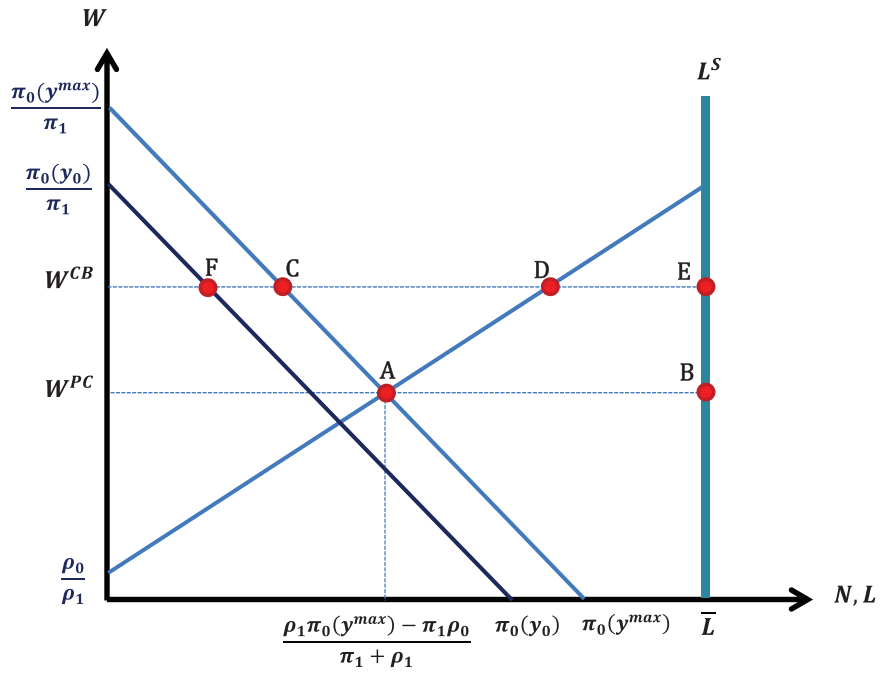

FIGURE 1 Frictional, structural and cyclical unemployment. *Source:* Authors' own. [Colour figure can be viewed at wileyonlinelibrary.com]

located to the rightmost possible position). If we additionally suppose that the real wage rate is at its competitive level (W^{PC}), that is, where the effective labor supply and labor demand meet each other, the equilibrium employment $N^* = \frac{\rho_1\pi_0(y^{\max})-\pi_1\rho_0}{\pi_1+\rho_1}$ is thus associated with a certain level of unemployment: $U^F_{PC} = \bar{L} - \frac{\rho_1\pi_0(y^{\max})-\pi_1\rho_0}{\pi_1+\rho_1}$. This unemployment, which is displayed as the distance $U^F_{PC} = \overline{AB}$ in Figure 1, is the conventional notion of frictional unemployment since it represents workers that, despite being actively looking for a job, do not accept a job offer for such a low real wage.

If we consider an above equilibrium real wage rate like W^{CB} (as a consequence, for instance, of collective bargaining agreements), the new situation would be characterized by lower frictional unemployment $U^F_{CB} = \overline{DE}$, as more workers are willing to accept job offers. However, a new type of unemployment would emerge as a consequence of a pure labor supply surplus $U^{ST}_{CB} = \overline{CD}$. This typology of unemployment is usually named structural unemployment, especially in a theoretical framework with homogeneous labor input (i.e., with one single real wage rate) like ours.

It is important to recall that the aforementioned scenario is linked to a labor demand at its maximum level. Nonetheless, the state of the business cycle is a variable that normally is below its maximum, which in turn brings about that labor demand is located to the left of the one related to that maximum level. In Figure 1, we depict a labor demand associated with a state of the business cycle $y_0 < y^{\max}$ to illustrate this point. In such a case, a new form of unemployment, other things equal, arises. That sort of unemployment is displayed as $U^C_{CB} = \overline{FC}$ in Figure 1 and will be called cyclical unemployment.[9]

[9] We will delve into the concepts of frictional, structural, and cyclical unemployment later.

To recapitulate, from the previous discussion we might state that we have an unemployment function depending only on two arguments: the real wage rate and the state of the business cycle. As is obvious from Figure 1, when the real wage rate rises, unemployment increases too. On the other hand, the business cycle shifts the labor demand outwards when booming and inwards when slowing down or busting, and, thus, unemployment is to be inversely related to the variable y:

$$U = U(W, y); \frac{\partial U}{\partial W} > 0; \frac{\partial U}{\partial y} < 0. \tag{4}$$

Now, for the sake of convenience, we assume that the unemployment function is additive in its two arguments:

$$U(W, y) = U_1(W) + U_2(y). \tag{5}$$

Using Equations (1) and (3), the additivity of the two components of unemployment is fulfilled due to the linearity of the system defining the functioning of the labor market. We could even provide a more specific functional form for the unemployment rate function (because the total labor force has been normalized to 100, and, therefore, one percentage point is simply a worker):

$$U(W, y) = \bar{L} - \pi_0(y) + \pi_1 W. \tag{6}$$

This assumption connects the present theoretical setting with the previous compartmentalization view of the unemployment rate, being the NRU the part depending on the real wage rate: $U_1(W) = U^{NR}(W)$, whereas the cyclical rate of unemployment is the part depending on the business cycle: $U_2(y) = U^C(y)$.

To be more precise, we define the NRU as the addition of frictional unemployment and structural unemployment. The NRU might be stated as the total labor force minus the number of persons employed when the real wage rate is set over its competitive level and the demand for labor is calculated at its maximum size, that is, when the state of the business cycle is $y = y^{\max}$. In formal terms and making use of our theoretical setting:

$$U^{NR}(W|y^{\max}) = \bar{L} - \pi_0(y^{\max}) + \pi_1 W. \tag{7}$$

On the other hand, the cyclical rate of unemployment might be defined, for a real wage rate over the competitive level W^{CB}, by assessing the labor demand when the business cycle is at its maximum minus the labor demand when the business cycle is measured at its actual level. Formally,

$$U^C(y) = N^D\left(y^{\max}, W^{CB}\right) - N^D\left(y, W^{CB}\right) = \pi_0(y^{\max}) - \pi_0(y). \tag{8}$$

3.2 | From the model to the empirical strategy

Before moving on forward, we should make a brief reflection on the role of the real wage rate. As we are implicitly considering that labor input is homogeneous in the model, there is only one single real wage rate. Nevertheless, we account for the possibility that the real wage rate is

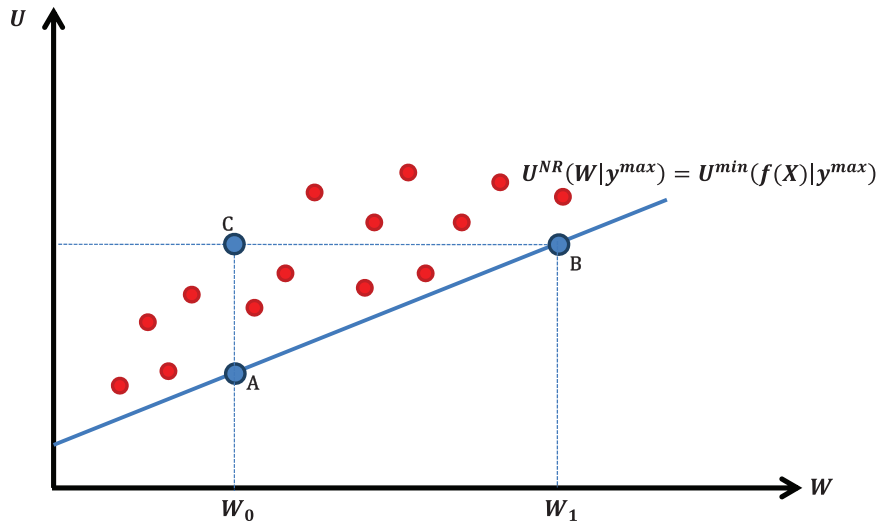

FIGURE 2 Natural unemployment as the lower envelope of total unemployment. *Source:* Authors' own. [Colour figure can be viewed at wileyonlinelibrary.com]

actually a variable affected by a vector of factors $X = (X_1, X_2, \ldots, X_n)$, such as the occupational mix, labor market institutions, or demographic determinants (e.g., age or sex): $W = f(X)$. For this reason, Equation (7) might be rewritten in terms of those determinants in the following way:

$$U^{NR}\left(f\left(X\right)|y^{\max}\right) = \bar{L} - \pi_0\left(y^{\max}\right) + \pi_1 f\left(X_1, X_2, \ldots, X_n\right). \tag{9}$$

Equation (9) relates the NRU with some determinant factors other than the business cycle, which is the main element behind cyclical unemployment. The problem with (9) is that it is to be estimated taking into consideration that the state of the business cycle ought to be at its maximum level. To overcome this difficulty, we make use of a composed error econometric model by means of an SF technique. The idea behind this approach is that when the state of the business cycle is at its maximum, then the cyclical unemployment rate should be zero by a hypothesis: $U^C(y^{\max}) = 0$. Following this reasoning, the NRU could be interpreted as a lower envelope of actual unemployment figures. Put in other words, the NRU could be conceptualized as a minimum unemployment rate attained when the GDP growth is maximum. In formal terms, that might be expressed by

$$U^{NR}\left(W|y^{\max}\right) = U^{\min}\left(f\left(X_1, X_2, \ldots, X_n\right)|y^{\max}\right). \tag{10}$$

This is what is displayed graphically in Figure 2. The solid line depicted in that figure reflects the NRU as a function of the real wage rate, which in turn is a summary variable for the aforementioned vector X. That line is positively sloped as it can be easily checked from Equation (7), and because of the reasons previously described.

In order to clarify our empirical strategy, let us compare some highlighted points in Figure 2. Both at point A and point B, located just over the frontier, unemployment is totally made up of natural unemployment because the state of the business cycle is at its maximum, which implicitly

entails that cyclical unemployment is zero. We would observe in our data a lower unemployment rate at point A, $U(A) = U(W_{0,}y^{\max}) = U^{NR}(W_0)$, just because the real wage rate is lower than at point B, $U(B) = U(W_{1,}y^{\max}) = U^{NR}(W_1)$. On the other hand, point C would be associated with the same unemployment level as point B; however, the composition would be rather different. As a matter of fact, point C would have the same amount of natural unemployment as point A, because they share the same wage rate, and the surplus over this amount would have to be considered as cyclical unemployment, according to our approach, and consistently with a state of the cycle below its maximum $U(C) = U(W_{0,}y^{0}) = U^{NR}(W_0) + U^{C}(y^{0} < y^{\max})$.

As the business cycle is usually below its maximum level, most of the observations in our data would be made up of natural and cyclical unemployment. That is why the point cloud in Figure 1 (red dots) is mainly located above the line defining natural unemployment. Hence, the cyclical unemployment rate will be modeled in this paper as unemployment exceeding that minimum natural level. Put differently, our methodological proposal sets, as pointed out above, the NRU as a lower envelope that will be estimated through a lower SF (commonly called "cost frontier"), and cyclical unemployment as the inefficiency term that makes the actual unemployment to be above that minimum "efficient" unemployment.

3.3 | From the empirical strategy to estimates

Our theoretical setting distinguishes between frictional, structural, and cyclical unemployment. In this way, it can be stated that we aligned ourselves with the compartmentalization hypothesis. This is a popular classification, which may even be found in economics handbooks[10]. In formal terms,

$$U_{it} = U_{it}^{F} + U_{it}^{ST} + U_{it}^{C}, \tag{11}$$

where U_{it} is the effective rate of unemployment in region i at time t, U_{it}^{F} represents frictional unemployment, U_{it}^{ST} is structural unemployment, and, finally, U_{it}^{C} reflects cyclical unemployment.

It is often felt that frictional unemployment proves extremely hard to eliminate and that there will always be some unemployment of this kind. For this reason, in Figure 1, we tacitly assumed that there was frictional unemployment even when the real wage rate was zero. This component is explained based on the "job-search theory" and stems from the existence of asymmetrical or imperfect information among jobseekers and employers, which in turn means that "matching" in the labor market may take some time and that there will always be a certain level of unemployment.[11]

Together with frictional unemployment, it is possible to find structural unemployment in the aggregate labor market. These two types of unemployment are usually linked to aggregate supply determinants (as opposed to cyclical unemployment, which tends to be linked to aggregate demand factors). Structural unemployment commonly appears to be due to imbalances between

[10] See Krugman et al. (2011), for instance.

[11] This theory was developed by Mortensen (1970) and McCall (1970); see Lippman and McCall (1976a, 1976b), Mortensen (1986), and Mortensen and Pissarides (1999) for a review of the topic. A recent example of this kind of literature may be found in the works of Tatsiramos and van Ours (2012, 2014).

supply and demand in the job market.[12] This is the motive to model it as a labor supply surplus in Figure 1 (conditioned on labor demand being at its maximum size).

It should be stressed that a large part of the macroeconomic literature has considered that the sum of frictional unemployment and structural unemployment corresponds to a notion of equilibrium unemployment, referred to as NRU. In formal terms, this idea may be expressed through Equation (12):

$$U_{it}^{NR} = U_{it}^{F} + U_{it}^{ST}, \tag{12}$$

where U_{it}^{NR} refers to the NRU in region i at time t. Despite the many definitions of this component of unemployment (not all of them compatible with each other), here it will be conceptualized as the medium (or long) term equilibrium unemployment rate (a view widely accepted).[13]

Clarifying even further, the notion of the NRU seeks to reflect the idea that, even when macroeconomic conditions are optimal (from a short-run perspective) and there is no problem concerning a lack of aggregate demand, there will always be "some" level of unemployment. The NRU should therefore be associated with aggregate supply determinants in macroeconomic models. Nevertheless, during a period of low economic growth or in a recession, resulting from an adverse demand shock,[14] the said aggregate demand would prove "insufficient" and cyclical unemployment would have to be added to the previously mentioned components. In other words, Equation (11) might be rewritten as

$$U_{it} = U_{it}^{NR} + U_{it}^{C}. \tag{13}$$

As Figure 1 evidences, wage rigidity (due to institutional factors) gives rise to an excess of available labor, leading to an imbalance and sparking structural unemployment (U_{it}^{ST})[15]. Hence, structural unemployment would exist even if there were a demand for labor associated with a period of economic boom.[16] In the same vein, the works of Bentolila and Jimeno (2003), Simón et al. (2006), and Bande et al. (2008) provide empirical evidence concerning the influence of the collective bargaining system on the Spanish labor market. Owing to the wage rigidity, such real wages are prevented from playing their role as an equilibrium mechanism in the Spanish labor market.[17]

[12] Such imbalances are due to institutional inflexibility and are linked to downward wage rigidity (minimum wage or collective bargaining), unemployment benefits, job protection legislation, jobseeker efficiency when searching for work, labor market inflow and outflow, labor force skills, low labor productivity, the industry composition of unemployment, or the demographic structure of the population, among other factors (Blanchard, 2017).

[13] The work of Rogerson (1997) offers several kinds of nomenclature for this term as well as varying definitions of the concept.

[14] Owing, for example, to a fall in consumer confidence or business confidence. A contractive monetary policy or a cut in public spending might also account for insufficient aggregate demand, giving rise to a higher cyclical unemployment rate.

[15] Elhorst (2003) cites certain works that have studied the impact of collective wage bargaining on unemployment. In most cases, a positive effect emerges that would seem to confirm the previously posited hypothesis.

[16] A different type of structural unemployment would be that emerging from the disparities between the skills required for the job vacancies and those possessed by the unemployed workers. This kind of structural unemployment does not fit in a homogeneous labor market framework, as the one shown in Figure 1. However, the basic idea that even in the best economic conditions there exist some structural unemployment remains.

[17] For a more comprehensive explanation of the phenomenon, see Jimeno and Bentolila (1998), García-Mainar and Montuenga (2003), Maza and Moral-Arce (2006), Maza and Villaverde (2009), or Bande et al. (2012).

Based on this, it may be stated that adjustment "via prices" fails to work correctly and that, as a result, adjustments mainly come about "via quantities" in the Spanish labor market.[18]

The final component in Equation (11) is the so-called cyclical unemployment (U_{it}^{C}). This element refers to the reduction in labor demand sparked by a lack of aggregate demand which reduces companies' sales. Given that labor demand is a derived demand, a reduction in aggregate demand in the macroeconomic goods market leads to labor demand to shrink. It should be stressed that this type of unemployment should be zero (from a strictly theoretical standpoint) when the economy is undergoing an "expansion" and, in contrast, is positive during periods of "slowdown" or "recession" when labor demand shifts to the left, as can be seen in Figure 1. As is well known, this type of unemployment can be corrected in the short term through expansive aggregate demand policies.

An important idea we would like to remark upon here is that we consider that none of the three components that make up Equation (11) can be negative (i.e., $U_{it}^{F} \geq 0$; $U_{it}^{ST} \geq 0$; $U_{it}^{C} \geq 0$). Although this assumption might seem naïve at first glance, it does not always hold in other theoretical scenarios. For instance, the concept of NAIRU is associated with negative cyclical unemployment ($U_{it}^{C} < 0$) in periods of rising inflation, as the same result can be found for some of the notions of NRU previously discussed. How is it possible that there are negative unemployed persons during an economic boom for cyclical reasons? The previous scenario also implies that the sum of frictional and structural unemployment is higher than actual unemployment during expansionary periods. If that were the case, what does it mean? We find it difficult to understand those situations unless you consider them as theoretical artifacts or pure abstractions to justify movements in the inflation rate.

As we are actually more attracted by the real aggregate labor market, we adopt the theoretical model described in this section, in which all components making up Equation (11) ought to be positive. In fact, we are really interested in measuring which part of unemployment remains even when aggregate demand is at its highest level and there is consequently no lack of aggregate demand. This has important consequences from the standpoint of economic policy since it would allow us to pinpoint, within the effective unemployment rate of each territorial unit and at each point in time, how many unemployment rate points are attributable to frictional and structural factors and how many to aggregate demand factors.

With this aim in mind, we apply the SF technique and estimate a composed-error econometric model. In this regard, we draw partially on the proposal of Hofler and Murphy (1989) and more recently Aysun et al. (2014). As noted before, we rationalize the NRU as a notion of medium (or long) term equilibrium unemployment, depending on factors that the literature has considered determinants of frictional and structural unemployment, which we denote as the vector of variables X_{it}. Thus, the natural minimum or "efficient" unemployment would be a function of a said vector of variables, $U_{it}^{NR} = f(X_{it})$.

Deviations from said minimum would be deemed inefficient and would result from insufficiencies in aggregate demand; in other words, cyclical unemployment is modeled as a nonnegative disturbance $U_{it}^{C} = u_{it} \geq 0$. Finally, assuming linearity, $f(X_{it}) = \beta X_{it}$, the "econometric" version of (11) would be

$$U_{it} = \beta_1 X_{it} + v_{it} + u_{it}, \tag{14}$$

[18] Cazes et al. (2013) show how, during the "Great Recession," in Spain, labor market adjustment was mainly carried out through the external margin of adjustment (redundancies and staff cutbacks) in the labor market.

where υ_{it} is a random conventional disturbance. Equation (14) implicitly assumes that cyclical unemployment has a minimum value equal to 0. Otherwise, situations could emerge in which the NRU was higher than actual effective unemployment, as already pointed out.[19] In other words, the U_{it}^{NR} component acts as a limit or lower boundary for effective unemployment ($U_{it} \geq U_{it}^{NR}$).

4 | METHODOLOGY

This section is also divided into two parts. In the first, a brief explanation of the SF technique is given and is used to decompose unemployment. In the second, a description is provided of the univariate filters employed to accomplish the work's second objective.

4.1 | SF analysis

The decomposition presented in the conceptual framework is based on the assumption that all the components are positive. As a result, the NRU constitutes a minimum value below which effective unemployment cannot fall, and any deviation from this minimum is considered inefficiency that can be corrected by applying aggregate demand policies. As already pointed out in Subsection 3.3, this is a composed-error model which can be estimated using SF. The first econometric models to introduce this technique can be found in the seminal papers of Aigner et al. (1977) and Meeusen and van Den Broeck (1977).[20] In its costs version, this estimation technique allows a minimum value which is situated below the observed dependent variable to be identified.

As already pointed out, the ultimate goal is to separate the effective rate of unemployment (U_{it}) into two components: natural unemployment (U_{it}^{NR}) and cyclical unemployment (U_{it}^{C})[21]. However, in order to identify the two components, the starting point is to specify natural unemployment as shown in Equation (15):

$$U_{it}^{NR} = \beta_1 X_{it} + \upsilon_{it}, \tag{15}$$

where X_{it} is a vector of explanatory variables, β_1 is the vector of coefficients to be estimated, and υ_{it} is a statistical noise deemed symmetrically and independently distributed as a $N(0, \sigma_{\upsilon}^2)$. This natural component constitutes a lower envelope or cost frontier below which the effective unemployment rate will never fall. However, the natural unemployment formulated econometrically in Equation (15) is not observed directly. The available information corresponds to the effective unemployment rate, which is greater than or equal to the natural ($U_{it} \geq U_{it}^{NR}$). The effective

[19] In the microeconomic literature, see, for example, Revoredo-Giha et al. (2009), Sav (2012), or Duncan et al. (2012), the "frontier cost" is the minimum possible and can never exceed the observed cost. Hofler and Murphy (1989) and Aysun et al. (2014) extrapolate this idea to the labor market to decompose the unemployment rate. We modify this interpretation slightly and apply it to the Spanish labor market.

[20] Kumbhakar and Lovell (2003) and Greene (2008) provide a highly detailed exposition of this type of econometric technique; see Burns and Weyman-Jones (1996) for an application of that technique in the case of the study of the efficiency in the electric distribution.

[21] As highlighted previously, the lack of sufficiently extensive and time-comparable information concerning existing vacancies in the labor market makes it extremely difficult to extract the frictional component (U_{it}^{F}) using the econometric techniques observed in some of the works referred to in the literature review. As a result, the said component will be estimated together with the structural component of unemployment.

rate of unemployment may thus be represented as the sum of U_{it}^{NR} and a nonnegative random disturbance identified with cyclical unemployment (U_{it}^{C}), through the following mathematical expression:

$$U_{it} = U_{it}^{NR} + u_{it}, \tag{16}$$

where $u_{it} = U_{it}^{C}$ and u_{it} is an error term which is expected to be positive and independently distributed. It should again be stressed that this term will always take a positive value or one equal to 0 in the best of cases (Aysun et al., 2014). Finally, by grouping Equations (15) and (16), we obtain expression (17) which coincides with Equation (14), previously presented:

$$U_{it} = \beta_1 X_{it} + \varepsilon_{it}, \tag{17}$$

where $\varepsilon_{it} = v_{it} + u_{it}$.

Taking account of the final specification of Equation (17), and the presence of a composed error econometric model, u_{it} and v_{it} are assumed to be independent of each other and identically distributed across observations. Then, we maximize the log-likelihood function of a SF model by using the Newton–Raphson method, and the estimated variance–covariance matrix is calculated as the inverse of the negative Hessian. This type of estimation allows us to obtain the two error components separately and to calculate the variance of each. It is thus possible to apply a statistical test to determine the existence of the frontier and whether it is a production or a cost frontier. As it will be shown, in our case, a lower SF (cost frontier) is estimated which, according to our approach, coincides with the natural unemployment (U_{it}^{NR}) and implies a lower limit for U_{it}.

Nevertheless, in order to estimate u_{it}, which is here identified with U_{it}^{C}, it is necessary to make assumptions about the distribution of the two error components of ε_{it} (Jondrow et al., 1982). In the case of the v_{it} component, there would appear to be no problem since there seems to be a strong consensus in the empirical literature that the said component is distributed in the form $N(0, \sigma_v^2)$, as we have stated before. The main problem emerges when it is needed to consider the distribution of the u_{it} term. Here, several distributions are proposed in the econometric literature: normal truncated (Stevenson, 1980), half normal (Aigner et al., 1977), exponential (Meeusen & van Den Broeck, 1977), and gamma (Greene, 1990). For the present study, and as occurs in the works of Hofler and Murphy (1989) and Aysun et al. (2014), half normal distribution is chosen for this error component.

4.2 | Univariate filters

In order to put our proposed decomposition into perspective, it is useful to compare it to other alternative methods used in the literature. To achieve this, three univariate filters are used which also allow effective unemployment to be decomposed, the HP filter, the QT decomposition, and finally, the BK filter.[22] These filters have been widely used when analyzing time series and enable any time series (K_t) to be broken down into its two components: the trend (T_t) and the cycle (C_t).

[22] See Hodrick and Prescott (1997) for a more detailed explanation of the HP filter. For a more extended definition of the BK filter, see Baxter and King (1999) and Pizarro (2001). The QT decomposition is a purely deterministic procedure, the aim being to model the element to be decomposed through a QT process: $Z_{it} = \delta_0 + \delta_1 T + \delta_2 T^2 + \omega_{i,t}$ In this case, Z_{it} is the variable to be decomposed, δ_0 is the constant term of the equation, T and T^2 are the components of the QT, and finally

At this point, it should be stressed that several of the studies cited previously in this text and which use these filters link the trend component to the concept of the NRU and the NAIRU, and make no "clear" distinction between the two (Adanu, 2005; Ball et al., 2013; Perman & Tavera, 2005; Villaverde & Maza, 2007, 2009). Along the similar line, the work of Blanchard and Katz (1997) defines the NRU as follows: "(…) The natural rate of unemployment is typically interpreted as the rate of unemployment consistent with constant (nonaccelerating) inflation," referring to the context of the Phillips curve and establishing no differences between NRU and NAIRU. Based on this, we are able to compare our estimations of the NRU with those obtained using the HP filter, with the QT decomposition, or with the BK filter. This comparison is also carried out for the cyclical component.

Applying these filters to our effective unemployment series at a regional scale yields the following equations:

$$U_{it} = U_{it}^{HPT} + U_{it}^{HPC}, \tag{18.1}$$

$$U_{it} = U_{it}^{QTT} + U_{it}^{QTC}, \tag{18.2}$$

$$U_{it} = U_{it}^{BKT} + U_{it}^{BKC}, \tag{18.3}$$

where U_{it} is the effective unemployment in region i at time t; U_{it}^{HPT}, U_{it}^{QTT}, and U_{it}^{BKT} refer to the trend component of the effective unemployment obtained through the HP filter, the QT decomposition, and the BK filter, respectively, for each region *i* at time *t*. Finally, U_{it}^{HPC}, U_{it}^{QTC}, and U_{it}^{BKC} refer to the cyclical components obtained through each filter for region *i* in year *t*.

5 | DATABASE

The data used in the present study were obtained from the Spanish Labor Force Survey (Encuesta de Población Activa, EPA) published by the National Statistics Institute (Instituto Nacional de Estadística, INE), the Statistic of Collective Bargaining Agreements (Estadística de Convenios Colectivos de Trabajo, ECCT), the Statistic of Labor Court Issues (Estadística de Asuntos Judiciales Sociales, EAJS), the Official State Gazette (Boletín Oficial del Estado, BOE), the BD-MORES Regional Database, and the Valencian Institute of Economic Research (Instituto Valenciano de Investigaciones Económicas, IVIE). All the variables used have an annual frequency for the period between 1982 and 2012 and are disaggregated for the 17 Spanish autonomous communities.[23] A summary of the variables used in this study, how they have been defined, and their source can be found in Table A1 in the Online Appendix.

The first part of the empirical analysis involves decomposing the regional unemployment rate. As a result, this is the dependent variable and the central one in our empirical work. In order to

$\omega_{i,t}$ is the error term. However, in the literature using QT decomposition, this latter term would, in turn, reflect the cyclical component of the variable we aim to decompose.

[23] The autonomous cities of Ceuta and Melilla have been excluded from the research due to the scant representativeness of some of the variables used.

carry out the decomposition, different explanatory variables which might affect the evolution of the unemployment rate are used (Aysun et al., 2014; Hofler & Murphy, 1989). The two first explanatory variables contained in Table A1 in the Online Appendix have a demographic component. The first of these is the female activity rate and reflects the impact of women's labor participation in the effective rate of unemployment.[24] According to Elhorst (2003), the influence of this variable on the unemployment rate gives rise to diverse results. The second one of the explanatory variables is the percentage represented by the population of 16–24 year-olds with regard to the total in each autonomous community. This variable is included as there is empirical evidence of a positive correlation between the weight of the youth population and the unemployment rate (Johnson & Kneebone, 1991; Murphy & Payne, 2003). This might be because the young, as a result of their limited work experience, are less skilled when it comes to finding jobs than their older counterparts. Their having less specific human capital might also prove to be a determining factor when accounting for high youth unemployment rates. Based on this, younger people tend to suffer for longer periods because of out of work.[25]

The second group of regressors is made up of a series of variables reflecting the industry composition of regional employment. The extant literature would seem to point to one of the causes of the differing unemployment rates at a regional scale being the industry composition of labor in each region.[26] Differences in wages, job skills, or competitiveness are key factors influencing the impact which the industry composition has on unemployment levels.[27] In a context where the Spanish regions evidence substantial differences in terms of industry composition, this is expected to be a determining factor underlying regional differences in unemployment rates. Another regressor is the share of net capital stock out of the total number of employed in real terms. This variable is included to compute the regional level of capitalization in each territory (Bande & Karanassou, 2013, 2014).[28]

Finally, we include three variables in order to capture the effect of labor market institutions on the evolution of effective unemployment.[29] The first of these variables is the Kaitz index (Kaitz, 1970), which attempts to account for the influence of minimum wage legislation. It is defined as the ratio of the minimum to the average wage. The advantage of this index is that it shows cross-regional variation despite the fact that in Spain there is a single national minimum (Galán & Puente, 2015; Pérez-Dominguez et al., 2002).

In the second place, the Employment Protection Legislation (EPL) in Spain, as in the case of the minimum wage, exhibits no cross-regional variation since there exists a single national

[24] Lázaro et al. (2000), Azmat et al. (2006), and Bertola et al. (2007) point to some of the driving factors behind the recurring female unemployment rates.

[25] In Maguire et al. (2013), some references explaining the reasons underlying the high rates of unemployment among youngsters in Spain (16–24-year olds) over the period 2007–2013 may be found.

[26] See Elhorst (2003).

[27] See Summers et al. (1986).

[28] For a more detailed definition about the construction of the net capital stock, see http://web2016.ivie.es/wp-content/uploads/2017/02/Metodolog%C3%ADa_basedatos_stockcapital_ED.pdf.

[29] Furthermore, we also computed the so-called unemployment benefit coverage rate, defined as the ratio of unemployment benefit recipients to unemployed persons, aiming at controlling for the effects of an institution like unemployment insurance. However, we are not confident about the meaningfulness of the results due to the obvious endogeneity problems in that econometric regression (since unemployed workers can be found on the left-hand side and on the right-hand side of the equation). As instrumental variables procedures in SF estimation are not straightforward to implement, we finally made the decision of not reporting these results. It is worth mentioning that overall outcomes were robust regardless of the inclusion or not of that covariate. These results are available upon request from the authors.

regulation. Thus, in order to account for the effects of this institution, we draw on a growing literature studying the impact of judicial rulings over labor market variables and its relationship with firing costs (Gabuthy & Lambert, 2008; Goerke & Pannenberg, 2010; Jimeno et al., 2015; Martín-Román et al., 2013). The underlying idea is that labor courts located in a specific region ruling systematically more likely in favor of employees increase firing costs for employers operating in that area. A formal proof of this statement can be found in Martín-Román et al. (2013). To take into account this effect, we include in the econometric specification the percentage of dismissal cases ruled (totally or partially) in favor of employees as a measure of the EPL.[30]

The third institutional variable intends to measure the influence of the collective bargaining structure over effective unemployment. The seminal work of Calmfors and Driffill (1988) and the survey of Flanagan (1999) pose different effects on the unemployment rate depending on the type and the level of centralization of collective bargaining. Other studies look into whether these different structures have distinct impacts on the wages of the workers covered (Dahl et al., 2013). For the Spanish case, Bande et al. (2007, 2008) focus their attention on the wage-setting mechanism at a regional level and its influence on the evolution of the Spanish regional unemployment. In the current paper, we use the share of workers covered by a firm-level agreement as a variable accounting for the role of collective bargaining in the wage-setting process. Table A2 in the Online Appendix shows some descriptive statistics of the variables referred to earlier which reflect the interregional differences between them.

6 | RESULTS

The first part of this section involves the decomposition of the effective rate of unemployment into natural unemployment (U_{it}^{NR}) and cyclical unemployment (U_{it}^{C}) through the use of the SF. The second part tests the robustness of the results by modeling the inefficiency component and by using an alternative estimator that exploits the first difference transformation.

6.1 | Decomposition of effective unemployment

Having introduced the SF technique as a decomposition mechanism for effective unemployment, the results corresponding to the SF estimations are now presented. This is where the present work differs slightly from the proposal put forward by Hofler and Murphy (1989), since we opt for a more comprehensive parameterization of the frontier.[31]

In this regard, five different econometric specifications have been used in the estimates carried out, which are the specific versions of the general Equation (17). Equation (19) is the benchmark specification (specification 1), we include, as control covariates, the demographic features (X_{it}) (percentage of youth population and female participation rate), industry composition (Z_{it})

[30] To have an idea of the sizeable cross-regional variation found in labor court rulings concerning labor disputes over layoffs in Spain, see Martín-Román et al (2015).

[31] This greater parameterization of the frontier relates to an interest in capturing some important determinant factors of the NRU. It has to be taken into account that the Hofler and Murphy (1989) approach considers only the frictional unemployment to be part of the frontier, whereas in our proposal the frontier is made up of both the frictional and the structural unemployment.

(percentage of people employed in agriculture, manufacturing, services, and energy) together with a dichotomous variable ($D2001$) which takes the value 1 after 2001 and 0 in the previous years.[32]

We also employed seven additional specifications to test the robustness of the results. Equation (20) adds a linear trend (T) to the previous control covariates (specification 2). Expression (21) decomposes the service industry into two components: Retailing (SRI_{it}) and nonretailing industry ($SNRI_{it}$), so Z'_{it} is a vector that represents the previous industry decomposition with this separation in the services industry (specification 3).[33] Equation (22) incorporates the share of net capital stock out of the total number of employed in real terms (RKS_{it}) (specification 4). Finally, expression (23) includes institutional variables (I_{it}) the Kaitz index, the percentage of dismissal cases ruled (totally or partially) in favor of employees, and the share of workers covered by a firm-level agreement (specifications 5–8).

It should also be pointed out that fixed regional effects have been used in all the specifications to reflect unobservable heterogeneity at a territorial scale (μ_i). In this case, both, β_0 and μ_i are fixed constants, and additional restrictions to estimate them are required. One way to do that is to introduce the restriction $\sum_{I=1}^{n} \mu_i = 0$. Then, the fixed effect μ_i represents deviations from the mean intercept β_0[34].

Finally υ_{it} is assumed to be independently $N(0, \sigma_\upsilon^2)$ distributed over the observations, and u_{it} are independently $N^+(0, \sigma_\upsilon^2)$ distributed with truncation point at 0:

$$U_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \beta_3 D2001 + \upsilon_{it} + \mu_i + u_{it}, \tag{19}$$

$$U_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \beta_3 D2001 + \beta_4 T + \upsilon_{it} + \mu_i + u_{it}, \tag{20}$$

$$U_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z'_{it} + \beta_3 D2001 + \upsilon_{it} + \mu_i + u_{it}, \tag{21}$$

$$U_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \beta_3 D2001 + \beta_4 RKS_{it} + \upsilon_{it} + \mu_i + u_{it}, \tag{22}$$

$$U_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \beta_3 D2001 + \beta_4 I_{it} + \upsilon_{it} + \mu_i + u_{it}. \tag{23}$$

Table A3 in the Online Appendix shows the results obtained for the eight SF estimations. Broadly speaking, it can be seen a great similarity between the coefficients obtained. It can also be seen that in all cases, it can be accepted that there is a cost frontier at a 1% level of statistical significance with the exception of specifications 6 and 8 (which are statistically significant at a 10% level).

A close look at the variables used when modeling the frontier yields the following conclusions. The female activity rate has a positive and significant effect on NRU at a regional scale,

[32] This dummy variable is introduced due to the fact that in 2001 methodological changes were made which affect how unemployment is measured. The methodological changes made may be seen at http://www.ine.es/epa02/meto2002.htm.

[33] For a more detailed explanation about the services in the retailing and non-retailing industry, see http://web2011.ivie.es/downloads/caphum/series-2013/metodologia-series-capital-humano-1964-2013.pdf.

[34] Hsiao (2014).

an effect reinforced when a trend is included in the model. This result seems to indicate that the gradual incorporation of women into the labor market since the early 1980s has led to an increase in regional NRUs, mainly because female unemployment rates are higher than those of men. With regard to the second demographic variable, a positive and significant effect of the percentage of young people on regional NRUs can also be seen. This effect is common to all specifications and has a greater coefficient than that of the female activity rate is found.[35] These results are consistent with the hypotheses formulated earlier concerning the youth population and reflect the importance of youth unemployment when determining aggregate unemployment levels.[36]

The second group of control covariates included in the model concern the industry composition. As with the previous case, all display a positive and highly significant effect in all specifications, reflecting the fact that, ceteris paribus, all the industries evidence a higher NRU than the one used as a reference. Given that the variable excluded is the percentage of workers in the construction industry, it may be concluded that the remaining industries display higher levels of unemployment and that it is the percentage of workers in the energy industry and in the service industry which are the most relevant variables when explaining unemployment levels. The previous result also holds when we decomposed the service industry especially for the nonretailing industry (specification 3).

It can also be seen how manufacturing and construction are the industries that have had the least impact on the dependent variable. One tentative explanation to account for these results might be found in the great weight which low-skilled jobs have in the service industry. In agreement with the literature, times of crisis cause long periods of unemployment among low-skilled workers, which increases their own rate of structural unemployment.[37] If we add to this the fact that in the service industry there is high job turnover and that in many instances firms offer little or no training,[38] we are left with a low-skilled workforce with low employability. As for the dichotomous variable reflecting the methodological change in how unemployment is measured after 2001, it has a negative and highly significant effect on all specifications. This result indicates that the new methodology adopted by the INE contributes towards lowering the effective rate of unemployment. On the other hand, the linear trend included in specification 2 does not prove to be significant and the share of net capital stock in specification 4 displays a positive value over the effective unemployment.

The last group of control variables is those related to the labor market institutions. The Kaitz index is included in specifications 5 and 8 and exhibits a negative but not statistically significant coefficient. One possible explanation for this result is the relatively low levels for the minimum wage in Spain during the time period considered in our database, which exerts limited pressure over the wage distribution. In the case of the EPL indicator (percentage of dismissal cases ruled totally or partially in favor of workers), we obtain positive and highly significant effects in specifications 6 and 8. This means that higher percentages of dismissal cases ruled in favor of workers tend to increase the level of unemployment in the economy.[39] Finally, the share of workers

[35] López-Bazo et al. (2005) also report a positive effect of the percentage of the youth population (16–25) on unemployment and establish that the said variable contributes significantly to explaining regional disparities in unemployment.

[36] Dolado et al. (1999, 2000, 2002) show some of the causes and consequences of the "inefficient" functioning of the labor market for young people in Spain.

[37] Using a panel that includes 21 OECD countries, Oesch (2010) offers empirical evidence concerning which variables most impact on low-skilled worker unemployment rates.

[38] A good example for the case of Spain might be certain jobs in the tourist industry.

[39] Similar results can be found in Okudaira (2018).

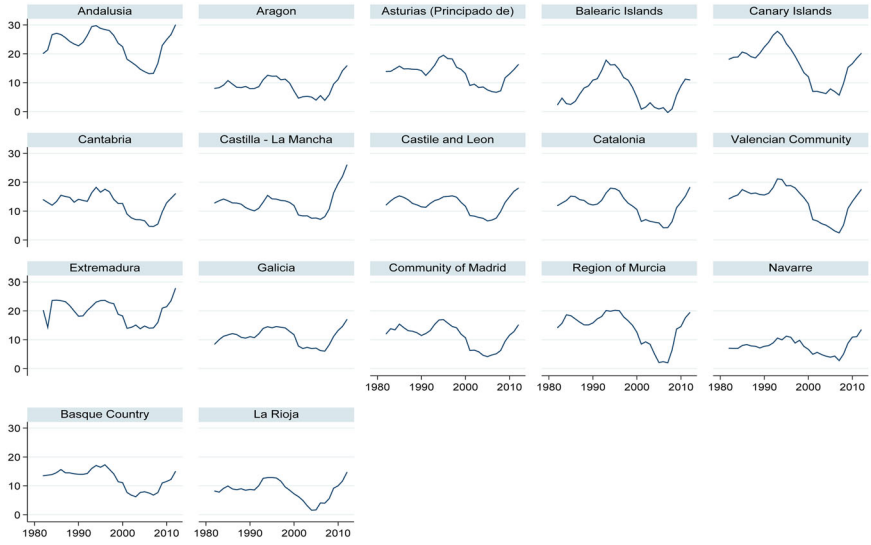

FIGURE 3 Natural unemployment (U_{it}^{NR}) by the autonomous community (1982–2012). *Source:* Authors' own. [Colour figure can be viewed at wileyonlinelibrary.com]

covered by a firm-level agreement also shows a negative and not statistically significant coefficient in specifications 7 and 8.

According to the results in Table A3 and following the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), the best estimate is achieved with specification 4. Following that specification, predictions are made regarding the values of the frontier and inefficiency. It is thus possible to obtain the decomposition of the effective unemployment rate in the components previously referred to U_{it}^{NR} and U_{it}^{C}. The estimations of U_{it}^{NR} have been obtained by standard linear predictions through the coefficients and the variables employed to model the frontier. In the case of U_{it}^{C}, the technique produces estimates via $E(u_{it}|\varepsilon_{it})$ that is defined as follows (Jondrow et al., 1982):

$$E\ (u_{it}|\varepsilon_{it}) = \sigma_* \left[\frac{f\,(\varepsilon\lambda/\sigma)}{1 - F\,(\varepsilon\lambda/\sigma)} - \left(\frac{\varepsilon\lambda}{\sigma} \right) \right], \tag{24}$$

where f and F represent the standard normal density and cumulative distribution function, respectively, $\varepsilon_{it} = v_{it} + u_{it}$, $\lambda = \sigma_u/\sigma_v$, $\sigma_* = {\sigma_u}^2{\sigma_v}^2/\sigma^2$, and $\sigma^2 = {\sigma_u}^2 + {\sigma_v}^2$

Figure 3 shows the evolution of the NRU (U_{it}^{NR}) for all the autonomous communities.[40] The mean value of this component throughout the whole period is 12.72 percentage points. Above the mean, we find certain extreme mean values such as Andalusia (23.00%), Extremadura (19.70%), and the Canary Islands (16.62%). The regions which evidence a lower mean U_{it}^{NR} value are the Balearic Islands (7.19%), Navarre (7.76%), and La Rioja (8.45%).[41] A different set of insights comes from the relative values, that is, the importance of U_{it}^{NR} when explaining overall levels of effective

[40] Estimations have been performed based on specification 4. We have also carried out a similar analysis using the other three specifications giving very similar results with values of the correlation coefficient around the 0.99. These results are available upon request from the authors.

[41] Detailed results are available to those interested upon request from the authors.

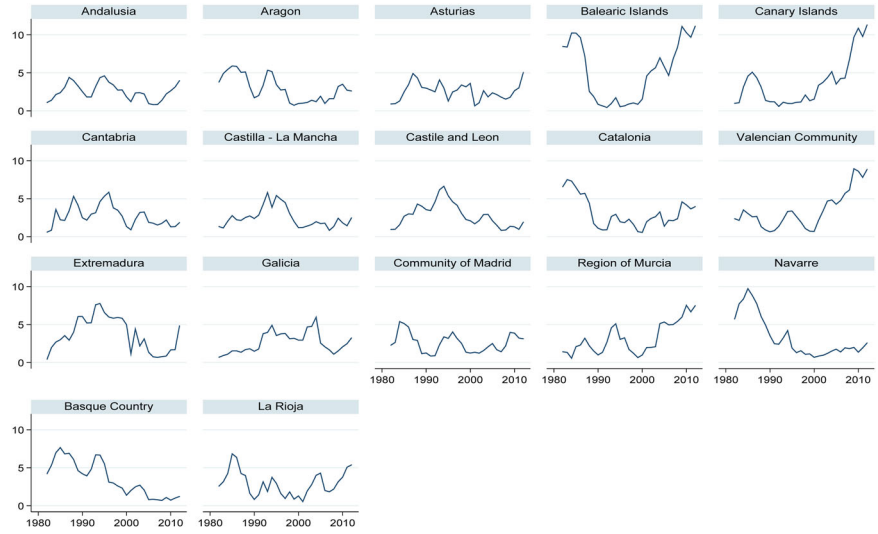

FIGURE 4 Cyclical unemployment (U_{it}^{C}) by the autonomous community (1982–2012). *Source:* Authors' own. [Colour figure can be viewed at wileyonlinelibrary.com]

unemployment. It is once again the regions displaying the highest levels of NRU which account for the greatest percentage of effective unemployment.

Specifically, this component explains about 90% of the effective unemployment in Andalusia, 84% in Extremadura, and around 82% in the Canary Islands. In the case of the regions in which the U_{it}^{NR} has less weight on effective unemployment, these are the Balearic Islands (58.36%), Navarre (70.24%), and La Rioja (74.31%), although Aragon with a rate of 74.95% joins the list. Finally, it is worth reflecting briefly on the similarity in the profile displayed by the evolution of this component of unemployment in all the autonomous communities. The said similarity is less clear at the start of the period but becomes more intense after the mid-1990s, displaying a noticeable "U" shape. Specifically, there is a sharp drop until the mid-2000s followed by a marked increase coinciding with the "Great Recession."

Figure 4 shows the cyclical unemployment (U_{it}^{C}) at a regional scale.[42] In aggregate terms, the mean value for this component is 3.13 percentage points, which represents one-quarter of NRU. The regions that most exceed this value are the Balearic Islands (5.13%), Extremadura (3.71%), and the Basque Country (3.52%), although the Canary Islands, the Valencian Community, and the Region of Murcia are also above the mean. In contrast, the regions showing the lowest mean value of cyclical unemployment are Castilla-La Mancha (2.48%), Andalusia (2.53%), and the Community of Madrid (2.57)[43]. In this second case, no comments need to be made concerning the relative importance of this component on the effective unemployment rate since both components are complementary and therefore, where natural unemployment displays a greater weight, cyclical displays less, and vice versa. With regard to the time evolution of this component in all the autonomous communities, certain similarities among them are also in evidence, with a slight final peak coinciding with the period linked to the "Great Recession."

[42] Estimations have been performed based on specification 4. We have also carried out a similar analysis using the other three specifications giving very similar results with values of the correlation coefficient around the 0.90. These results are available upon request from the authors.

[43] Detailed results are available upon request from the authors.

6.2 | Robustness check

To test the robustness of the results, we will follow two different approaches. First, we re-estimate specifications 1–4 by modeling the inefficiency component in the SF analysis. Second, we will put into place a technique following the methodology proposed by Chen et al. (2014) to find a consistent estimator.

6.2.1 | Inefficiency modeling

As we explained before, the natural rate of unemployment is associated with aggregate supply determinants and the cyclical unemployment rate is related to the aggregate demand determinants. Previous estimations only include supply factors when modeling the frontier because we were only interested in the global decomposition. However, the SF technique allows to identify which variables might influence the inefficiency component of unemployment. The simplest way to do that is to make the variance parameter of u_{it} a function of exogenous covariates (S_{it}) [and also the mean (Battese & Coelli, 1995)]. That is,

$$u_{it} \sim N^{+}\left(0, \sigma_u^2\left(S_{it}, \varphi\right)\right), \tag{25}$$

where φ is the vector of parameters to be estimated, u_{it} follows a Half Normal distribution and $\sigma_u^2(S_{it}, \varphi) = \exp(S_{it}\varphi)$. In this case, the aggregate demand component included in S to model the cyclical unemployment is the growth rate of the GDP as defined in Table A1 in the Online Appendix. This modeling seems also necessary because of the cyclical pattern that can be seen in the estimation of the inefficiency component presented in Figure 4.

Table A6 in the Online Appendix presents the results for the four specifications (Equations 19–22) including the GDP growth rate as an exogenous variable in the inefficiency component. The sign and the magnitude of the coefficients in the frontier are similar to those obtained before. Regarding the GDP coefficient, we find that as the economy grows the cyclical component of the unemployment rate falls. The last two lines in Table A6 present the correlation between the frontier and the inefficiency components in previous estimations and those obtained after modeling inefficiency. The results show the robustness of the predictions with a correlation close to one in the frontier component and higher than 0.75 in the inefficiency.

6.2.2 | Maximum likelihood estimation based on deviations from means

Maximum likelihood estimation treating the unit-specific intercepts as parameters (Greene, 2005) may be subject to the ''incidental parameters problem'' because the number of parameters grows with the number of regions. This approach leads to inconsistent variance estimates, especially in short panels.[44] To solve that problem, Chen et al. (2014), Lai and Khumbhakar (2018), and Belotti and Ilardi (2018) propose an alternative estimator exploiting the first difference transformation. This approach removes the individual effects by the usual within transformation and achieves consistent estimations.

[44] The incidental parameters problem is no longer an issue for the MLDVE when $T \to \infty$ with fixed n (Belotti and Ilardi, 2018)

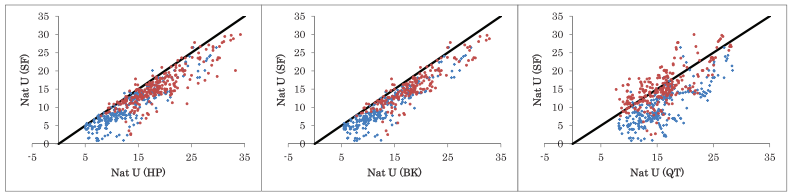

FIGURE 5 Comparison of the natural unemployment by estimation method (1982–2012) [Colour figure can be viewed at wileyonlinelibrary.com]

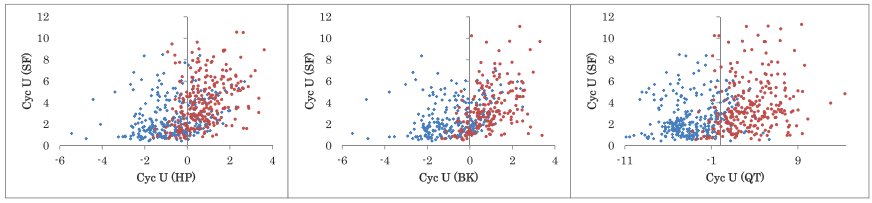

FIGURE 6 Comparison of the cyclical unemployment by estimation method (1982–2012). *Notes*: The blue points refer to the years in which the effective unemployment, at the aggregate level, is lower than the aggregate natural unemployment. The red dots represent the years in which effective unemployment, at the aggregate level, is higher than aggregate natural unemployment. *Source*: Authors' own. [Colour figure can be viewed at wileyonlinelibrary.com]

Although in this case, the panel is not short ($T = 31$), we follow the proposal of Chen et al. (2014) and Belotti and Ilardi (2018) in order to obtain a consistent estimation. The results of these estimations, when the inefficiency is modeled and when it is not, are shown in Table A7 in the Online Appendix. In general, the sign of the variables and similarity in the magnitude of the coefficients are confirmed as well as the existence of a cost frontier. Finally, the last two rows confirm the high correlation between the estimates made with this procedure and those previously obtained. However, with inconsistent parameter estimates the correlation analysis is not enough, and it is necessary to resort to other methods such as scatter plots representing the predictions perform with both procedures. The results in the graphs show that the data are located next to the 45-degree line, which again reinforces the robustness of the results.[45]

7 | COMPARISON WITH FILTER DECOMPOSITION

In this section, the results of natural unemployment (U_{it}^{NR}) and cyclical unemployment (U_{it}^{C}) obtained by means of the SF estimations (specification 4) are compared to those obtained using the univariate filters defined previously.[46] In Figures 5 and 6, we present that comparison by means of the scatter plots between the SF estimations and the results of each filter for both types of unemployment.

[45] The scatter plots are not included in the paper, but are available from the authors upon request.

[46] We have followed the recommendations of Ravn and Uhlig (2002) to establish the value for the "λ" parameter with regard to the HP filter. In the case of the BK filter, the following values have been established in line with the recommendations of Pizarro (2001).

The three graphs in Figure 5 show a strong correlation between the different estimations of natural unemployment and present a higher concentration of points below the 45-degree line. This means that the values obtained by the SF estimations are lower, and the HP filter, the QT decomposition, and the BK filter lead to a "mean overestimation" of the natural unemployment. Figure 5 also presents two types of points: the blue points represent the years of economic expansion, and the red points represent those of recession.[47] In the case of the QT decomposition, the results also confirm that the "overestimation" is stronger in the growth period because the blue points are situated further away from the bisector in comparison with the red points (in HP and BK filters this relation is not so evident).

In the same vein, scatter plot graphs in Figure 6 compare the results for cyclical unemployment. In this case, all the points are located in the first and fourth quadrants which prove that the cyclical values of the univariate filters are lower in relation to the cyclical values of the SF estimations. In this case, we can see that the blue points are located on the left of the red points. This indicates that the "underestimation" of cyclical unemployment is more pronounced during the expansive phases than in the recessive phases of the business cycle.

Those results are supported by the descriptive statistics of the natural and cyclical unemployment in Tables A4 and A5 and by Figures A1 and A2 in the Online Appendix. Figure A1 shows how the evolution of the estimations obtained is very similar, except for the case of the QT decomposition. All of them display great variations in comparison with the QT estimations, which display greater cyclical behavior; this result is also in evidence when observing the data corresponding to the standard deviation in Table A4 of the Online Appendix. Figure A2 represents the cyclical unemployment estimated using various methods. Now the estimations obtained by means of the HP filter and the BK filter are very similar and resemble the SF estimations more closely.

8 | ECONOMIC POLICY IMPLICATIONS

In our view, the SF estimations of NRU and, consequently, of the cyclical unemployment are quite appealing from an economic policy viewpoint. From our econometric work, three key features that might be useful for economic policy outcomes can be drawn.

First, in the previous sections, it has been shown that when estimating the natural unemployment (U_{it}^{NR}) and cyclical unemployment (U_{it}^{C}) differences emerge depending on which method is used. The HP filter, the QT decomposition, and the BK filter are univariate filters that use the past values of the variable to be decomposed. These filters are based on purely statistical criteria and therefore do not employ economic variables when estimating the various components of observed unemployment (Gómez & Usabiaga, 2001). A further issue to arise when positing the use of these filters is that the results are sensitive to the choice of the statistical parameters required to carry them out. In this way, different estimations may be obtained depending on the choice made by the researcher concerning these parameters (Fabiani & Mestre, 2000). On the other hand, the SF estimations incorporate multivariate information based on economic theory. Such methodological differences mean that the SF proposal is likely to yield results that differ from those obtained using the univariate filters. From an economic policy point of view, knowing the determining

[47] We have employed the HP filter to estimate the natural component of the effective unemployment in Spain for the period 1982–2012. In line with this, we consider that when the effective unemployment rate is lower than its natural component, the business cycle is in its expansive phase. On the other hand, if the effective unemployment prevails over the natural unemployment, the business cycle is in its recessive phase.

factors behind the NRU might allow the policymakers to act directly on them with the aim of reducing natural unemployment.

The second issue to be highlighted is that the evolution of the SF estimations of natural unemployment can be affected by the business cycle too since a certain "cyclical influence" can be seen in this component of unemployment. Aysun et al. (2014), which is the closest paper to ours, reach a similar conclusion when examining the cyclical pattern of their measure of structural unemployment. The theoretical support for this empirical observation can be found, for instance, in Blanchard (2018). When discussing the fulfillment of the so-called "independence hypothesis" and the difference between "persistence" and "permanence," this author states that all relevant models imply an effect of aggregate demand shocks on potential output and on the natural rate that will last for some time. According to this idea, the NRU is affected by economic ups and downs in the labor market and there are some motives for that.[48] Apart from aggregate demand considerations, it is likely that some labor market institutions (e.g., unemployment benefits, employment protection legislation, etc.) change over the business cycle triggering procyclical movements in the NRU. Being aware that the NRU is also affected to some extent by the business cycle is important from an economic policy standpoint. This observation should encourage policymakers to act countercyclically with the aim to diminish the cyclical variations not only of the cyclical unemployment but the natural unemployment too.

Finally, according to the SF estimations, there is greater scope for action for aggregate demand policies when reducing cyclical unemployment compared to the estimations offered by the univariate filters. This statement is true for all Spanish regions since, in line with Table A5 of the Online Appendix, the SF estimations show positive mean values for the whole period unlike the values given by the univariate filters. Put it another way, provided that cyclical unemployment still remains positive, fiscal and monetary economic policies have room for maneuver. This result is confirmed by the coefficient of the GDP variation obtained when modeling inefficiency in the robustness analysis section.

9 | CONCLUSIONS

The present work pursues two objectives. The first is to present a proposal to decompose the effective unemployment rates of the 17 autonomous communities in Spain over the period 1982–2012 into two components: the so-called natural unemployment (U_{it}^{NR}) and cyclical unemployment (U_{it}^{C}). To do this, we construct a simple theoretical model which conceptualizes the natural component as the minimum unemployment rate reached when the GDP growth is maximum (NRU) and the cyclical component as a nonnegative element that makes the actual unemployment to be above that minimum "efficient" unemployment. To ensure that our formal framework is fulfilled, we apply the stochastic cost frontier methodology following the approach of Hofler and Murphy (1989) and later developed in Warren (1991), Bodman (1999), and Aysun et al. (2014). The results underscore the fact that the bulk of effective unemployment is due to factors associated with the natural more than to cyclical unemployment. It can also be seen how it is natural unemployment which mainly accounts for the rise of effective unemployment during the "Great Recession."

Our second objective is to compare and contrast the SF estimations of the natural component with the estimates obtained using three types of time-series filters: the HP filter, the BK filter, and the QT decomposition. In this way, we base the comparison on the work of Rogerson

[48] This finding has already been supported for the case of regional labor markets in Spain by García-Cintado et al. (2015).

(1997), which includes some definitions of the NRU that can be linked with the aforementioned econometric techniques. Our findings bring to light the existence of differences in the estimations between the various techniques applied. The above-mentioned differences might have important implications for economic policy. First, and according to our methodological proposal, natural unemployment is overestimated for the period 1982–2012 when applying the HP filter, the QT decomposition, and the BK filter if compared to the SF estimations. Thus, policymakers' decisions might be flawed if the scale of natural unemployment is not identified correctly. In the same way, erroneous or inefficient economic policies may be applied. However, our study also points out that cyclical unemployment might be understated when it is computed by means of the popular HP filter, BK filter, and QT decomposition according to our SF estimations. This result indicates that the policymakers have a greater margin of action to implement aggregate demand-side policies.

Also from an economic policy perspective, the results set out in the present work might help policymakers when deciding to implement economic policies affecting the labor markets. Regardless of the method used, natural unemployment is the principal cause of high rates of effective unemployment. In this way, SF estimations also seem to point to the same conclusion. Although it should also be pointed out that all in all the SF estimations for the NRU over the whole business cycle are lower than those of the univariate filters.

Based on this, the insistence should be on measures that focus on aggregate supply policies. Some such measures might be aimed at enhancing workers' human capital. This would help reduce natural unemployment in its structural component. Fostering interregional worker mobility and introducing changes in collective wage bargaining mechanisms (amending the system for reviewing wages in accordance with work productivity) would help curb natural unemployment in its structural component. On the other hand, introducing improvements in public employment services and in the way information is provided concerning vacancies would help reduce jobseekers' job-search time. This would improve matching efficiency in regional labor markets and cut natural unemployment in its frictional component. Finally, our results show that there is room for implementing more active monetary and fiscal policies because cyclical unemployment could be higher than previously thought.

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