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THE TIME-VARYING NAIRU IN THE US ECONOMY (1990-2022)*

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Abstract

The study argues that there is time-varying nonaccelerating inflation rate of unemployment, (NAIRU) in the US economy, testing the hypothesis during the 1990–2022 period. Time-varying NAIRU is estimated with both annual and quarterly inflation and unemployment with the accelerationist Phillips curve. Reasons for the rises and falls in NAIRU are discussed with emphasis on productivity, change in productivity and wage aspirations. NAIRU has risen from 5.30 to 6.40 percent between 2000–2010 when productivity is in declining trend; and manufacturing productivity has declined between 2015–2021 in spite of the rise in overall productivity from 1.2 to 2.6 percent, without a fall in the NAIRU. The analysis shows that NAIRU shows comovement with productivity growth rather than change in productivity growth. Results imply that downward dynamic of the NAIRU relates more to productivity rise in the manufacturing sector, rather than total productivity. It seems that rising share of the services sector to over 80 percent with the decline in manufacturing has reflected unfavorably on productivity.

Keywords: NAIRU, Unemployment, Phillips curve, Productivity, Wage aspirations

ABD Ekonomisinde Zamana Göre Değişen NAIRU (1990–2022)

Öz

Çalışmada ABD ekonomisinde zamana göre değişen enflasyonu hızlandırmayan işsizlik oranı (NAIRU) bulunduğu varsayımından hareketle, sözkonusu hipotez 1990–2022 dönemi için sınanmaktadır. Zamana göre değişen NAIRU hem üç aylık, hem de yıllık enflasyon ve işsizlik verisi kullanılarak, hızlandırmacı Phillips eğrisi ile tahmin edilmektedir. NAIRU'daki düşüş ve yükselmelerin nedenleri verimlilik, verimlilikteki değişimler ve ücret beklentileri çerçevesinde araştırılmaktadır. 2000–2010 arasında verimlilik düşüş eğiliminde iken NAIRU yüzde 5.30'dan, 6.40'a yükselmiş; 2015–2021 arasında ise ekonominin genelinde verimlilik yüzde 1.2'den 2.6'ya yükselmesine rağmen, imalat sanayiindeki verimlilik düşüş göstermiş, buna paralel olarak NAIRU'nun da azalmadığı tespit edilmiştir. Ayrıca NAIRU'nun verimlilik büyümesindeki değişimlere değil, verimlilikteki büyümenin kendisine duyarlı olduğu ölçümlenmiştir.

Araştırmadaki bulgular, uzun dönemli işsizlikteki düşüşün toplam verimlilik artışı ile değil, imalat sanayiindeki verimlilik artışı ile ilgili olduğuna işaret etmektedir. 2000'li yıllarda azalan imalat sanayii payı karşısında milli gelir içindeki payı yüzde 80'lere yükselen hizmetler sektörünün artan payının NAIRU üzerinde yukarı yönde baskıya yolaçtığı düşünülmektedir.

Anahtar Sözcükler: NAIRU, İşsizlik, Phillips eğrisi, Verimlilik, Ücret beklentileri

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The Time-Varying NAIRU in the US Economy (1990-2022)

Introduction

After Samuelson and Solow coined the name Phillips curve during the 1959 American Economic Association (AEA) meetings, Milton Friedman addressed the matter in his 1968 AEA presidential address and Robert Lucas in 1996 Nobel prize lecture. Since then, the tradeoff between inflation and unemployment has widely been recognized by academics and has been at the heart of macroeconomic policy. Among the mainstream economists, there is general agreement that fluctuations in production and employment are induced by monetary changes, and this is what happens at least in the short run. Apart from real business cycle (RBC) theorists who totally refute the tradeoff, there is consensus among professionals that macroeconomic policy results in business cycles, pulling the two aggregates in opposite directions. In spite of the consensus, there are different views as for the dynamics through which this tradeoff arises. Different channels through which imperfections arise during the equilibrium dynamics are enlisted as imperfect information, labor market rigidities like unions, bargains, long-term labor contracts, expectations forming, etc.

The concept of NAIRU emanates from the tradeoff between inflation and unemployment, i.e. the Phillips curve, which also implies that there is some level of unemployment corresponding to a stable level of inflation. The term was brought up during the inflationary environment of the 1970s and although used by Tobin in 1980, noninflationary rate of unemployment (NIRU) had initially been referred to in Modigliani and Papademos in 1975. NAIRU is the de facto rate of unemployment, which is compatible with stable inflation; the so-called steady state (Gordon, 1997). Acting as a speed limit, inflation will accelarate whenever rate of unemployment is below NAIRU and will decelerate whenever it is above.

The strongest appeal of the curve has been its prediction power no matter how it has proven wrong during the stagflation of the 1970s. Therefore, the US Federal Reserve (Fed) has used NAIRU as a benchmark for stable inflation through long years of policymaking under which inflation would accelerate and

vice versa. It is especially important for central banks in forming expectations of future inflation, to use the unemployment gap as the real activity variable. Deviations from the NAIRU give measure of the inflationary pressures and are used to compute output gap. There are many studies in the economic literature estimating NAIRU for different countries in different periods with various technical models.

One important trait of NAIRU is its time-varying character, although there is no agreement about the reasons why it is changing. NAIRU has changed notably during certain times, like its decline during the Goldilocks (New Economy) period, (Gordon, 1997) in the second half of 1990s, with a parallel rise in productivity. Beforehand NAIRU did rise during the unfavorable environment of oil shocks, when productivity slowdown was also being experienced. These coincidences have motivated research on the subject to measure and materialize the link between productivity and employment by academics, like Grubb, Jackman and Layard (1982), Braun (1984), Blinder (2000), DeLong (2000), Ball and Moffit (2001), Staiger, Stock, and Watson (2001) and the classics such as Long and Plosser (1983) as well as Prescott (1986).

Motivated with similar intuition, we presume existence of a time-varying NAIRU (TVN) in this paper, estimate it with Phillips curve and observe its time series characteristics during the 1990–2022 period. As per the relevant literature, NAIRU can vary in time due to reasons like demographic factors, labor markets (composition of the labor force, unionization, labor laws etc), wage aspirations, wage-price behavior, issues related to the production process (industrial organization, capacity utilization etc.), level of technology and productivity, supply shocks, economic policies of the government (openness to trade, factor mobility etc.) and demand management policies (Gordon, 1998; Ball & Mankiw, 2002; Ball, 2009; Yiğit & Gökçe, 2012). Among the possible reasons that might have affected NAIRU, "productivity" and "wage aspirations" have been addressed in previous research, concepts which we investigate with similar intuition in this study.

First, we estimate the accelerationist Phillips curve à la Friedman by algebraic decomposition and iterative estimation in Section 4 and obtain the TVN series both with quarterly and annual data. Second, observing the relation between NAIRU and productivity growth as well as the change in productivity growth in Section 5, we find out a strong statistical relation until 2010. Third, we further investigate the relation between change in productivity growth and NAIRU by measuring the rise in productivity over wage aspirations. For this purpose, we define two alternative gap variables (the long-run trend) as: the difference between productivity growth and past productivity growth and difference between productivity growth and past wage growth. Finally, in

Section 5, we examine the sectoral shares of manufacturing and services in total GDP as well as the share of labor force in manufacturing for we find evidence that NAIRU is related to the productivity in the manufacturing sector rather than overall productivity. The section also includes a discussion about growth models relying on services sectors rather than manufacturing and their implications on productivity.

Previously, Ball and Moffit (2001), Staiger, Stock, and Watson (2001), and Ball and Mankiw (2002), have observed the association between overall productivity and NAIRU. The first two of the papers have examined existence of the NAIRU, with an inward shift of the Phillips curve due to productivity rises and Ball and Mankiw (2002) emphasize the higher relevance of the change in productivity growth as well as productivity growth itself. The abovementioned studies observe the four decades from 1960 to 2000, while we examine the 1990–2022 period for the US economy.

This paper undertakes a brief overview of the evolution of macroeconomic thought around NAIRU and natural rate of unemployment (NRU) in Section 2. Section 3 provides literature survey of the mostly recent empirical studies with the particular methods undertaken. The Phillips curve estimation of this paper and the associated iterative process to extract the TVN are also explained in this section. Data analysis follows and the Phillips curve and NAIRU are estimated in Section 4. Section 5 discusses the underlying reasons of why and how NAIRU may have changed with particular emphasis on *productivity* and *wage aspirations*. This Section also includes a discussion about sectoral GDP shares and growth models. Results are reported and evaluated in 4 and 5 and conclusions follow in Section 6.

1. Theoretical Framework: the Phillips Curve and NRU vs NAIRU

As envisaged by the english economist A.W. Phillips in 1958, Phillips curve was an empirical observation of the relation between level of unemployment and nominal wage inflation of the UK. In 1960, Samuelson and Solow presented price inflation version of the curve versus unemployment uttering the name “Phillips curve” during the 1959 AEA meetings. Empirical power of the curve lasted well through first half of the 1960s, after which, it started deteriorating especially during the stagflation of 1970s.

When the curve became controversial during the two oil crises of the 1970s, monetarists came to the scene defending validity of the tradeoff in the short term, and that it would be converging to the natural rate in the long run.

Friedman (1968) and Phelps (1967, 1968) based their argument on "adaptive expectations" as the main factor bringing monetary non-neutrality, noting that economic units would realize inflation and correct their expectations in time, leading the way to long-run vertical Phillips curve at the NRU.

Mainstream theory accepts a tradeoff between inflation and unemployment in the short run, i.e. a change in the money supply will affect aggregate demand, pulling inflation and unemployment to opposite directions. The inverse relation between the two aggregates implies the existence of a stable inflation corresponding to a certain rate of unemployment, which is the essence of the theory. Only a small group of economists (new classics and the real business cycle) refute the tradeoff, advocating monetary neutrality.

On the right wing, new classics claim that under perfectly competitive markets and perfect information, people have "rational expectations" even in the short run, which do not involve any systematic error. Money is neutral and changes in the quantity of money will affect only the general price level but not the relative prices, income and employment (Ball and Mankiw, 2002). Economists have assumed that economic agents have perfect foresight, and supply is vertical even in the short run. Output fluctuations are only the result of technological developments and/or shocks, and labor market traits and demand management policies and/or fluctuations have no effect on production and unemployment (Long & Plosser, 1983; Prescott, 1986).

Monetarists have emphasized NRU a concept emanating from the presidential speech of Milton Friedman in 1968. It is not only them taking NRU to define the long-run level of full employment, but new Keynesians also agree that NRU is same as NAIRU, and that the two concepts can be used interchangably. Monetarists also see NRU and NAIRU as synonyms. Recognizing the short-run tradeoff between inflation and unemployment[1] Friedman (1968) certifies that the economy will always converge to NRU in the long-run. It is only a small group of new Keynesians such as Tobin who differentiate between the two terms saying that NRU implies unchanging unemployment dependent on long-run structural traits of the labor markets, whereas NAIRU has a time varying character, depending on macroeconomic policy, demographic changes, productivity and demand-supply etc. The Keynesian flavor embedded in the term implies that it especially contains cycles emerging from demand side of the economy. The apparent rise in NAIRU during the 1980s and its fall in the second half of 1990s have empirically revealed its time-varying character.

1 Arising from unanticipated inflation.

Basically, NRU implies rather competitive markets[2], whereas NAIRU involves imperfect competition. NRU is the situation where all markets clear in the Walrasian sense, whereas new Keynesian NAIRU can contain excess demand and excess supply in the individual markets. NAIRU is the equilibrium unemployment emerging from nonclearing markets where excess demand in the individual markets raises and excess supply lowers the general price level.

NAIRU rises during the oil shocks, parallel to the productivity slowdown and falls during the second half of 1990s, with the parallel rise in productivity. As mentioned above these movements have initiated research on the subject by academics like Grubb, Jackman and Layard (1982), Braun (1984), Blinder (2000), DeLong (2000), Ball and Moffit (2001), Staiger, Stock and Watson (2001) as well as Long and Plosser (1983) and Prescott (1986).

The question of why and how the NAIRU should change through time has not been answered with sufficient empirical research yet. Various possible reasons have been specified in the literature such as: demographic factors, labor market traits, wage aspirations, wage-price behavior, production process, technology and productivity, supply shocks, economic policies pursued (growth model, factors of production etc.) as well as the demand management policies (Gordon 1998; Ball & Mankiw, 2002; Ball, 2009; Yiğit & Gökçe, 2012).

Alternative explanation for the TVN is the *hysteresis hypothesis* (Blanchard & Summers, 1986; Ball & Mankiw, 2002) which suggests that higher unemployment may endure even after the initial recession/shock (be it demand or supply origin) is gone, which will result in persistent long-run unemployment. Simply hysteresis means that, past values of unemployment will pull the NAIRU in its own direction like a magnet.

2. Previous Studies and the Estimation Method

The criticism brought up about the stagflation of oil shocks has been overruled by arguments about supply shocks and acceptance of long-run vertical Phillips curve by both monetarists and new Keynesians for the 1970s and 1980s

2 Friedman has stated in his 1968 AEA speech that "The natural rate of unemployment, in other words, is the level that would be ground out by the Walrasian system of general equilibrium equations, provided there is embedded in them the actual structural characteristics of the labor and commodity markets, including market imperfections, stochastic variability in demands and supplies, the cost of gathering information about job vacancies and labor availabilities, the costs of mobility and so on."

(Phelps, 1967, 1968; Fischer, 1977; Taylor, 1980) after which the Phillips curve has provided stable inflation predictions until mid 1990s.[3] Ironically one result of the favorable environment was less studies conducted on the subject, until the late 1990s when falling unemployment rates without accelerating inflation provided motivation to conduct new research.

Empirical estimations can be classified under three groups: 1) Statistical tests 2) Phillips curve (PC) models 3) Structural VAR (SVAR) models and Elmeskov models. Statistical models are highly practical giving first insight about series and the nature of the data, although they lack the structural traits of the economy. Phillips curve equations are strong in reflecting structural traits; however they do not encounter for endogeneity between the right-hand side variables and consider only two variables. SVARs encounter for the two-way causality between variables also enabling imposition of long-run constraints on the function.

Even though the Phillips curve estimations have been criticized as statistically imprecise, these NAIRU functions have provided the best estimates of inflation (Stock & Watson, 1999; Ball & Mankiw, 2002) This is one reason why the method is widely used in empirical analysis. The PC tradeoff has been preferred in the paper to get better hold of the behavioral relations in the economy via a statistical model. Although there is a recent literature eg. Ratner and Sim, 2022 critical about validity of the curve asserting that PC is not a stable tool anymore, this work only conveys the information that there is a change in the slope due to the labor market conditions already encountered under the theoretical conceptualization of NAIRU. In this paper we adopt the structural Phillips curve equation with certain algebraic decomposition and iteration as in Ball and Mankiw (2002), extracting the NAIRU as the long-run trend for the 1990-2022 period. Our primary aim is to observe movements of the series through time, and to analyze the possible reasons of why it has exhibited fluctuations.

Table 1 below lists the selected research on the subject by date and method employed.

3 Through the first half of 1990s the 6 percent NAIRU successfully predicted the value of inflation for the years to follow (Gordon, 1997; Ball & Moffit, 2001).

Table 1. Empirical Work on NAIRU

Authors	Model	Period	Countries	Findings
Structural and/or Statistical Models				
Ball (1997)	OLS regression, statistical analysis	1980-1990 annual	OECD countries	monetary policy affects NAIRU
Gordon (1997)	(triangular) PC estimation	1955-1996 quarterly	USA	TVN exists, declined in mid-1990s by easy labor market, higher supply, IT revolution
Staiger, Stock & Watson (1997)	PC estimations, delta method, Gaussian standard errors	1955-1994 monthly, quarterly	USA	NAIRU imprecise, depends on variables included, large standard errors
Gordon (1998)	(triangular) PC estimation	1965-1998 quarterly	USA	TVN exists, not NRU NAIRU declined: supply shocks, medicare, new technology, measurement, also decline in itself
Estrella & Mishkin (1998)	PC structural estimates	1954-1997 annual	USA	NAIRU uncertainty affects policy reaction function
Ball, Mankiw & Nordhaus (1999)	OLS regression, statistical analysis	1980-1998 quarterly	OECD countries	demand affects NAIRU, NAIRU declined by rising demand
Ball & Moffit (2001)	PC estimation	1962-2000 annual	USA	1990s PC shifted favorably by productivity rise
Fabiani & Mestre (2001)	systems of equations with PC, Okun Law, etc	1970-1999 quarterly	Euro Area	NAIRU estimate robust to alternative systems' assumptions
Laubach (2001)	state space model, PC estimation	1973-2001	G-7	UN-inflation tradeoff cannot be precise due to NAIRU uncertainty
Staiger, Stock & Watson (2001)	PC estimation	1960-1999 annual	USA	NAIRU exists, PC shifts inward due to productivity and labor market trends, not by supply shocks nor mark-up
Ball & Mankiw (2002)	PC iterative regression, statistical analysis	1960-2000 annual	USA	NAIRU related to productivity/productivity acceleration
Ball (2009)	(iterative) regression, statistical analysis, disinflation measures	1980-2007 annual	20 developed countries	NAIRU related to disinflation policies

Filho (2010)	PC estimation, statistical methods	1986-2007 quarterly	four Latin American countries	NAIRU estimation imprecise: Δ by parameter and model chosen
Us (2017)	unobserved components model, Kalman filter	2000-2015 quarterly	Turkey	NAIRU rose with UN, responded less to UN gap
Ratner & Sim (2022)	Post Keynesian Kaleckian PC estimation	1970-2020	USA	decline in PC slope due to declining bargaining power of workers.
STRUCTURAL VAR				
Estrada, Salido & Hernando (2000)	SVAR	1980-1999 quarterly	Spain	NAIRU rose 1981-1985, then followed actual UN
Groenewold & Hagger (2000)	SVAR	1978-1997 quarterly	Australia	1990s UN rose by hysteresis
Hjelm (2003)	SVAR	1950-2004 annual	Sweden	NAIRU, output gap, budget balance estimated simultaneously
Zhao & Hogan (2006)	SVAR	1960-2000 annual	USA	NAIRU, core inflation estimated
Yiğit & Gökçe (2012)	SVAR	1998-2011 quarterly	Turkey	NAIRU rose from 8.4 to 12.5 percent

Note: UN is unemployment, IT is information technology.

3. Phillips Curve, Data and the Estimation Method

In construction of the model below we adopt the accelerationist Phillips curve à la Friedman (1968), which is also widely used in previous studies. In Equation 1, inflation (∏) is a function of –adaptive–inflation expectations, and detrended unemployment (U) where U^* is the NRU. Natural rate U^* is the rate observed when inflation expectations are realized, which contains all shifts in the inflation-unemployment equation other than those coming from expected inflation, i.e. U^* is the long-run trend unemployment. Average expected inflation should equal average of actual inflation in the long-run, thus average unemployment should equal average natural rate.

$$\prod = \prod_{-1} + a\ (U - U^*) \qquad a < 0 \tag{1}$$

The NRU is not constant and is not expected to stay still through time, even showing large fluctuations that may render the inflation unemployment

tradeoff very volatile. In practice Equation 2 is more widely used with addition of the variable *v*, the supply shock. In its textbook definition, *v* stands for short-term exogenous shocks such as those of commodity prices, exchange rates and financial sector prices which are expected to bring frequent and volatile fluctuations. On the right- hand side, movements of the U* are expected to come from more institutional factors such as labor market frictions, wage setting and state of unions.

$$\prod = \prod_{-1} + a\ (U - U^*) + v \qquad \alpha < 0 \qquad (2)$$

Possible endogeneity between *U* and the supply shock *v* is another problem in estimation of the model, and previous research has avoided collinearity among variables in various ways.[4] Since other methodologies adopted are also not exempt from criticism, it is assumed that the two series are independent and the Phillips curve is estimated with OLS as in Ball and Mankiw (2002), and Ball (2009).

Another criticism may come for the assumption of adaptive expectations of inflation, which has indeed been raised by the rational expectations school (Sargent, 1971; Lucas, 1972). On this matter, we bring up the justification that US inflation has exhibited high persistence since the 1960s demonstrating an autoregressive pattern rather than being white noise.

3.1. Assumptions and Estimation

Having assumed that unemployment and supply shocks are non-collinear, we assume a priori constant *U** in Equation 3 (Ball & Mankiw, 2002).

Rearranging Equation 2 we get expression 3 below:

$$\Delta \prod = a\,U^* - a\,U + v \qquad (3)$$

4 Although Lucas (1973) has used nominal GDP growth as the explanatory variable and Barro (1977) has stressed the unanticipated money variable, Ball and Mankiw (2002) argue these variables are also subject to criticism. Another option to avoid endogeneity is to use instrumental variables for *U* uncorrelated with the supply shocks, however Ball and Mankiw (2002) also argue that they are hard to find and are not used commonly in estimations.

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Dividing both sides by a and regathering, Equation 3 reduces to:

$$U^* + v / a = U + \Delta\prod / a \quad (4)$$

Under the assumption that U^* is constant, we regress the change in inflation on unemployment to obtain an estimate for "a" in Equation 3. Next step is to substitute the value of "a" in Equation 4 to compute the right-hand side, which equals to the sum of long-run trend U^* plus a ratio of transitory fluctuations ($U^* + v / a$). We then use the Hodrick Prescott (HP) filter to extract long-run trend from this sum, which is the TVN.

Apparently, there is inherent conflict in our computations from the initial assumption about TVN (U^*) being a constant, and therefore, we attempt to correct this through the iteration procedure as suggested in Ball (2009). We substitute the filtered U^* series in Equation 2 to obtain a new value for "a" which is further substituted in the right-hand side of Equation 4 to compute a new series and to re-HP filter the new U^*. We carry on with the iterative process until the "a" coefficient (thus the NAIRU) converge to their consistent values, obtaining the final TVN.

The resulting NAIRU series for the period 1990-2022 are provided in graphs 1 and 3 below. NAIRU with the two frequencies show similar curvature, with only quarterly data exhibiting more fluctuations due to higher data frequency, as expected.

3.2. The Data and Unit Root Tests

Unemployment (U), consumer price index (CPI), productivity (PRD) are from the Bureau of Labor Statistics' (BLS) databank, which are quarterly (yearly) and are seasonally adjusted.[5] Unemployment (16 years and over) is average of the three months for each quarter; CPI for all urban consumers is the (CPI-U), and both series are with base year 1982. Change in productivity (output per hour) is the percent change from previous quarter (from previous year) at annual rate. Inflation ($\prod$) is the log ratio of CPI to one lagged CPI index (four lagged index for annual). U, $\prod$, PRD are in percentage rates.

Three individual tests are applied for all variables: Augmented Dickey Fuller (ADF), Phillips Perron (PP) and Kwiatkowski, Phillips, Schmidt, Shin

5 Bureau of Labor Statistics (BLS), www.bls.gov (2023, January). Originally 1982-84 base year CPI-U series is converted to 1982. Unemployment is the LNS14000000; CPI (CPI-U) is CUSR0000SAO and productivity is the PRS85006092 series.

(KPSS) to test stationarity of the time series variables. In Table 2 below, variables are stationary, i.e. I(0), as per result of at least two tests at five percent level of significance.

Table 2: Unit Root Test Results

Variables	**Test Statistic Values**					
	ADF Level		**PP (t stat) Level**		**KPSS (LM stat) Level**	
	No trend	**Trend**	**No trend**	**Trend**	**No trend**	**Trend**
∆∏ change in infl (quarterly) I(0)	**-9.32**	**-8.65**	**-55.95**	**-85.18**	**0.19**	0.17
∆∏ change in infl (annual) I(0)	**-8.80**	**-8.86**	**-10.45**	**-14.28**	**0.35**	0.27
U unemployment rate I(0)	**-2.32(3)**	-2.37(2)(3)	-2.54(2)	-2.56(2)	**0.11**	**0.12**

	cst	**cst-trnd**		**cst**	**cst-trnd**
ADF and PP CV's 5%	-2.88	-3.44	KPSS	0.46	0.15
ADF and PP CV's (4) 5%	-2.97	-3.57	KPSS	0.46	0.15

(1) Bold figures are stationary series at 5% significance level. (2) Nonstationary. (3) DF-GLS (ERS) test. (4) Annual change in inflation series dof=29. (5) Schwartz information is used to choose the lag length of ADF, DF tests whereas Bartlett Kernal spectral estimation with Newey-West bandwidth is criterion for the PP tests.

3.3. Estimation Results

3.3.1. Quarterly Data

Results from Equation 3 of the iterative process with the converged coefficient IaI = 0.170 are presented in Table 3.

Table 3. Estimation Results of the Accelerationist Phillips Curve
(Dependent Variable: Change in Inflation)

Variable	**Coefficient**	**Standard Error**	**t-Statistic**
*U-U**	-0.17	0.06	-2.81
(*U-U**)(-1)	0.195	0.04	4.51
∆∏ (-1)	-0.43	0.12	-3.73

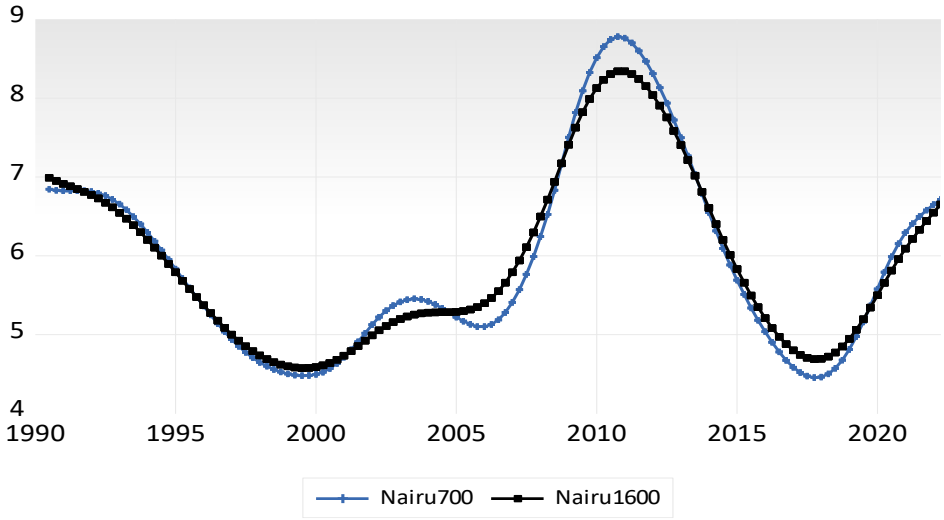
$\Delta\prod$ (-2)	-0.24	0.04	-5.75
D1	2.09	0.27	7.74
D2	3.16	0.80	3.93
R2 = 0.66 R2 adj = 0.65 F-stat = 46.6 F-test CV 5% = 2.29 t-test CV 5% = 1.98 dof = 126			

Notes: Dummy D1=1 for 2005Q3, 2009Q1, dummy D2= -1 for 2005Q4, 2008Q4, for quarterly inflation.

Substituting the 0.170 value for "a", *total shocks* (long-term and short-term shifts of the Phillips curve) are computed on the right-hand side of 4 below. Then long-run trend of total shocks is HP filtered with a lambda value of 1600. Alternatively, NAIRU is also computed with a lambda of 700, and graphs are presented in Figures 1 and 2.[6] Although the former series provide a more smoothened NAIRU, both show similar fluctuations.

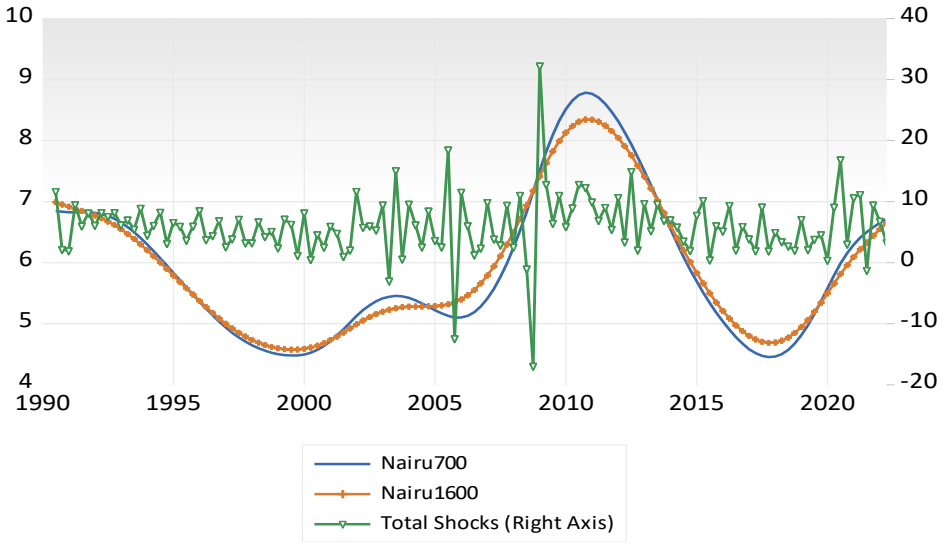
$$U^* + v / a = U + \Delta\prod / a \quad (4)$$

Figure 1. NAIRU (Lambda=700) vs NAIRU (Lambda=1600) (%)



6 Since HP filtering is much criticized in the recent literature for involving drawbacks like end-point bias etc, the NAIRU has alternatively been estimated with a four-quarter moving average method and PC was re-estimated with this new trend series. Results are very close to those in Table 3.

Figure 2. NAIRU (Lambda=700, 1600) vs Total Shocks of the Phillips Curve (%, Annualized)



Results with quarterly data are similar to those of the yearly series and both of the curves with lambdas 700, 1600 reveal proximate values. There is decline in the NAIRU throughout the 1990s (from 1990Q4 7.0 percent to 4.6 by 1999Q4) from where on it steeply rises reaching a higher plateau around 8 percent by 2010. The decline between 2010Q4 and 2017Q4 from 8.3 to 4.7, reverses back to a rise to 6.7 percent by 2022Q2.

3.3.2. Annual Data

Table 4. Estimation Results of the Accelerationist Phillips Curve (Dependent Variable: Change in Inflation $\Delta\prod$)

Variable	Coefficient	Standard Error	t-Statistic
U-*U**	-0.77	0.24	-3.24
U(-1)	0.58	0.25	2.35
U(-2)	-0.63	0.23	-2.78
$\Delta\prod$(-1)	-0.75	0.10	-7.42
D2	2.09	0.96	2.18
R2 = 0.67 R2 adj = 0.62 F-stat = 12.2 F-test CV 5% = 2.8 t-test CV 5% = 2.05 dof = 29			

Notes: Dummy D2=1 for 2009-2012 high unemployment.

Figure 3. NAIRU (Lambda=300) vs NAIRU (Lambda=1000) (%)

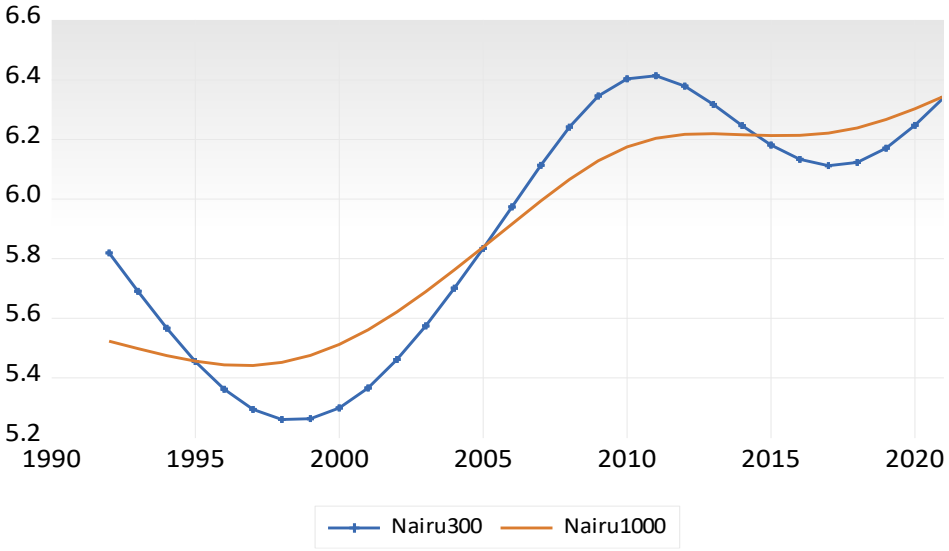
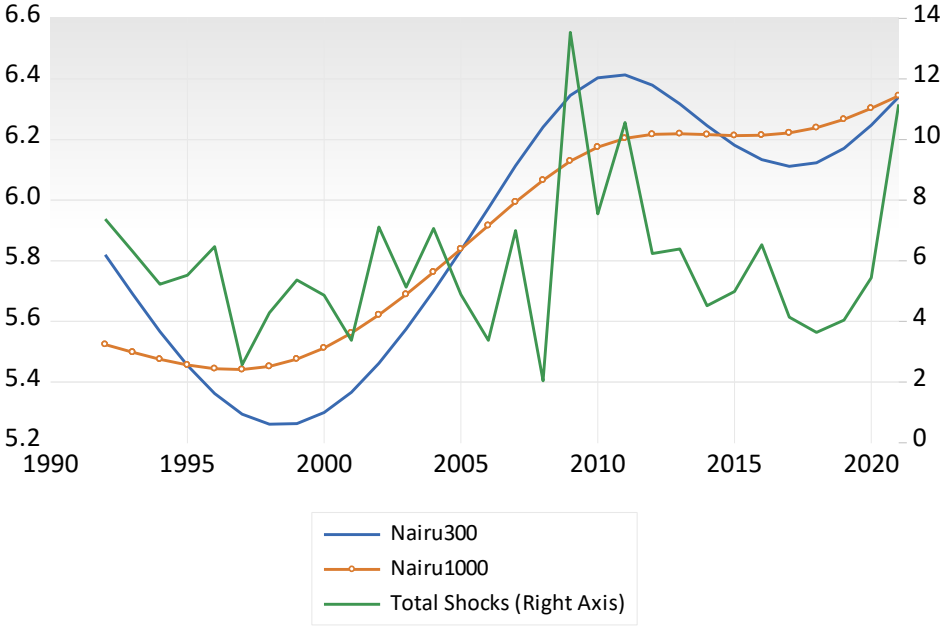


Figure 4. NAIRU (Lambda=300, 1000) vs Total Shocks of the Phillips Curve (%, Annualized)



The kinked line in Figure 4 is total of long-term and short-term shocks, $U^* + v / a$; and the TVN by two alternative lambda coefficients of 300 and 1000 (see Roberts, 1998) are presented in Figure 3 for purposes of comparison. It is usual to use a lambda of 100 with the annual series, however since the TVN has not converged, a lambda of 300 has been appropriate to adopt.

The two smoothened NAIRUs follow very similar paths, and arithmetic differences are small in magnitude. From the values 5.82 (300) and 5.52 (1000) in 1992, the decline through the 1990s result in 5.26 and 5.48 percent respectively in 1999 (4.9 percent in Ball & Mankiw, 2002).[7] NAIRU rises until 2005 reaching 5.83, 5.84 percent and 6.40 and 6.18 by 2010. Mildly around 6.18 and 6.21 in 2015, it is 6.34 by both series in 2021. Lambda parameter 300 shows higher curvature as expected, yet both series decline through 1990s and rise during the 2000s reaching 6.34 percent in 2021.

4. NAIRU and Productivity

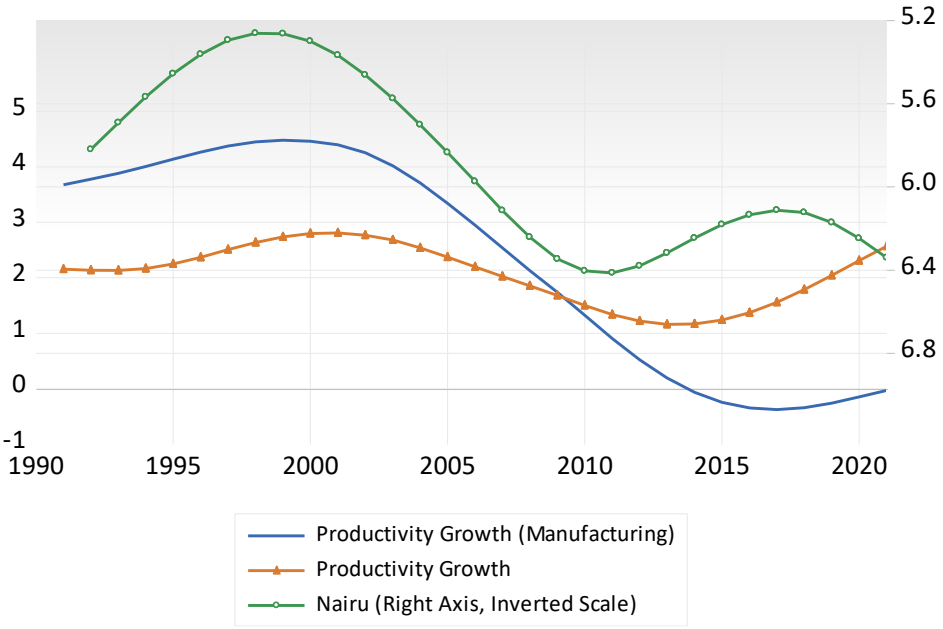
4.1. Productivity Growth

The rise in productivity during the 1990s has caught attention of economists during the so-called Goldilocks period (New Economy) when it rose almost two-fold during 1996 -2000, compared against the 1974–1995 period. The catchy rise from 1.5 to 2.6 percent between the two periods was majorly due to the developments in information technologies (IT) (Ball & Mankiw, 2002), which makes it worthy to examine the relation between unemployment and productivity. Although there is significant number of studies on the subject for 1990s, not so many have been conducted for the 2000s. Previous research provides evidence in favor of the relation between the two variables in Ball and Moffit (2001), Ball and Mankiw (2002), and Staiger, Stock, and Watson (2001). Gordon (1998) and Staiger et al. (2001) have also accounted for wages and capacity utilization in their detailed studies, however, have not found empirical relevance around these matters.

Figure 5 follows the relation between NAIRU and productivity growth during 1990–2022 with yearly data, which shows similar fluctuations.

7 It is a general characteristic of the US economy to demonstrate a ratio of 6,5 percent structural unemployment, which has been computed by major researchers in the field. NAIRU of around 6 percent (although differing statistically by methods and data adopted) has been common up until mid 1990s, whereas NAIRU has declined to around 5 percent by end of the decade.

Figure 5. NAIRU (Lambda=300) vs Rise in Productivity (Lambda=100) (%, Annual)



Rise in productivity and the fall in NAIRU follow a parallel pattern during the 1990s with higher acceleration in the second half of the decade of explosive IT. Gap variables (Figures 8-10) do not rise during the period. Comovement is symmetrical opposite during 2000s when productivity starts declining,[8] and the NAIRU rising considerably from 5.30 to 6.40 by 2010. Although productivity growth continues to fall (severely in manufacturing) between 2010–2015, NAIRU declines slightly from 6.40 to 6.18 percent.[9]

During 2015-2021 there is an astonishing rise of more than two-fold, from 1.2 to 2.6 percent in annual growth of overall productivity. However, there is no strong answer from NAIRU; which only slightly falls to 6.11 in 2017; even rising back to 6.34 by 2021. Low manufacturing productivity growth is still an issue between 2015–2021, navigating below zero then. This seems to point at the weak effect of services sector as opposed to manufacturing in creating employment.

8 Which is rather convex during 2000-2005 although with an increased rate in the second half of the decade.

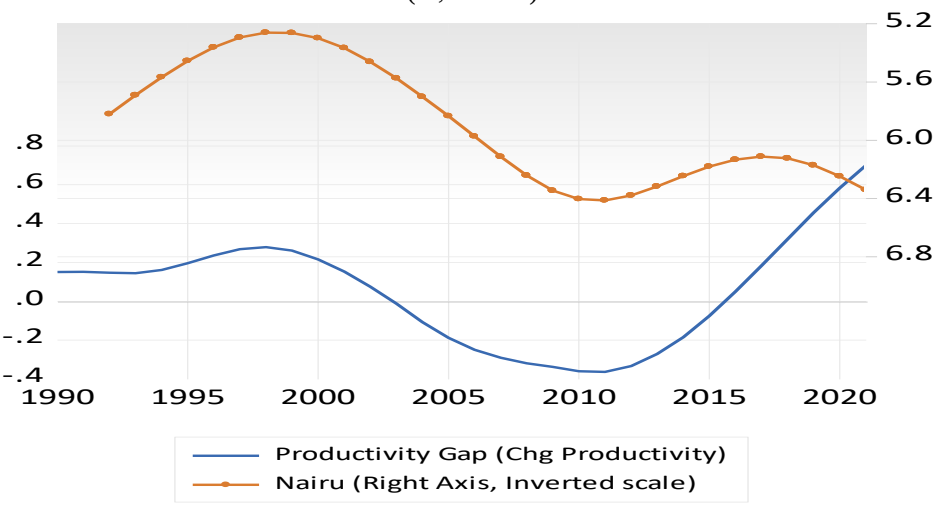
9 Probably due to the rise in productivity gap and manufacturing gap as well as the wage gap during the period.

NAIRU seems to have comovement with the productivity variables, although the relation has broken down by 2010. After 2010, NAIRU has not shown much movement navigating between 6.40-6.18-6.34 percent. Total productivity and manufacturing diverge, with manufacturing demonstrating severe falls, against the rise in total productivity. Economic developments that lead to the more than two-fold rise in overall productivity growth between 2015–2021 should be analyzed, as it shows some new breakpoint. Interestingly the rise in total productivity does not create a strong push down on the NAIRU rates. Section 5.2 below provides the US sectoral shares of production and the labor force.

4.2. Change in Productivity Growth

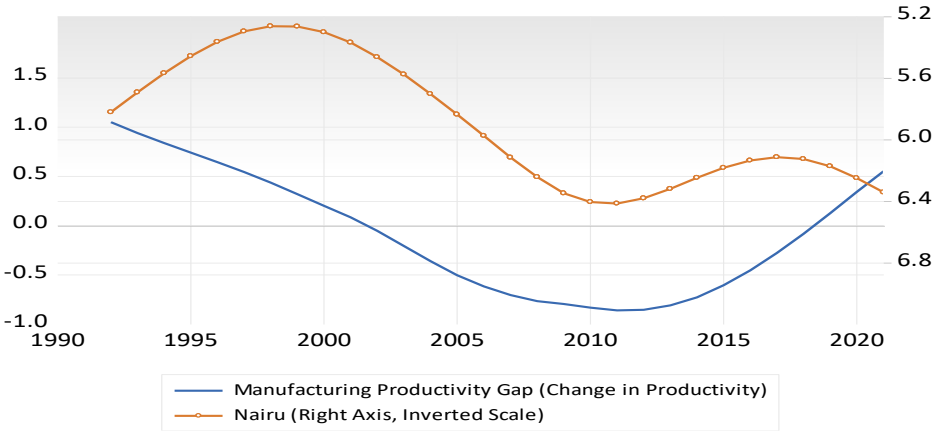
Ball and Mankiw (2002) argue that it is not productivity growth but rather the change in productivity growth that causes a shift in the Phillips curve. Ball and Moffit (2001) have similar findings that favorable shift in the Phillips curve is due to the rise in productivity over the wage aspirations (higher productivity acceleration). Thereby, we find it relevant to define a "gap" variable measuring the change in productivity growth: the difference between current productivity growth and past productivity growth over the past five years.[10] The long-run trend of productivity gap is HP filtered to compare with the NAIRU series in Figure 7.

Figure 7. NAIRU (Lambda=300) vs Change in Productivity Growth (Lambda=100) (%, Annual)



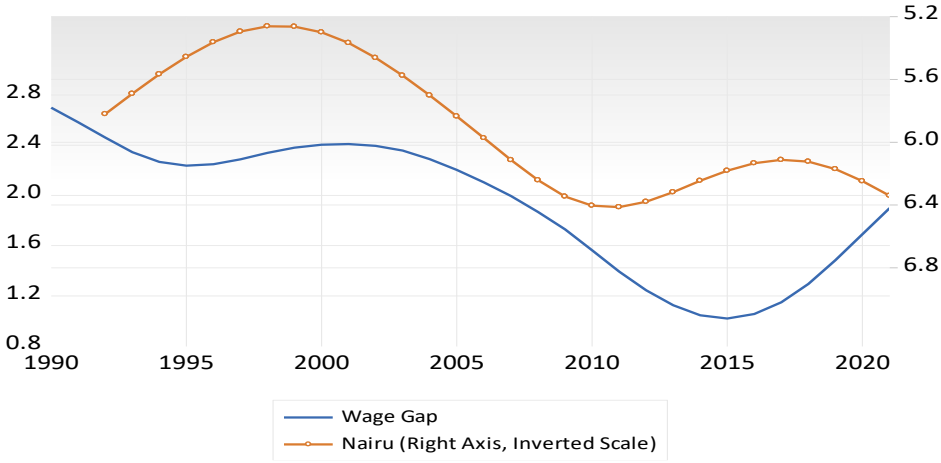
10 Five year moving average.

Figure 8. NAIRU (Lambda=300) vs Change in Manufacturing Productivity Growth (Lambda=100) (%, Annual)



An alternative gap variable is also defined as the difference between productivity growth and wage growth in the past. Before past productivity growth was proxy for the wage growth in the past. Indeed, both variables are tied to wage aspirations of the workers, which is the reason why we measure productivity gap as the difference of productivity growth and wage growth in the past (moving average of the last five years' growth). The gap series is HP filtered to obtain long term trend to test against movements in NAIRU (Figure 9). From Figures 7, 8 and 9, we observe that *NAIRU* and the productivity gap follow similar (negative) fluctuations, rather than the manufacturing and the wage gap.

Figure 9. NAIRU (Lambda=300) Wage Gap (Lambda=100) (%, Annual)



Change in productivity graphs computed with the five-year moving averages do not demonstrate better comovement with the NAIRU than productivity growth as opposed to Ball and Mankiw (2002), and Ball and Moffit (2001). When the NAIRU rises from 5.30 to 6.40 percent during 2000-2010, *wage gap also shows a steep fall, contrary to expectations*. It is a period when productivity, manufacturing productivity (and all the gap variables) fall and the gap between productivity and wage increases narrows in favor of wage aspirations. Thus, employment doesn't respond to the change over past productivity, but rather to the current growth trends. When the NAIRU falls slightly during the 2010–2017 period, there is an increase in changes in productivity growth both.

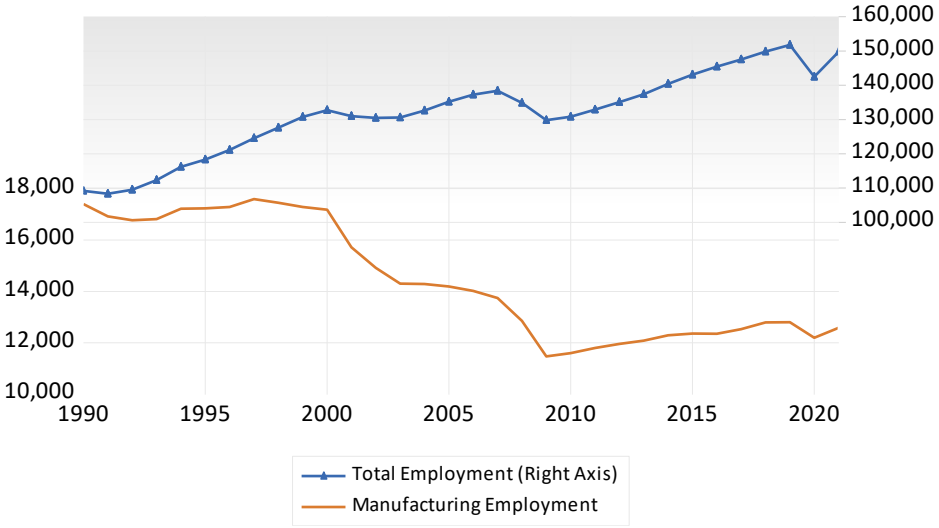
4.3. Sectoral GDP Shares and Employment

Table 5. GDP Sectoral Shares by Five Year Tranches

	Manufacturing	**Industry**	**Services**
1990–1994	18.3	26.5	71.2
1995–1999	16.9	24.4	73.9
2000–2004	15.7	23.3	75.5
2005–2009	13.5	22.0	76.8
2010–2014	12.3	20.0	78.9
2015–2019	12.1	19.3	79.6
2015–2021	11.0	18.1	80.9

As followed in Table 5, share of manufacturing is 18.3, 16.9 percent and share of services sector is 71.2, 73.9 during the 1990s and respectively 15.7–13.5 and 75.5–76.8 percent during the 2000s. During the 2000s when both productivity indicators are falling, share of services sector is on the rise. When total productivity rises twofold (in spite of the severely declining performance of manufacturing) during 2015–2021, manufacturing share is even lower as 12.1–11 percent. During the 31-year period, services sector (in US dollars) has grown about 10 percent, while manufacturing has declined by seven percent.

Figure 6. Total Employment vs Manufacturing Employment (Thousand People)



In the 1990s employment in manufacturing fluctuates well above 17 million, which shows a steep fall to 15.7 million people during the 2001 recession. Although recession lasts short and economy recovers, employment declines throughout the decade, even faster after 2007. The 2008 recession has had its effects on the economy, however effects on manufacturing are more severe. Production employment rises weakly after 2010, reaching only 12.5 million people by 2021 (Figure 6). Apparently, there is a fall of the share of production in total employment.

4.4. Services Sectors and Growth: Historical Perspective

Historically, services have followed industrial production chronologically, with the demand for them completing and/or improving upon the production. (Chang, 2011). However, during the 1980s neoliberal debate has argued that services sectors are of higher importance for growth and productivity having replaced industry and manufacturing in developed countries; which has been confronted with the counter argument that it is actually *manufacturing* which is the main drive of *technological advances* for higher growth, acting upon a wide base of *diversified sectors*, also meeting *the foreign demand*, and creating balance of payments (BOP) surplus. The IT revolution of the 1990s along with the rise in productivity in the US sets example in favor of the counter argument, which has

brought in higher rates of growth and employment without inflation, implying an inward shift of the Phillips curve.

As the leading economy of the 18–19th centuries, England had been producing 20 percent of the total world output, with 46 percent share in world trade volume, 35 percent of employees working in production, during the post-industrial revolution period (Chang, 2011)

Role of England changed from 1860 on when she started liberalizing her trade regime, losing her role to US and Germany through time. Still, she remained a strong industrial hub and had a BOP surplus of upto four percent of GDP until the 1970s. Meanwhile England also showed tendency towards higher share of the services sectors (finance, insurance, information, communication etc) in GDP, resulting in the US surpassing her in mass production and trade. Similar dynamic seems to be at stage with the new actors China, India, Asian countries and other emerging markets versus the industrialized world.

The argument that higher services sectors is preferable and is the resulting outcome in a developed country has not been validated by the growth and employment problems UK has tackled with since the 1970s.

For one thing, fall in the total share of industry and production is result of the higher productivity resulting in quick fall of prices of the items produced in these sectors relative to services. Also, certain services sectors extracted from production (like catering, warehouse, training etc) and classified under services, have contributed to the artificial shrinkage. Substitution of production with imports, high prices in the services sectors are other relevant reasons contributing to services' growth (Chang, 2011).

The inherent dynamic of a shrinking production should not be taken with ease as it will result in more and more stagnant technology and/or innovative processes, which will affect growth and employment adversely, and reflect on NAIRU in the long run. In time, the country will envisage less competitive production base to meet the demand for exports which will also trigger BOP problems. Stagnant technology in the smaller and ineffective production sectors may also raise the need for technology transfers from abroad.

Conclusions

During the 1990s there is rise in productivity and falling NAIRU due to the technological innovations related with the IT revolution. Situation is symmetrical opposite in the 2000s when productivity is in a declining trend, and the NAIRU is rising from 5.30 to 6.40. During the decade all gap variables are in

a declining trend with slowing rates of productivity growth relative to their recent past. The fall in manufacturing productivity is particularly striking.

Productivity continues to fall through the years 2010 to 2015 whereas NAIRU declines though slightly from 6.40 to 6.18 percent[11]. In the following period of 2015–2021, manufacturing goes on with weak performance in spite of a big leap forward in overall productivity of over two-fold from 1.2 to 2.6 percent. During the six years there is no fall in the NAIRU, which is even rising slightly. The developments are totally different from the situation when productivity has risen from 1.5 to 2.6 percent and NAIRU has fallen more than one percent during the years between 1974 and 2000. The relation between NAIRU and productivity seems to have broken down in the post 2010 period.

Since there is hardly any downward trend in the NAIRU in spite of the astonishing rise in *total productivity*, downward dynamic of unemployment during the 1990s may have stemmed from the productivity rise of the manufacturing sector. From this perspective, the long run sectoral composition of US GDP with higher services causes concerns for further falls in NAIRU unless some new strong technological paradigme emerges, whose chances may be lower than before with less research, development and innovations with the eroding manufacturing sector.

Ball and Mankiw (2002), and Ball and Moffit (2001) have both stressed the change in productivity growth instead of the productivity growth itself, as the main reason causing shift in the Phillips curve, an idea which they both have proven with models. Following their footsteps we have also considered productivity gap and wage gap comparing NAIRU with the long-term trend of both series, which have not provided better comovement over productivity growth. NAIRU does not seem to respond to past levels of productivity growth.

The US economy has envisaged technological jump during the 1990s, after which GDP sectoral shares have shifted towards higher services from 76 to over 80 percent by 2000–2021, at the expense of industry and manufacturing. The dynamics of slowing productivity and competitiveness could be hidden in the new sectoral composition of national income which reflects on the higher plateau of NAIRU as well as the falling employment rates of the economy. The inflation unemployment relation in the post 2010 period seems to involve a new dynamic which needs to be delved into with further research.

11 Probably due to the rise in productivity gap and manufacturing gap variables as well as the wage gap during the period.

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