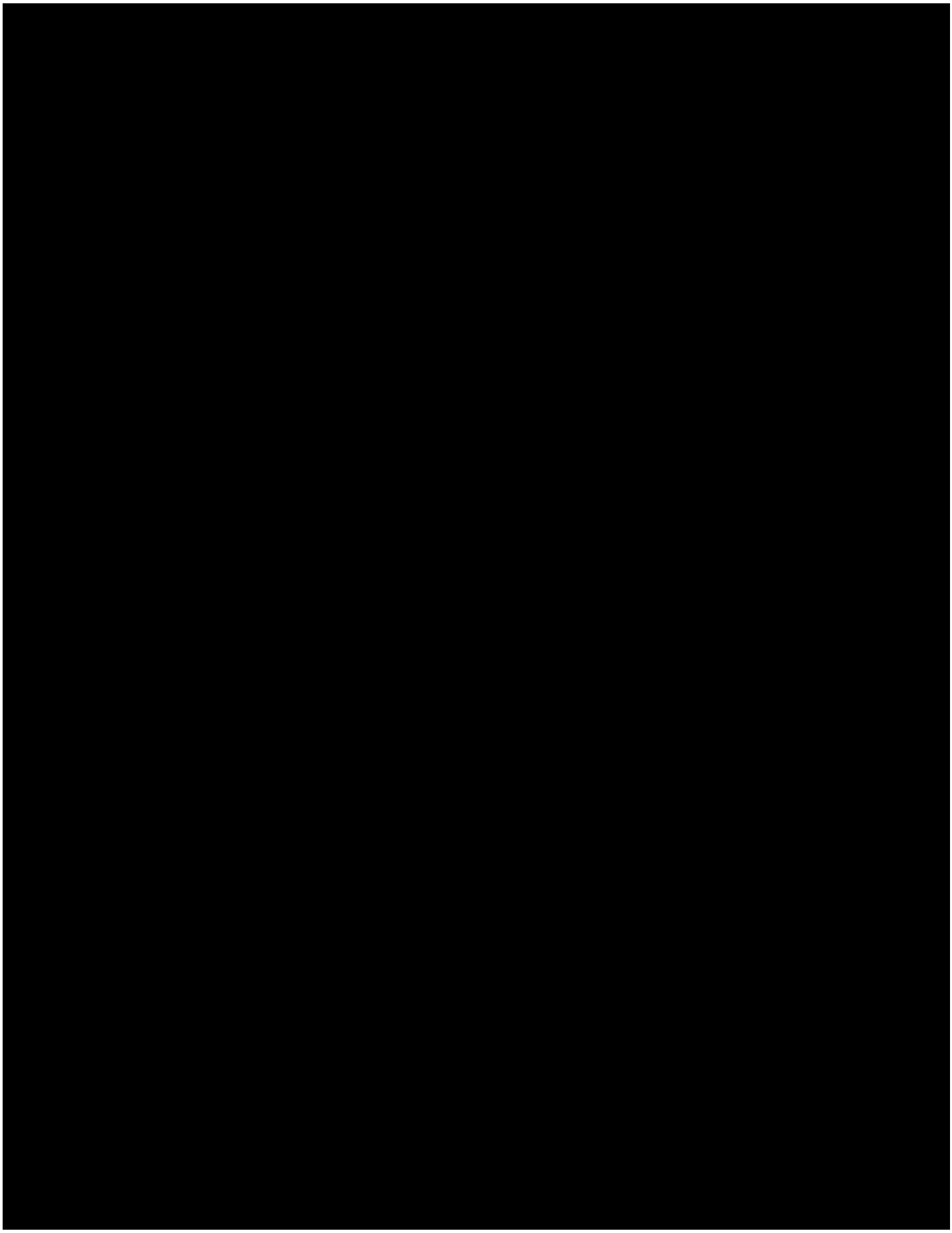

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Immigration and Wage Dynamics in Germany

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Abstract

German wages have not increased very rapidly in the last decade despite strong employment growth and a 5 percentage point decline in the unemployment rate. Our analysis shows that a large part of the decline in unemployment was structural. Micro-founded Phillips curves fit the German data rather well and suggest that relatively low wage growth can be largely attributed to low inflation expectations and low productivity growth. There is no evidence – from either aggregate or micro-level administrative data – that large immigration flows since 2012 have had dampening effects on aggregate wage growth, as complementarity effects offset composition and competition effects.

JEL Classification Numbers: C23, E31, J30, J60

Keywords: wage growth, Phillips curve, immigration, micro-data, panel regression, Germany

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I. Introduction and Executive summary

The performance of the German economy and its labor market have been impressive in recent years and there is widespread perception that wages should have grown faster. Despite rapid GDP growth, booming employment and dropping unemployment that has reached record lows, nominal wage growth seems to have stabilized around 2.5 percent. This has led many commentators to conclude that the time-honored relationship between labor market slack and wage inflation – the Phillips curve – does not hold for Germany anymore.[1]

Many reasons have been invoked to try and rationalize such a phenomenon. One widely cited argument is that competition from foreign labor may have put downward pressure on wages. Increased competition from foreign labor – so the argument goes – has curtailed workers' bargaining power and flattened the slope of the Phillips curve: wages have become less sensitive to variations in the unemployment rate. Also, because immigrants tend to work in relatively low paid jobs, overall wage growth may have been dampened by a change in the composition of the labor force.[2]

Theoretically, immigration may affect wage dynamics in two different ways, through so called *competition* and *composition* effects.

- Immigration may in principle push down wages due to increased *competition* in the labor market. Native workers may lose bargaining power when confronted to a larger pool of competitors, which would result in lower wage growth *for given labor demand*.[3] However, other forces tend to work in the opposite direction.

    - First, labor demand is not fixed. An inflow of foreign labor will lead to a corresponding increase in labor demand, as the demand for goods and services will grow in tandem with the larger population. In the long run, induced capital accumulation should even further boost labor demand.

    - Second, the more foreign labor inflows are concentrated in a limited number of sectors/occupations, the less immigration weighs on overall wage dynamics. In a nutshell, immigration exerts *downward* pressure on the wages of workers to which immigrants are close substitute (typically earlier generations of migrants and low -skilled native workers), but *upward* pressure on the wage of workers to which immigrants are complements (typically high-skilled, native workers). As a way of illustration, assume that immigration is

[1] See e.g., Blau J. (Oct. 2017).

[2] See e.g., Wolff G. (Nov. 2017), Bundesbank (2018).

[3] Competition from foreign labor could also materialize itself through the threat of offshoring production to lower labor cost countries. This threat has possibly contributed to the wage moderation period early 2000s.

exclusively concentrated in the construction sector. Immigrants will exert pressure on wages in the construction sector, pushing down construction costs and housing prices. At the same time, the larger pool of workers will boost demand for other goods and services, increasing demand for labor and wages in these activities. Wages in construction will be pushed down, but wages for e.g., doctors, nurses, engineers, etc. will tend to increase faster.[4]

- Immigration also affects overall wage dynamics through *composition* effects. Immigrants usually tend to be concentrated in lower-skilled, lower-paid sectors. And even when controlling for skills, age, experience and sector of activity, immigrants tend to be paid less than natives. Therefore, mechanically, large immigration would weigh on overall wage growth through changes in the composition of the labor force.

All in all, whether immigration exerts a dampening influence on overall wage growth will depend on i) the size of the immigration flow, ii) its sectorial distribution and iii) the degree of substitution with native labor.[5] The international literature is discordant on this point, which, at the end of the day, remains an empirical question. [6] Given large immigration and the seeming disconnect between employment and wages in Germany in recent years, a "German answer" to this empirical question is of special interest.

To analyze the impact of immigration on aggregate wages in Germany we follow a two-pronged approach.

- First, we follow Gali (2010) and Bentolila et al (2007) and derive a micro-founded Phillips curve based on *aggregate* data where immigration is allowed to play a role in affecting both the slope and the intercept of the Phillips curve. We also complement the micro-founded approach with a more reduced form specification, allowing for richer dynamics and potentially better fit.

- The second approach focuses on *micro-level* data. We rely on social security data to construct a panel data set where both cross-sectional and longitudinal dimensions can be used to disentangle *competition* from *composition* effects of migration on aggregate wages.

    - *Composition effect*. Because immigrants to Germany are paid less than natives, aggregate wages would have risen by 0.49 percent more over the period 2012–2016 (about 0.12 percent per year) if the immigration boom had not taken place. The overall negative composition effect for 2012–2016 of - 0.49 percent is partly accounted for by the specific attributes of the migrant population. For example, immigrants are relatively young (-0.05 percent),

[4] This mechanism can in principle also be found within sectors. When immigration is mainly low-skilled, it ends up pushing up wages of higher-skilled labor in the same sector.

[5] Negative effects, if any, will also tend to be larger in the short term.

[6] See Ottaviano and Peri (2012) and literature cited therein in contrast to Borjas/Katz (2007), to name just a few.

work in marginal jobs or part-time (-0.08 percent) and are usually employed in sectors that pay less (-0.24 percent). Even controlling for all these factors, immigrants are paid less than natives bringing aggregate wages down by -0.18 percent over the period (see Text Table).

- *Competition effect*. After controlling for the fact that the wages of immigrants are typically lower than those of native workers, wages of men are typically higher than wages of women, and wages in manufacturing are typically higher than average wages, among other factors, we find a small but positive effect of immigration on wages over 2012–2016. The so-called competition effect of immigration leads to an increase of aggregate wages of 0.26 percent per year as the dampening effect of immigration on wages of substitute labor is more than compensated by stimulating effects on wages of workers for which immigrants are complement. We also find that the substitution effect dominates and puts downward pressures on the wages of incumbent foreign workers.

Putting it all together, we conclude that immigration seems to have had only negligible impact on aggregate wage growth in Germany. The Phillips curve is alive and well and accounts for the bulk of wage dynamics, suggesting no role for immigration on aggregate.[7] Analysis based on social security data confirms this result and shows that *competition* and *composition* effects broadly cancel out. Post-crisis, large immigration waves did tend to dampen wage growth of foreign labor in direct competition with the newcomers, but this negative effect was more than offset by higher wage growth for relatively skilled and native workers.

The rest of the paper is structured as follows. Section II presents key stylized facts and argues that the natural rate of unemployment has dropped in Germany following the Hartz reforms, with important implications for the specification and estimation of the wage Phillips curve. Section III derives a theoretical specification of the wage Phillips curve that allows immigration to play a distinct role in wage formation. Section IV estimates it along competitive specifications and establishes that immigration did not play any significant role in explaining overall wage developments in Germany. Section V relies on administrative micro-data and corroborates the conclusion of Section IV.

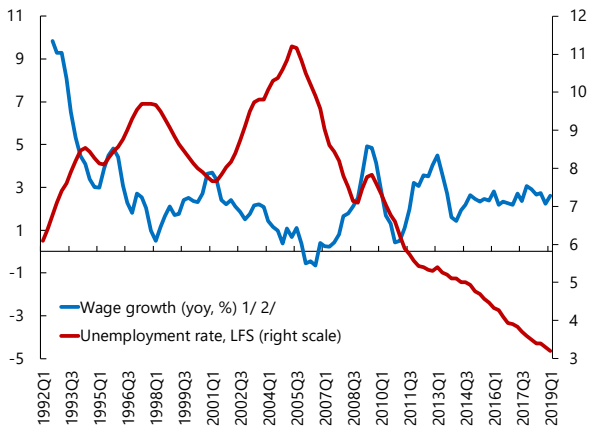
[7] This is consistent with recent results from Weber and Weigand (2018), who do not find any negative effects of immigration shocks on wages in a structural macro-econometric analysis conducted over the period 1970-2014.

II. Labor Market Stylized Facts

A. Unemployment, structural reforms, and labor market tightness

From the beginning of the 1990s to mid-2000, unemployment had been trending upward in Germany amid lackluster GDP and employment growth. The unemployment rate had reached a peak of 11 percent in 2005, the highest rate among the G7 countries, and Germany was dubbed the sick man of Europe (The Economist, 2004). Arguably, the relentless increase of German unemployment rate up to the mid-2000s was largely due to the combination of technological factors and institutional shortcomings (Ljungqvist and Sargent, 1998, Hutter and Weber, 2019). While technological changes, such as automation and computerization, increased the pressure on the low-skilled labor market segment, weak institutions, such as inefficient labor market-matching mechanisms and deteriorated employment incentives (Krause and Uhlig, 2012, Jung and Kuhn, 2014), led to strong hysteresis effects in unemployment (Klinger and Weber, 2016a).

Figure 1. Wage Growth and Unemployment
(Percent)



Sources: Bundesbank, Haver Analytics; and IMF staff calculations.
1/ per employee hour worked.
2/ three-month moving average.

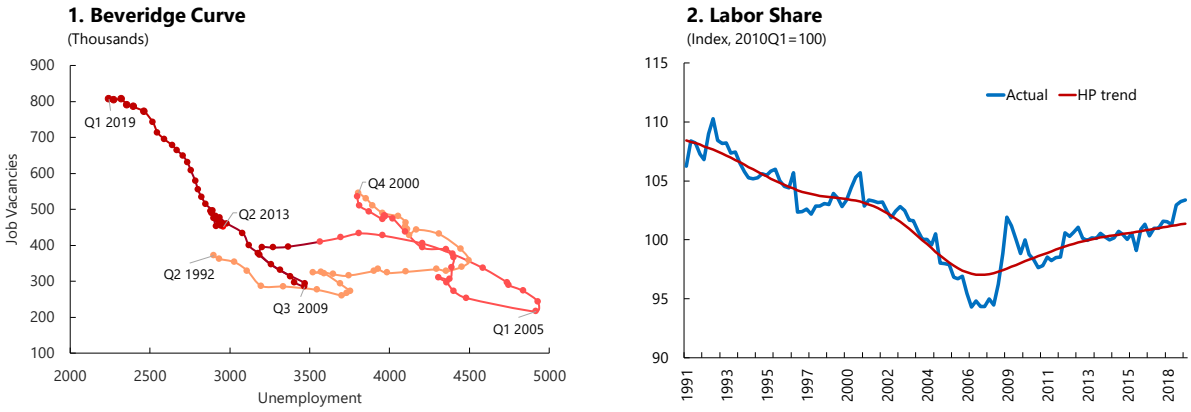
The upward unemployment trend was broken mid-2000 by the introduction of major labor market reforms. The so-called Hartz reforms were enacted in a sequence of major steps between 2003 and 2005. The first steps (Hartz I to III) focused on reforming the Federal Employment Agency and developing better tools for improving matching efficiency (temporary agency, self-employment, retraining, stronger incentives to accept jobs, etc.). The last step was the reform of the unemployment insurance benefits (Hartz IV), implemented in January 2005.[8] The labor market reforms coincided with a new implicit social contract (subscribed by the largest labor unions) that focused on dampening labor costs and increasing

[8] Before Hartz IV, German workers unemployed for more than 52 weeks were entitled to indefinite income support based on previous net earnings – the so-called unemployment assistance – at a rate that was only slightly below the typical unemployment insurance. The incentive for relatively high paid employees with depreciated (or firm-specific) skills to look for new jobs (at a potentially lower pay) was low. Hartz IV eliminated this unique feature and merged unemployment assistance with social assistance, eliminating the former. Long-term unemployed workers are now only entitled to (much lower) means-tested payments based on basic needs and family status and conditional on the beneficiary's willingness to work.

employment growth. Employers and employees basically agreed that wage moderation was a pre-requisite for job creation.

The reforms had spectacular impact on Germany's unemployment rate. By reducing the long-term unemployment assistance and by improving matching efficiency, labor market reforms increased the incentive to look for work and brought down the reservation wage. This development can be seen on a Beveridge curve that shows the downward sloping cyclical relationship between unemployment and vacancy rates (Figure 2.1). Structural changes in the labor market leading to changes in the long-term structural unemployment – or natural rate of unemployment[9] – are typically characterized by shifts of the Beveridge curve. Following a persistent rightward drift during most of the 1990s (higher unemployment for similar vacancies), the Beveridge curve shifted back inwards after the Hartz reforms (after 2005). This reflects better incentives and a more efficient matching of vacancies and unemployed. In other words, a significant part of the decline in unemployment between 2005 and 2008 seems to reflect a more efficient (not a tighter) labor market (see Klinger and Weber, 2016b or Krause and Uhlig, 2012).[10] The reforms helped accelerate the ongoing wage moderation process as can be seen on the downward shift of real unit labor costs (real wages over labor productivity or labor share) between 2000 and 2007 (Figure 2.2). After the financial crisis, unemployment and vacancies resumed their typical negative relationship along a new Beveridge curve, a sign that the transition to a new and lower long-term structural unemployment rate seems to have been completed.

Figure 2. Lower Unemployment Reflects More Efficient Labor Market



Sources: Bundesbank, Destatis, Federal Employment Agency, Haver Analytics; and IMF staff calculations.

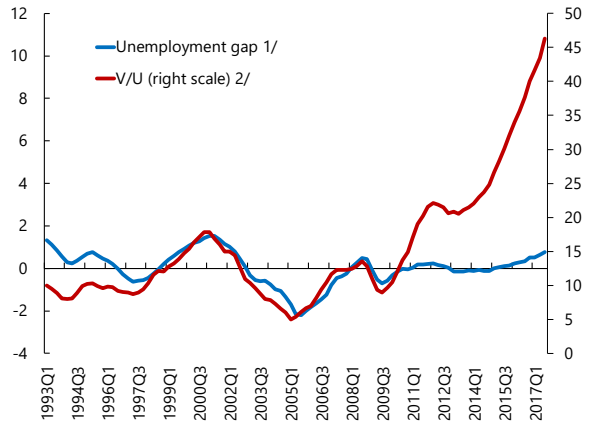
[9] We use the terms long-term structural unemployment, natural unemployment and NAIRU interchangeably in this paper. The difference between the three definitions do not matter for our analysis. See Ball and Mankiw (2002) for a discussion.

[10] Klinger and Weber (2016b) find that a strongly decreasing separation rate may also have played an important role. The sustained reduction in unemployment can be attributed to the fact that the rising scarcity of labor motivates firms to keep their employees in order to avoid long and costly hiring processes.

B. Wage Inflation and the NAIRU

While useful to visualize shifts in the level of structural unemployment, the Beveridge curve may be unreliable at times as an indicator of slack. It is true that the ratio of job vacancies to unemployed (V/U) can generally be thought as a measure of labor market tightness – a higher ratio theoretically implies higher search costs and ensuing wage pressure. However, when employers have access to a large pool of jobseekers outside of the national labor force – as was the case in Germany after 2011 (see next section for a discussion) – companies may be encouraged to post more vacancies as they are aware of the greater potential to fill them. In such cases, the ratio of vacancies to unemployed would overestimate tightness since vacancies are posted domestically while domestic unemployed typically underestimates the pool of available labor.[11] Looking at Figure 3, the correlation between (V/U) and an alternative measure of slack based on the unemployment gap (the deviation of unemployment to the non-accelerating inflation rate of unemployment, NAIRU) is very strong up to 2009. After 2009, the two series start diverging, suggesting that (V/U) started to grossly overestimate labor market tightness.

Figure 3. Labor Tightness Measures
(Percent)



Sources: Bundesbank, Destatis, Federal Employment Agency, World Economic Outlook; and IMF staff calculations.
1/ IMF WEO measure.
2/ Ratio of vacancies to unemployed.

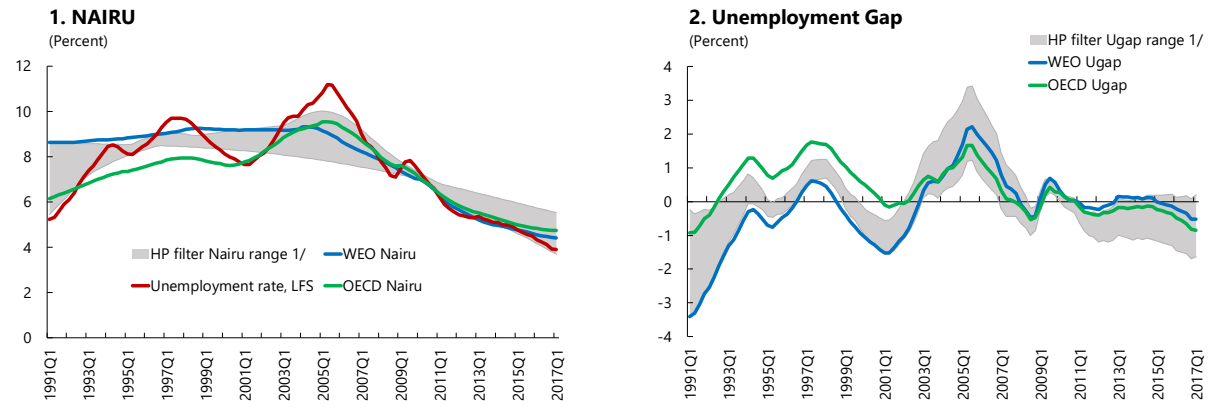
When it comes to assessing inflationary pressures the concept of NAIRU is usually preferred (because of its relationship with other measure of long-term equilibrium such as potential output via the Okun's law). We will rely on the NAIRU to compute the unemployment gap – the deviation of unemployment from its structural equilibrium – a measure of labor market slack.

Since the NAIRU is unobservable, researchers typically use filtering methods based on the actual level of unemployment, inflation and output to simultaneously estimate the unemployment and output gaps relying on the Phillips curve and the Okun's law relationships (see Benes et al. 2012 for an example). Results for Germany are displayed on Figure 4. Some differences between OECD and WEO estimates are clearly visible, reflecting methodological and estimation choices, but they are dwarfed by the growing gap with V/U

[11] See Klinger and Weber 2018.

displayed on Figure 3. The WEO NAIRU hovers above the range of HP-filtered NAIRU estimates between 1991 and 2001, while the OECD NAIRU is below it.[12] The two estimates converge after the crisis.[13] But how good are NAIRU unemployment gaps at measuring labor market slack in Germany?

Figure 4. A Thousand Estimates of Labor Market Slack



Sources: World Economic Outlook; and IMF staff calculations.
1/ lambda one thousand to one million.

The original (1965) Phillips curve implicitly assumed that the NAIRU was constant, meaning that the headline unemployment rate was a sufficient statistic for the degree of tightness on the labor market; lower unemployment rate meant tighter labor markets and resulted in higher wage growth. However, as shown on Figures 4, the NAIRU can vary over time.[14] The following two charts show the relationship between inflation and unemployment (Figure 5.1) and inflation and the unemployment gap (Figure 5.2). Controlling for the shift in the NAIRU as is done on Figure 5.2 reinstates the negative relationship between wage inflation and labor market slack characteristic of the Phillips curve.[15]

[12] It is common knowledge that a certain degree of imprecision typically plagues filtered measures of the NAIRU (See Aiyar and Voigts (2019) and Kangur, Kirabaeva, Natal and Voigts (2019) for a recent account). We take this into account by considering a swath of NAIRU estimates (painted in grey) computed by running HP filters with lambda parameters comprised between 1'000 and 1'000'000.

[13] Both estimates are based on multivariate Kalman filters. The OECD NAIRU exploits the relationship between the unemployment gap and consumer price inflation (see e.g., Richardson et al., 2000), while the WEO NAIRU is structured around two economic relationships (Okun's law and Phillips curve) that comprise the output gap, the unemployment gap and inflation (see e.g., Benes et al. 2012 and WEO 2015 Chapter 3).

[14] For example, the Hartz reforms are credited for improving matching efficiency, increasing flexibility and lowering workers' bargaining power and their reservation wage and with it lowering the structural level of unemployment.

[15] This result is independent of the particular NAIRU estimate used.

Figure 5. The Phillips Curve is Alive and Well

Sources: Destatis, Haver Analytics, IMF WEO; and IMF staff calculations.

C. Immigration and wages

Following the crisis, employment quickly bounced back in Germany, supported by large immigration flows (Figure 6.1). [16] In 2010, there were less than 15 million people with a migrant background in Germany, but by 2017 the figure rose to 19 million – almost 24 percent of the population.[17] Note that Germany was in good company post-crisis as many other advanced economies experienced similar or even larger immigration flows (Figure 6.2).

Strong immigration since 2012 is often mentioned to explain German sluggish wage growth (see Deutsche Bundesbank, 2018). The argument seems straightforward: migration leads to higher labor supply and therefore higher competition on the labor market, dampening wage growth. While plausible a priori, it is important to recognize that the wages of workers that are *complement* to immigrants, typically high-skilled native workers, will tend to be lifted by immigration. For example, downward pressure on low-skilled wages would increase profits, supporting firms' expansion plans and their demand for complementary higher-skilled labor.[18] Also, increased labor supply creates additional labor demand as the economy grows.

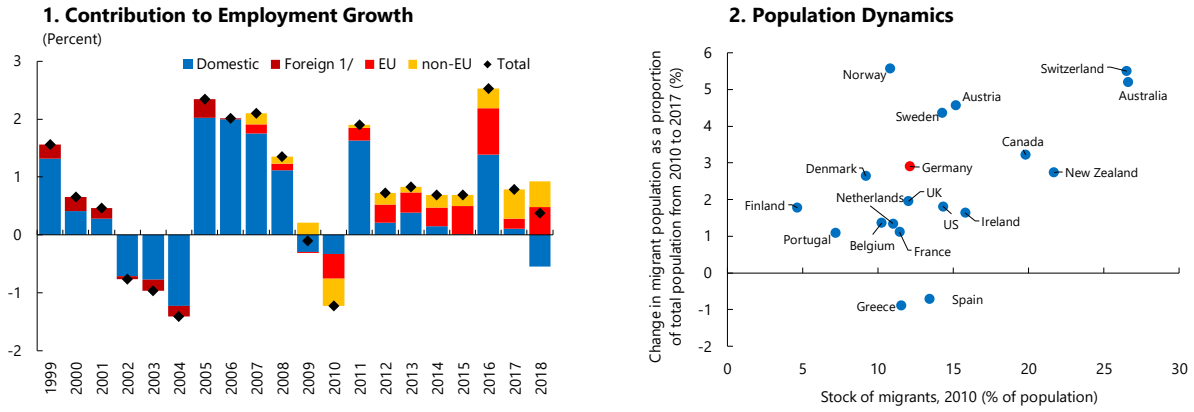
[16] Dubbed the German job miracle by Paul Krugman (2009).

[17] The average total net migration to Germany per year over 2011-2017 was 526,000 persons, up from roughly 132,000 over 1995-2010. In 2015 alone, 2.1 million people migrated to Germany, while 1 million people left, resulting in a net inflow of 1.1 million. This partly reflected the sharp rise in immigrants seeking protection. In 2015, the number of asylum seekers increased by 39 percent, and by another 54 percent in 2016. In 2018, out of the total stock of immigrants, 70% were from European countries, in particular from the European Union (44 percent).

[18] See Ottaviano and Peri (2012).

Over the long run, the capital stock is expected to adjust, boosting labor demand until the capital-labor ratio is back to a level consistent with balanced growth.[19]

Figure 6. Strong Immigration to Most Dynamic Countries Post-Crisis



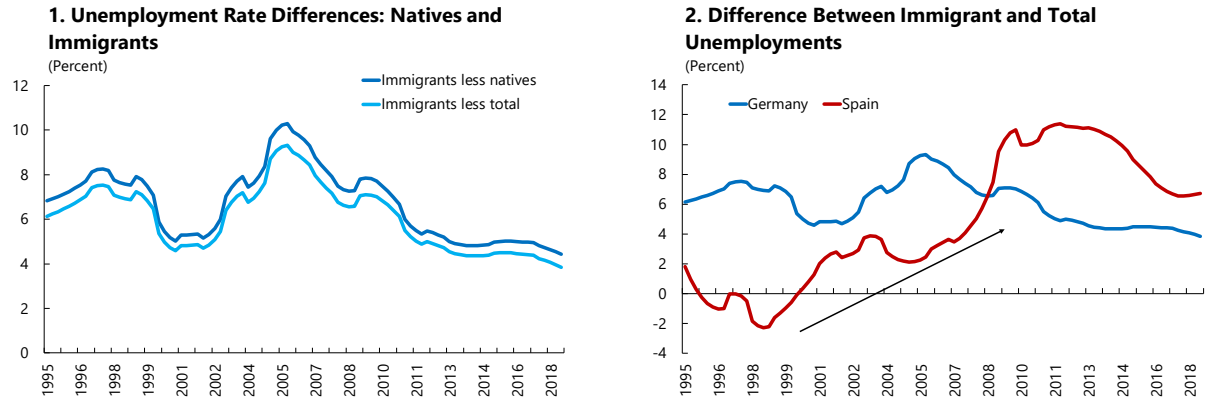
Sources: Eurostat, United Nations; and IMF staff calculations.
1/ From 2007, foreign employees are divided in EU and non-EU citizens.

Now, transitory downward pressure may in principle still appear if i) the adjustment of the economy is substantially delayed or ii) the distribution of immigrants is similar to natives across sectors and skills making them strong substitute. The dampening effect could even be enhanced in situations when large migration flows increased migrants' labor supply to the point where their unemployment rate increases significantly, and their reservation wages decline as a consequence (supply-push story).

Comparing Germany's recent immigration surge with the one in Spain in the 2000s is instructive in this regard. In Spain, the unemployment gap between foreign workers and natives increased steadily throughout the 1990s up to the financial crisis of 2008 as workers were added at a faster pace than the labor market could absorb them: a supply-push story. In Germany, in contrast, the relative unemployment rate of foreign workers remained roughly constant from 2012 to 2018 (dipped a bit, even), suggesting a demand-pull story: higher demand for labor was met with foreign labor. The downward pressure on wages, if any, is then likely to have been lower in Germany than in Spain as foreign workers' reservation wages had no reasons to decline during the period (Figure 7).[20]

[19] Ramsey (1928).
[20] See Bentolila et al. (2007) for a detailed analysis of the impact of immigration on wages in Spain.

Figure 7. Demand-Pull vs Supply-Push



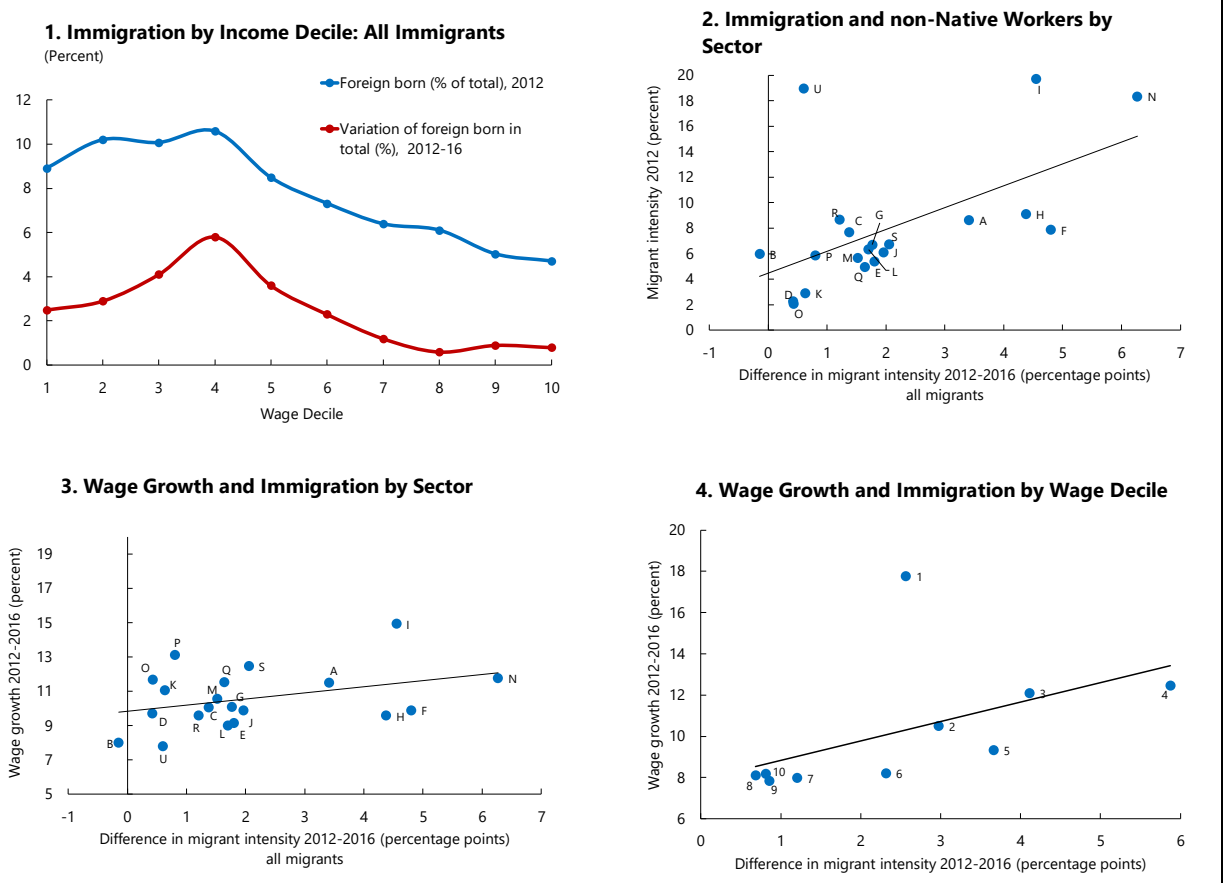
Sources: Eurostat; and IMF staff calculations.

A deep-dive in data from the social security panel (covering 38 million employees over the period 2012-2016) provided by IAB (Institut für Arbeitsmarkt- und Berufsforschung, the research institute of the federal employment agency) reveals that the population of migrants has increased the most in i) sectors where wage increases were the highest, and ii) where previous immigrant workers were already the most active in 2012. Figure 8 shows that immigration flows were the largest in sectors where labor demand and therefore wage growth was the highest (Food and accommodation, I, Support, N, Transport, H and Construction, F) and in sectors where earlier generations of migrants were already the most represented and where wages where the lowest.[21] This suggests that downward wage pressure due to immigration may have been more muted in Germany than in Spain (demand-pull) and if anything concentrated in low-skilled, low pay activities.

Without counterfactual analysis, these stylized facts are of course only suggestive. Whether wage growth, on aggregate, would have been higher absent immigration is an empirical question that sections III to V will tackle from two different angles, exploiting both time series and cross-sectional information, aggregate and micro-level data. We first read aggregate time series data through the lens of economic theory and design Phillips curves that allow immigration to play an active and separate role in wage dynamics. The focus will be on the validation of traditional Phillips curve and the impact of immigration on aggregate wage growth. We then turn to micro-level administrative data to better understand the role of immigration on wage dynamics by decomposing its effect across different representations of the population. The analysis also allows to disentangle *competition* effects – the impact of migration on wages assuming a constant share of migrants – and *composition* effects – the mechanical impact on aggregate wages of changing the shares of lower paid migrants.

[21] Note that the large increase in wages in the first decile of the wage distribution (the outlier on Figure 8.4) can be attributed to the introduction of the minimum wage, which did not by itself trigger an inflow of migrant.

Figure 8. Immigration Looks Like a Demand-Pull Story in Germany



Sources: Eurostat, The Institute for Employment Research; and IMF staff calculations.

III. Deriving the Phillips Curve from First Principles

Following Gali (2011) we derive a traditional wage Phillips curve from first principles. Starting from a representative household model where individual members are forward-looking, rational and derive positive utility from consumption and negative utility from work, Gali (2011) shows (see Appendix A for detail) that when households maximize intertemporal utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, \, \{N_t(i)\}),$$

for $U(C_t, \{N_t(i)\}) = \log C_t - \int_0^1 \frac{N_t(i)^{1+\varphi}}{1+\varphi} di,$

subject to a sequence of budget constraints:

$$P_t C_t + Q_t B_t \leq B_{t-1} + \int_0^1 W_i(i) N_t(i) di + \Pi_t \ ,$$

and forecast future unemployment rates based on an AR(2) process for unemployment (a good statistical representation for Germany), it is possible to derive a traditional Phillips curve:

$$\pi_t^w = \alpha(1-\beta)^{-1} + \gamma \bar{\pi}_{t-1}^p - \delta \hat{u}_t - \psi_1 \Delta \hat{u}_t,$$

for δ>0, γ>0, α>0, 0<β<1 and ψ_1<0, all parameters defined in Appendix A. The theoretical model tells us that wage inflation can be represented as a function of past price inflation, current unemployment gaps $\hat{u}_t$ and the change in the unemployment gap $\Delta\hat{u}_t$ that can be estimated using linear methods:

$$\pi_t^{w,4} = a_0 + a_1 \pi_{t-1}^8 + a_2 \hat{u}_t + a_3 \Delta \hat{u}_t + \varepsilon_t \ , \qquad (1)$$

where we expect a_1 and $a_3$to be positive, and a_2 to be negative given δ >0, γ>0, α>0, 0<β<1 and ψ_1<0. $\pi_t^{w,4}$ is a 4-quarter moving average nominal wage inflation and π_{t-1}^8 is an 8-quarter moving average quarterly inflation lagged one quarter.

Gali's traditional New Keynesian (NK) theoretical model can be extended to account for the role of immigration. Following Bentolila et al. (2007), we allow for heterogeneous labor force composed of imperfectly substitutable native and immigrant workers. Aggregate employment can then be expressed via the CES specification:

$$N_t = \left(\delta_1 N_{1,t}^{\rho} + \delta_2 N_{2,t}^{\rho}\right)^{1/\rho},$$

where $N_{1,t}$ and $N_{2,t}$ are respectively native and immigrant workers, imperfect substitutes with elasticity of substitution defined by $\sigma = (1-\rho)^{-1}$.

Properly accounting for the effect of immigration on the Phillips curve requires some modifications to the theoretical wage setting equation. It can be shown that the NK framework can be extended to incorporate the effect of immigration.[22] The empirical representation of this new theoretical model (equation (2) below) is isomorphic to equation (1) but includes the excess unemployment rate of immigrants over total unemployment $u_{2,t} - u_t$, and interactions terms involving the immigration rate ir_t, where ir_t is defined as the migrant share in total employment.

[22] See Appendix A and Bentolila et al. (2007) for more details.

$$\pi_t^{w,4} = b_0 + b_1\hat{\pi}_{t-1}^{8} + b_2\hat{u}_t + b_3\Delta\hat{u}_t + b_4\left(u_{2,t} - u_t\right) + b_5 u_{2,t} ir_t + b_6 u_{2,t} ir_t^2 + \varepsilon_t \ . \qquad (2)$$

In this setup, immigration can in principle affect wage setting in *two* different ways: via either the *intercept* or the *slope* of the Phillips curve (PC).

- First, immigrants are more mobile and keener to accept jobs at potentially lower wages than natives (lower reservation wage, lower bargaining power), and this effect will be the more pronounced the higher the unemployment rate of immigrants with respect to natives. Intuitively, the larger the unemployment gap between immigrants and natives $(u_{2,t} - u_t)$, the stronger the immigration rate ir_t, the larger the downward pressure on wages. Therefore, the unemployment gap, and interactions terms between immigrants' unemployment rate and the rate of immigration could in principle explain downward shifts in the otherwise standard Phillips curve's *intercept* (through coefficients b_4 to b_6 , expected to be negative).

- Second, because immigrants have different preferences (lower elasticity of substitution between consumption and leisure and lower wage elasticity of labor supply than natives), their labor supply curve will be more vertical, which in principle could affect the slope of the Phillips curve for a given NAIRU through coefficients b_2 and b_3.

In the next section, we estimate equation (1) and (2) and also turn to more reduced form specifications that relax the NK model's theoretical restrictions and potentially provide a better fit.

IV. The Phillips Curve: from Theory to Empirics

We start from the restricted, micro-founded specifications (1) and (2) derived in section III and relax the most constraining assumptions.

- We first relax the model-consistent (rational) expectation hypothesis and rely instead on survey measures (consensus) of expectations. We allow for both backward and forward-looking expectations through the parameter c_1.

- We then relax the assumption of constant productivity growth implicit in equations (1) and (2). Real wages are expected to follow productivity growth in the long term, which is consistent with German data (see Appendix B), but persistent deviations are possible. This suggests a role for an error-correction mechanism in the Phillips curve.

The resulting data generating process can be written as:

$$\pi_t^{w,4} = c_0 + c_1\pi_{t-1}^{8} + (1 - c_1)\pi_{t+8}^{4} + c_2\hat{u}_t + c_3\hat{e}_{t-4} + \varepsilon_t \ , \qquad (3)$$

where $\hat{e}_{t-4}$ is the residual from the following error-correction specification:

$$\log(W_t) = \mu_0 + \mu_1 * \log(YL_t) + \mu_2 * dum * \log(YL_t) + e_t$$

in which nominal compensation W_t is a function of labor productivity YL_t in nominal terms and an interaction terms with a time dummy that takes values of 1 between 2005Q1 to 2008Q1 and 0 otherwise to account for the effect of the labor market reforms on wage setting.

Finally, we build on the reduced form specification (3) by adding the immigration rate ir to the regression, as in Bundesbank (2018):

$$\pi_t^{w,4} = d_0 + d_1\pi_{t-1}^{8} + (1 - d_1)\pi_{t+8}^{4} + d_2\hat{u}_t + d_3\hat{e}_{t-4} + d_4 ir_t + \varepsilon_t \,, \qquad (4)$$

The inclusion of ir_t is meant to capture any additional impact of the immigration rate on wage inflation; the idea being that if foreign labor plays a role in dampening wage inflation, for given slack and price inflation expectations, d_4 should be significant and negative.[23]

The estimation results are summarized in Table 1. The specifications directly derived from the NK model's microfoundations (equations 1 and 2) are shown in columns I and II. As predicted by theory, the unemployment gap and the change in the unemployment gap both play a role in explaining aggregate wage dynamics. The coefficients are large, highly significant and have the expected sign.[24] Inflation expectations – as measured by lagged price inflation – is positively related to wage inflation. Other coefficients related to the impact of immigration on wage growth are statistically non-significant, suggesting that immigration played no additional role in explaining aggregate wage dynamics in Germany.[25] Immigration does not affect the slope of the Phillips curve either, as coefficients associated with the unemployment gap are not significantly different in column I and II. Estimation results from equations (3) and (4) are shown in the last two columns. Again, with the exception of the coefficient related to immigration, most coefficients have the expected sign and are highly significant. Positive deviations of wages from the long-term equilibrium determined by labor

[23] To allow for the possibility that the effect of immigration on wage setting could already be absorbed by the downward trend in the NAIRU post-crisis (see Figure 4.1) – as better matching could ensue from access to a larger pool of workers – we also kept the NAIRU constant at its end of 2009 level in the estimation, forcing all potential effect of immigration to the variable *ir* in equations (2) and (4). We also tried (not shown) a specification with interaction terms as in (2), but estimates were not statistically significant and sometimes even wrongly signed. Various lags of the immigration variable were also tried for robustness and to check for potential endogeneity bias with similar results.

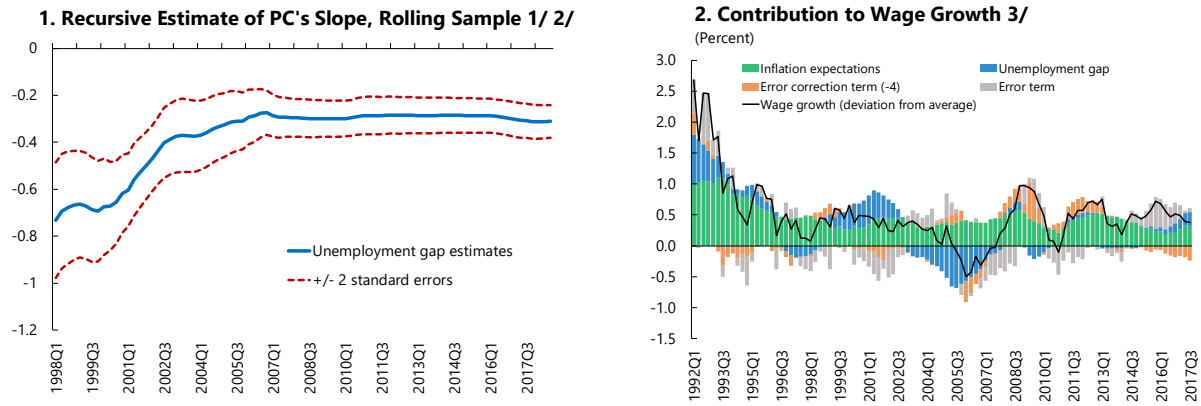
[24] See Appendix A, equation A8.

[25] One exception is the effect of the gap between the unemployment rate of immigrants and total unemployment rate in Germany shown in column II of Table 1, which appears positive and significant, meaning that a larger positive gap induces more wage growth. This result seems largely spurious, though, as the coefficient seems to be picking up some of the explanatory power from lagged inflation whose coefficient remained positive but became insignificant.

productivity have dampening effects on wage growth as shown by the negative coefficient on the error-correction term.

Table 1 suggest that ignoring immigration does not affect the performance of the Phillips curve in Germany. The adjusted R-squared are high for equations (1) and (3) and there is no evidence of omitted variable bias. The coefficients are also stable, suggesting the equation is well specified. Figure 9.1 displays estimates of the slope of the Phillips curve from rolling window regressions of equation (1). Beyond the initial uncertainty due to short sample, the estimated coefficient rapidly converges to its long-term, stable, significant and negative value. Another way to make the same point is to decompose wage growth into its main drivers. Figure 9.2 displays the contributions to wage growth derived from the RHS variables of equation (3). The exercise allows an easy visualization of the main drivers. First, the equation does a rather good job at explaining wage inflation in Germany. The contribution of the error term (grey bars) remains limited for the most part, with the exception of the pre-crisis period and the more recent period (2014-2015) when the model would have expected even lower wage growth due to low inflation expectations (green bars) and a realignment of wages with productivity from above (orange bars). The unemployment gap (blue bars) seems to have played the dominant role at the beginning of the 1990s and during the Hartz reforms; they have been consistently pointing towards higher wages since 2016.

Figure 9. Standard Phillips Curve is Alive and Well (continued)



Sources: Bundesbank, Destatis, Eurostat, Consensus Forecasts, Haver Analytics; and IMF staff calculations.
1/ specification I.
2/ step size = 1.
3/ specification III.

Table 1. The Wage Phillips Curve – Germany 1992–2017

	Specification			
	(I)	(II)	(III)	(IV)
$Inflation_{t-1}$	0.688***	0.392		
	(0.239)	(0.290)		
$Inflation\ expectations$			0.642**	0.178
			(0.293)	(0.311)
$Ugap$	-0.311***		-0.308***	
	(0.066)		(0.057)	
$Change\ in\ Ugap$	0.666***			
	(0.231)			
$Ugap$		-0.290**		-0.114***
$(constant\ NAIRU\ after\ 2009)$		(0.142)		(0.035)
$Change\ in\ Ugap$		0.848***		
$(constant\ NAIRU\ after\ 2009)$		(0.191)		
$Error\ correction\ term_{t-4}$			-0.105***	-0.105***
			(0.024)	(0.022)
$Immigration\ rate$				0.029
				(0.056)
$Foreign\ -\ total\ unemployment$		0.204**		
		(0.081)		
$Immigration\ rate\ *$		0.002		
$Foreign\ unemployment$		(0.014)		
$Immigration\ rate^2\ *$		-0.001		
$Foreign\ unemployment$		(0.001)		
c	0.311***	-0.117	0.157***	-0.238
	(0.117)	(0.786)	(0.045)	(0.458)
Sample	1992-17	1995-17	1992-17	1995-17
Observations	103	91	103	91
Adj. R-squared	0.69	0.47	0.73	0.55

Serial correlation and heteroskedasticity-robust Newey-West standard errors in parenthesis.
***/**/* indicate significance at the 1%/5%/10%-level.

V. Immigration and Wages: Evidence from Social Security Data

A. Model estimation

In this section we look at labor market data from a different angle. The idea is to isolate the role of immigration in explaining wage developments by breaking down wage differences according to workers' individual characteristics. To do so we exploit administrative data from the Federal Employment Agency and build a large panel that allows for the grouping of workers according to their individual characteristics such as age, gender, nationality, qualification, sector, region, type of working arrangement over five years 2012-2016 (the following Table 2 describes the structure of the panel).[26]

Table 2. Panel Structure

Category	Dummy index	Characteristic
Sex	i	Male
		Female
Age		15 to under 25
	j	25 to under 35
		35 to under 45
		45 to under 55
		55 to under 65
		65 and older
Nationality	k	German
		Europe without EU
		EU
		8 asylum countries
		Other migrants
Qualification	l	Low (without apprenticeship)
		Medium (with apprenticeship)
		High (with university degree)
Sector	m	A Agriculture, forestry and fishing
		B Mining and quarrying
		C Manufacturing
		D Electricity, gas, steam and air conditioning supply
		E Water supply; sewerage, waste management and remediation activities
		F Construction
		G Wholesale and retail trade; repair of motor vehicles and motorcycles
		H Transportation and storage
		I Accommodation and food service activities
		J Information and communication
		K Financial and insurance activities
		L Real estate activities
		M Professional, scientific and technical activities
		N Administrative and support service activities
		O Public administration and defence; compulsory social security
		P Education
		Q Human health and social work activities
		R Arts, entertainment and recreation
		S Other service activities
Region	n	West Germany
		East Germany
Working time	o	Covered by social security + full-time
		Covered by social security + part-time
		Marginal

[26] See section II for a graphic visualization of the data.

Combinations of the different characteristics in Table 2 lead to 14'960 different cells per year. An example for such a cell would be German workers, male, active in the agriculture sector, 25–35 years old, low-qualification, East-Germany, full-time. For each of those 14'960 cells per year, the database breaks down the information on wages into 154 wage groups at 50 euros intervals.

Relying on a restricted weighted least squares (WLS) panel estimation, we explain wage developments (log wages on the left-hand-side) by controlling for the various employees´ or jobs´ characteristics through dummy variables *D* (for sex, age, nationality, qualification, sector, region, and working time)

$$lnw_{ijklmno,t} = \sum_{t=1}^{3} \beta_t^{time} D_t^{time} + \sum_{i=1}^{2} \beta_i^{sex} D_i^{sex} + \sum_{j=1}^{6} \beta_j^{age} D_j^{age} + \sum_{k=1}^{5} \beta_k^{nat} D_k^{nat} + \sum_{l=1}^{3} \beta_l^{qual} D_l^{qual} + \sum_{m=1}^{19} \beta_m^{sec} D_m^{sec} + \sum_{n=1}^{2} \beta_n^{reg} D_n^{reg} + \sum_{o=1}^{3} \beta_o^{wt} D_o^{wt} + b\left(\frac{mig}{all}\right)_{m,t-1} + \varepsilon_{ijklmno,t} \quad (5)$$

We restrict the weighted sum of each cross-sectional effect to be zero. The weights reflect the specific employment share, averaged over all periods. As an example, the restriction on the dummy variables for gender would be:

$$\sum_{i=1}^{2} weight_i^{sex}\, \beta_i^{sex} = 0 \quad \text{with} \quad weight_i^{sex} = \frac{employees_{i=male\ or\ female}}{all\ employees}$$

These weighted restrictions allow us to interpret the coefficients of the dummy variables as deviation from the average wage, other things being equal. Time fixed effects (D_t) summarize any time-dependent drivers of average wages which cannot be accounted for by the cross-sectional dummies, like the trend-like increase in average wages due to e.g., productivity growth or inflation expectations.[27]

To analyse whether immigration dampens wage growth, we also control for the sector of activity through an index (m), which measures the migrants' share in total employment – or migrant intensity – by sector. On the one hand, the demarcation by sector allows to approximate relevant labor markets where wage pressure from additional competition could appear. On the other hand, the sectoral breakdown also takes into account potential positive complementarity effects often thought to be relevant across different qualification levels. Moreover, the analysis according to this relatively rough demarcation is unlikely to be distorted by sizeable cross-effects. To control for the possible endogeneity of immigration to wage growth, the variable (*mig/all*) is lagged by one period.[28]

[27] To avoid spurious results, we controlled for the minimum wage introduction in 2015. More specifically, we created an indicator variable and interacted it with the time fixed effects before (2013/14) and after (2015/16) to represent workers who have earned below minimum wage in 2014.

[28] We also tried a distributed lag model including terms for t, t-1 and t-2 for robustness with no material changes in the overall (positive) effect of these variables on wage growth.

In order to gain further insights into the wage effects of migration, we split the sample in two halves, below and above the median wage. Doing so allows us to measure the impact of (*mig/all*) on both higher and lower incumbent wages. This is of special interest since substitution and complementarity effects may be unevenly distributed across the wage structure.

Table 3. WLS Panel Wage Equation – Germany 2012–2016

		dependent variable: log real wage					
		wage groups below median wage			wage groups above median wage		
		N = 43300			N = 13963		
		F(40, 43260) = 4331558.58			F(37, 13925) = 3689999.04		
		Prob > F=		0.000	Prob > F=		0.000
		Root MSE=		0.011	Root MSE=		0.014
		coeffient	S.E.	p value	coeffient	S.E.	p value
migrant intensity (t-1)		**0.001**	**0.001**	**0.153**	**0.007**	**0.003**	**0.011**
nationality	German	0.003	0.000	0.000	0.003	0.000	0.000
	Europe without EU	-0.006	0.003	0.033	-0.067	0.006	0.000
	EU	-0.031	0.003	0.000	-0.042	0.004	0.000
	8 asylum countries	-0.087	0.009	0.000	-0.124	0.029	0.000
	other migrants	-0.048	0.005	0.000	-0.077	0.009	0.000
sex	male	0.013	0.001	0.000	0.063	0.001	0.000
	female	-0.011	0.001	0.000	-0.086	0.001	0.000
age	15-25	-0.132	0.001	0.000	-0.163	0.010	0.000
	25-35	0.009	0.001	0.000	-0.138	0.002	0.000
	35-45	0.053	0.001	0.000	-0.002	0.001	0.189
	45-55	0.067	0.001	0.000	0.046	0.001	0.000
	55-65	0.060	0.001	0.000	0.047	0.001	0.000
	over 65	0.020	0.003	0.000	-0.138	0.012	0.000
qualification	low	-0.063	0.001	0.000	-0.213	0.004	0.000
	medium	0.021	0.000	0.000	-0.070	0.000	0.000
	high	0.068	0.003	0.000	0.223	0.001	0.000
sector	Agriculture, forestry and fishing	-0.101	0.006	0.000	-0.265	0.031	0.000
	Mining and quarrying	0.126	0.024	0.000	0.066	0.011	0.000
	Manufacturing	0.113	0.003	0.000	0.040	0.007	0.000
	Electricity, gas, steam and air conditioning supply	0.146	0.014	0.000	0.236	0.010	0.000
	Water supply; sewerage, waste management and remediation activities	0.092	0.009	0.000	-0.047	0.008	0.000
	Construction	0.011	0.002	0.000	-0.167	0.004	0.000
	Wholesale and retail trade; repair of motor vehicles and motorcycles	0.053	0.003	0.000	-0.110	0.003	0.000
	Transportation and storage	0.006	0.004	0.155	-0.161	0.008	0.000
	Accommodation and food service activities	-0.189	0.007	0.000	-0.384	0.051	0.000
	Information and communication	-0.001	0.006	0.892	0.069	0.004	0.000
	Financial and insurance activities	0.117	0.007	0.000	0.213	0.007	0.000
	Real estate activities	-0.170	0.005	0.000	-0.051	0.011	0.000
	Professional, scientific and technical activities	0.027	0.004	0.000	-0.008	0.003	0.011
	Administrative and support service activities	-0.077	0.008	0.000	-0.238	0.009	0.000
	Public administration and defence; compulsory social security	0.034	0.006	0.000	0.057	0.010	0.000
	Education	-0.028	0.004	0.000	-0.013	0.003	0.000
	Human health and social work activities	0.039	0.003	0.000	-0.050	0.004	0.000
	Arts, entertainment and recreation	-0.083	0.004	0.000	-0.190	0.013	0.000
	Other service activities	-0.085	0.003	0.000	-0.093	0.009	0.000
job	SVB+full-time	0.499	0.001	0.000	0.140	0.001	0.000
	SVB+part-time	-0.067	0.002	0.000	-0.362	0.001	0.000
	marginal	-0.795	0.002	0.000	0.000	0.000	0.000
region	West	0.027	0.000	0.000	0.008	0.000	0.000
	East	-0.087	0.001	0.000	-0.065	0.002	0.000
year	2013	7.185	0.008	0.000	8.010	0.013	0.000
	2014	7.212	0.009	0.000	8.031	0.014	0.000
	2015	7.236	0.009	0.000	8.050	0.014	0.000
	2016	7.255	0.010	0.000	8.064	0.014	0.000
minimum wage	2013-2014	-0.781	0.003	0.000			
	2015-2016	-0.773	0.003	0.000			

Database: Federal Employment Agency.

Table 3 presents the results of the panel WLS estimations for the upper and lower half of the wage distribution. Focusing on nationality, our analysis suggests that – all things equal – being German is a positive for wages. The deviation with respect to the national wage average is +0.3 percent (it is small, due to the large share of native workers in the average). All other nationality groups tend to have wages below the national average, even after controlling for the other characteristics mentioned in Table 3 such as level of qualification, or gender. For example, workers from the 8 most important asylum countries earn wages that are on average 8.7 percent below the average wage in the lower part of the wage distribution or, if in the upper part of the wage distribution, 12.4 percent below that average. Similarly, wages of men are typically higher (controlling for everything else) and such are wages in the manufacturing sector.

B. Competition effect

Controlling for all factors, including that wages of foreigners are typically lower, the coefficient of the immigration variable is positive and equal to 0.0071 for the upper and 0.0014 for the lower wage half. These coefficients are to be interpreted as *marginal* effects: overall wages would increase by 0.71 (0.14) percent if the immigration rate increased by 1 percentage point of total population.[29] While increased immigration could in principle put downward pressure on wages of workers in direct competition with immigrants (see discussion in section II), the overall effect on wages is estimated to be positive. In other words, higher wages for workers that are complement to migrants more than compensate for potential declines in wages of workers that are substitute for immigrants. As expected, our results suggest that complementarity plays a more important role for the higher-wage jobs segment where skills complementarity with migrants is likely to be the largest.[30] On average, migration induced a yearly increase in the sectoral migrant's shares of 0.48 percentage point of total employment. Applying this value to the estimated coefficients in the two wage halves, this translates into an overall yearly wage increase of 0.26 percent.

Drilling down, we build on Figure 8.2, which shows a positive relation between the migrant share in 2012 and its change during 2012 and 2016. In other words, immigration seems to concentrate in sectors where the share of foreign workers is already high, pointing to higher competition and possible negative effect on wage growth among workers of foreign nationality (Brücker et al. 2014). We test this hypothesis by running another panel regression that looks at the effect of immigration on wages separately in the four non-German groups (Europe without EU, EU, 8 asylum counties, other migrants) and obtain a coefficient estimate of -0.033 (p-value = 0.00). Because the average migrant intensity of the four groups increased from 1.79 percent in 2012 to 2.37 percent in 2016, or 0.14 percentage points per

[29] In the panel regression, the wage effects of immigration are identified using variation over economic sectors. Therefore, statements can be made by how much the wage in a sector changes due to migration. Since all sectors together make up the whole economy, the measured effects stand for identical total effects.

[30] This result is also in line with Weber and Weigand (2018) who show – using an instrumental variables approach – that (non-refugee) immigration does not dampen aggregate wage growth.

year, our coefficient estimate implies a negative yearly wage effect of -0.48 percent. Thus, while Table 3 shows that the overall wage effect of immigration is positive, competition within groups suggests negative wage pressure within respective migrant groups.

So far our estimates suggest a positive overall effect of immigration on wages in Germany. But those calculation assume a constant share of the migrant's population to the total. This assumption has to be relaxed to compute the overall effect of immigration on aggregate wages. Mechanically, a higher share of foreign workers with lower wages should have a negative effect on the overall wage sum. We turn to so-called composition effects in the next subsection.

C. Composition effect: shift share analysis

Foreigners tend to be paid less than German workers, all other things equal. Since immigrants also tend to be younger and lower-skilled than natives, increasing the share of immigrant workers in the total labor force mechanically weighs on wages.

To compute the magnitude of this composition effect we resort to a traditional shift-share analysis. In a nutshell, we compute a counterfactual composition of the labor force under the assumption that no immigration had happened between 2012 and 2016. From this counterfactual structure, we calculate the impact of migration on all relevant dimensions (e.g., total variation in the share of men, foreign workers, workers in each of the sectors, and for each qualification). In practice, to conduct the shift-share analysis, we multiply the coefficients for the dummy variables in equation 5 with the difference between the actual and counterfactual structures in 2016.[31] This yields the total increment of wages with respect to changes in the gender or age distribution, sectoral composition, and so on. Results are summarized in the text table.

Shift-Share Analysis: Composition Effect Broken Down, 2012-2016	
Contribution of:	
nationality	-0.18
sex	0.02
age	-0.05
qualification	0.01
sector	-0.24
job/working time	-0.08
region	0.02
Total	**-0.49**

The shift-share analysis suggests that immigration has reduced average wage growth by 0.49 percent in Germany over the period 2012-16 (-0.12 percent per year), which can be broken down as follows. Migration increased the share of workers with foreign nationality who typically earn wages below average (-0.18 percent), but given that immigrants are mainly male and residents of Western Germany, this had a *ceteris paribus* minor but positive (+0.04 percent total) effect on wages. The single most negative impact of increased migration on average wages is due to the concentration of migrant in low-paid sectors (-0.24 percent).

[31] We use the coefficients estimated from the whole sample, i.e., without splitting into two wage halves.

All in all, the composition effect for 2012-2016 amounts to -0.49 percent, i.e., wages would have been 0.49 percent higher in 2016 absent the effect from net migration. This has to be put in relation to a positive *competition* effect of +0.26 percent per year. Loosely, this would imply an overall effect on net wages of +0.14 percent per year (0.26-0.12 percent). This result is in line with the conclusion from the analysis of Phillips curves in Section IV: there is no evidence of downward pressure on aggregate wages from immigration. If anything, the overall effect has been (very) slightly positive.

VI. Conclusion

Wage growth has been remarkably subdued in Germany over the last fifteen years despite uninterrupted decline in unemployment, casting doubts about the usefulness of traditional Phillips curves. Given that more than half of post-crisis employment growth can be attributed to foreign labor, it seems important to investigate the potential role of immigration on wage dynamics. Is the Phillips curve still relevant? What has been the role of immigration in explaining recent wage trends?

Relying on a two-pronged approach, our analysis confirms that the Phillips curve is alive and well in Germany and that immigration did not seem to have played an independent role in explaining aggregate wage fluctuations. In the short term, wage growth reacts to the degree of tightness in the labor market and to inflation expectations. In the longer term, real wage developments are driven by productivity growth. We also establish that a large part of the secular decline in unemployment in Germany reflected a more efficient and not a tighter labor market: the NAIRU declined significantly throughout the 2000s on the heels of important labor market reforms.

To assess the role of immigration with greater precision, we also exploit a unique set of administrative micro-level data on German workers collected by IAB. The analysis shows that pure composition effects were negative from 2012-2016 reflecting the relatively lower level of migrants' wages. There is also some evidence that strong immigration led to additional competition and downward wage pressure within respective migrant groups in low-wage sectors. But these two dampening forces were more than offset—at the aggregate level—by wage increases for better-skilled and better-paid workers that are typically complement to migrants in the production process. Overall, *competition* effects resulted in upward pressures on wages – especially in the upper-half of the wage distribution – and more than offset composition effects, resulting in a negligible (if positive) impact of immigration on wage growth. These findings corroborate earlier studies for Germany that relied on time series analysis and are in line with similar research conducted in the United States.

Appendix A: Deriving the Wage Phillips Curve from First Principles

AA.1. The General Case

Starting from a representative household model where individual members are forward-looking, rational and derive positive utility from consumption and negative utility from work, Gali (2011) shows that when households maximize intertemporal utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, \, \{N_t(i)\})$$

$$\text{For } \; U(C_t, \{N_t(i)\}) = \log C_t - \int_0^1 \frac{N_t(i)^{1+\varphi}}{1+\varphi} di,$$

and subject to a sequence of budget constraints:

$$P_t C_t + Q_t B_t \leq B_{t-1} + \int_0^1 W_t \, (i) N_t(i) di + \Pi_t$$

where $N_t(i)$ is the fraction of household members specialized in type i labor (for wage $W_t(i)$), B_t is the nominal purchase of one period riskless bond valued at price Q_t and Π_t is a lump-sum component of income (e.g., dividends, transfers, etc..). C_t is household consumption (price P_t), β is the usual time preference parameter and φ is the inverse of the (Frish) elasticity of labor supply.

As in Calvo (1983) it is assumed that workers are imperfect substitutes (and therefore enjoy some degree of monopoly power over their labor services) and get to reset their optimal wage at irregular interval with probability $1 - \theta_w$ each period (probability is 1 for perfectly flexible wages). When reoptimizing in period *t*, workers choose a wage W_t^* that maximizes household utility subject to a sequence of isoelastic demand schedules for their labor type (as they provide all demanded labor at the preset wage) and the household sequence of budget constraints (equations A1, A2, A3): When setting W_t^* households know that they may not be able to reset wages for several periods in the future and therefore take into account all future expected developments in their optimal decision.

The first order condition for this problem can be written as[1]

$$\sum_{k=0}^{\infty} (\beta \theta_w)^k \, E_t \left\{ \frac{N_{t+k|t}}{C_{t+k}} \left(\frac{W_t^*}{P_{t+k}} - M^w MRS_{t+k|t} \right) \right\}$$

where $MRS_{t+k|t} = C_{t+k} N_{t+k|t}^{\varphi}$ is the relevant marginal rate of substitution between consumption and labor in period $t + k$ as of t and M^w is the worker's desired wage markup (over the marginal rate of substitution).

[1] See Gali (2010).

Log linearizing the preceding first order condition yields (around a perfect foresight zero steady-state inflation condition) we obtain the wage setting rule:

$$w_t^* = \mu^w + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\{mrs_{t+k|t} + p_{t+k}\} \quad \text{(A1)}$$

where $\mu^w = \log(M^w)$ and $mrs_t = c_t + \varphi n_t$. Note that when wages are perfectly flexible, we have $w_t^* = w_t = \mu^w + mrs_t + p_t$ as workers are able to re-optimize every period. Now log-linearizing the expression for aggregate wage around a zero-inflation steady state, we obtain an expression for the average wage index:

$$w_t = \theta_w w_{t-1} + (1-\theta_w)w_t^* \quad \text{(A2)}$$

and combining (AI.1) and (AI.2):

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w(\mu_t^w - \mu^w) \quad \text{(A3)}$$

where wage inflation $\pi_t^w = w_t - w_{t-1}$, $\mu_t^w = w_t - p_t - mrs_t$ is the average wage markup and $\lambda_w > 0$ is a function of wage stickiness, the wage elasticity of demand for labor and time preference. In other words, wage inflation depends positively on one period ahead expected wage inflation and negatively on the deviation between the desired wage markup and its actual value (a negative deviation calls for higher wages).

Solving (AI.3) forward we obtain:

$$\pi_t^w = -\lambda_w \sum_{k=0}^{\infty}\beta^k E_t\{(\mu_{t+k}^w - \mu^w)\} \quad \text{(A4)}$$

meaning that today's wage inflation is a function of future expected deviations of average wage markups form their desired levels. Intuitively, if markups are above (below) the desired level, workers that get the chance to adjust their wage will tend to adjust it downward (upward) pushing wage inflation down (up). Because unemployment can be written (in log-linearized form) as $u_t = l_t - n_t$ for l_t the participating population and that participating workers would in principle accept employment (at given wage rate) if $w_t - p_t \geq c_t + \varphi l_t$, we can rewrite equation (AI.4) as:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w\varphi(u_t - u^n) \quad \text{(A5)}$$

for the natural interest rate $u^n = \frac{\mu_w}{\varphi}$, the rate of unemployment that would prevail in the absence of nominal wage rigidities. Allowing for wages that are not re-optimized to be indexed to some measure of past price inflation $\bar{\pi}_{t-1}^p$, the steady state inflation rate π^p and productivity growth g, equation (AI.5) can be written as:

$$\pi_t^w = \alpha + \gamma\bar{\pi}_{t-1}^p + \beta E_t\{\pi_{t+1}^w - \gamma\bar{\pi}_t^p\} - \lambda_w\varphi(u_t - u^n) \quad \text{(A6)}$$

For the indexation rule:

$$w_{t+k|t} = w_{t+k-1|t} + \gamma\bar{\pi}^{p}_{t+k-1} + (1-\lambda)\pi^{p} + g \text{ and } \alpha = (1-\beta)((1-\gamma)\pi^{p} + g)$$

Solving (AI.6) forward as we did for (AI.3) yields an expression for fundamental wage inflation:

$$\pi^{w}_{t} = \alpha(1-\beta)^{-1} + \gamma\bar{\pi}^{p}_{t-1} + \lambda_{w}\varphi\sum_{k=0}^{\infty}\beta^{k}E_{t}\{(u_{t}-u^{n})\} \quad \text{(A7)}$$

as a function of the discounted sum of future expected unemployment gaps – the deviation of unemployment from its natural rate.

Following Gali (2011) we derive an empirical counterpart to (AI.7) by assuming that the unemployment gap $\hat{u}_{t} = u_{t} - u^{n}$ follows an AR(2) process (a good approximation for Germany):

$$\hat{u}_{t} = \phi_{1}\hat{u}_{t-1} + \phi_{2}\hat{u}_{t-2} + \varepsilon_{t}$$

then (AI.7) can be rewritten as:

$$\pi^{w}_{t} = \alpha(1-\beta)^{-1} + \gamma\bar{\pi}^{p}_{t-1} + \psi_{0}\hat{u}_{t} + \psi_{1}\hat{u}_{t-1}$$

$$\text{Where } \psi_{0} = -\frac{\lambda_{w}\varphi}{1-\beta(\phi_{1}+\beta\phi_{2})} \text{ and } \psi_{1} = -\frac{\lambda_{w}\varphi\beta\phi_{2}}{1-\beta(\phi_{1}-\beta\phi_{2})}.$$

$$\text{or, equivalently: } \pi^{\omega}_{t} = \alpha(1-\beta)^{-1} + \gamma\bar{\pi}^{p}_{t-1} - \delta\hat{u}_{t} - \psi_{1}\Delta\hat{u}_{t} \quad \text{(A8)}$$

for $\delta = -(\psi_{0}+\psi_{1}) > 0$, which is a micro-founded equivalent to the traditional reduced form Phillips curve used in many empirical applications.

AA.2. A Micro-founded Phillips Curve with Immigration

We derive a micro-founded Phillips curve that allows immigration to play a role in wage-setting. As in Bentolila et al. (2007)[2] we assume a production function with constant returns to scale and two inputs, labor (N) and raw material (M):

$$Q_t = N_t^{1-a} M_t^a$$

$$N_t^p = \delta_1 N_{1t}^p + \delta_2 N_{2t}^p$$

Q_t denotes final output net of capital consumption, and $N_{1,t}$ and $N_{2,t}$ are native and immigrant workers respectively. Following the envelope theorem, marginal costs plus the markup can be expressed as a function of the labor index:

$$mc_{Q,t} + \mu^p + \omega_t - (q_t - n_t) - \ln(1-\alpha) + \mu_t^p$$

where ω is the average real wage, mc_Q is the real marginal cost of producing Q_t, and μ^p (=log($\epsilon/\epsilon - 1$)) is a constant price markup. Lower case letters represent logs of variables in level. It is also assumed that immigrants and native workers are different in their marginal rate of substitution between consumption and leisure (mrs). Household utility, for *i*=1,2, is defined as:

$$U_{i,t} = lnC_{i,t} - e^{\xi} \frac{N_{i,t}^{1+\phi_i}}{1+\phi_i}$$

where $C_{i,t}$ is a composite consumption basket and ξ is a preference parameter. The marginal rate of substitution between labor and consumption is given by:

$$mrs_{i,t} = c_{i,t} + \phi_i n_{i,t} + \xi_t$$

It is also assumed that the slopes of labor supply curves of immigrant and native workers are not the same. Labor supply of immigrants is taken to be less elastic than that of native workers $\phi_2 > \phi_1$. Total labor n and total wage ω can be written as:

$$n_t = \bar{\lambda} n_{1,t} + \left(1 - \bar{\lambda}\right) n_{2,t}$$

$$\omega_t = \bar{\lambda} \omega_{1,t} + \left(1 - \bar{\lambda}\right) \omega_{2,t}$$

Logged labor supplies (l_i) and the relative labor supply of immigrants vis-à-vis natives ($irl_t = l_{2,t} - l_{1,t}$ are implicitly defined by (see Bentolila for details and definition of parameters):

[2] See their paper for detailed derivations.

$$\omega_t = q_t + \psi l_t + \phi_{21} irl_t + \xi_t + \bar{\mu}^{\omega}$$

Assuming as in Gali (2011) sluggish real wages, you can derive the following equation for the change in real marginal cost $\Delta\left(mc_{Q,t} + \mu^{p}\right)$:

$$\Delta\left(mc_{Q,t} + \mu^{p}\right) = -\frac{1-\Gamma}{\Gamma}\left[\bar{\psi} u_t + (\bar{\phi}_{21} + v)\left(u_{2,t} - u_t\right) + \rho\bar{\phi}_{21} u_{2,t} ir_t + \frac{\rho^2}{2}\bar{\phi}_{21} u_{2,t} ir_t^2\right] + \alpha\Delta s_{Q,t}$$

where $u_{2,t}$ is defined as the unemployment rate of foreign workers, and thus $\left(u_{2,t} - u_t\right)$ as the difference between foreign and native unemployment rates and $s_{Q,t}$ as the real price of raw materials.

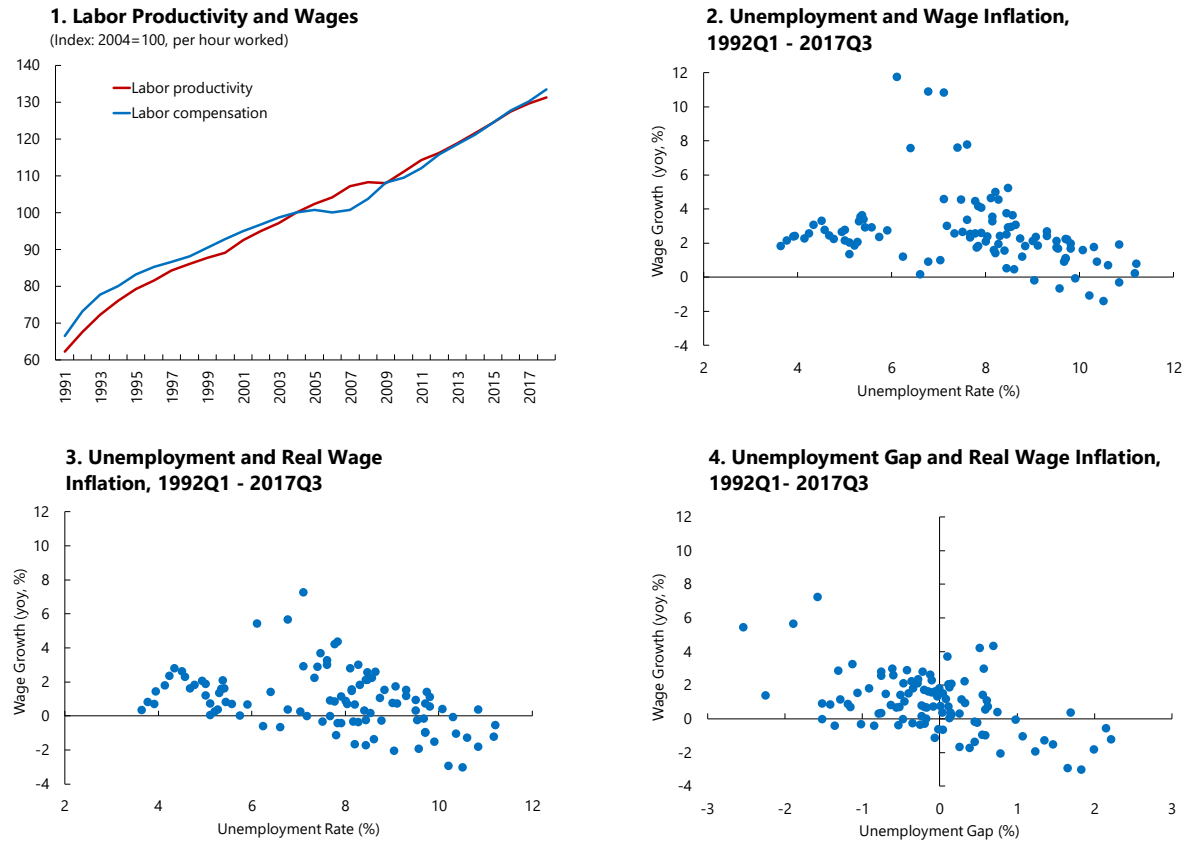
Assuming constant productivity growth, markup and real price of raw materials, an AR(2) process for the unemployment gap u and sticky real wages as in Gali, the above equation can be rewritten as:

$$\pi_t^{w} = \tau_0 + \tau_1 \hat{\pi}_{t-1} + \tau_2 \hat{u}_t + \tau_3 \Delta\hat{u}_t + \tau_4\left(u_{2,t} - u_t\right) + \tau_5 u_{2,t} ir_t + \tau_6 u_{2,t} ir_t^2 + \varepsilon_t$$

Appendix B: Short and long-term determinants of wage dynamics in Germany

Over the long term, wage growth follows productivity growth and inflation quite closely in Germany. Ignoring short to medium-term fluctuations, nominal compensation per hour worked follows total output per hour quite closely. From 1991 to 2017, output per hour roughly doubled. Labor compensation increased at the same pace for most of the period with the exception of 2003-2010 when the relation seemed to temporarily break down. The Hartz reforms combined with a general effort to improve German competitiveness through wage moderation are clearly visible in the temporarily divergent paths between compensation and productivity (see Figure 10.1).

Figure 10. Wages are Driven by Slack, Inflation Expectation and Productivity Growth



Sources: Destatis, Bundesbank, Haver Analytics; and IMF staff calculations.

Over the shorter term, the wage Phillips curve seems alive and well. Figure 10.2 shows the original (1965) Phillips curve relationship, unemployment against wage inflation, and suggests a recent "flattening". Post-2005, wage inflation has remained roughly constant while unemployment has fallen continuously. Figure 10.3 controls for the impact of inflation expectations (where inflation expectation is assumed equal to realized inflation in t+1, in line with the rational expectation hypothesis on average) on wage formation by depicting *real* wage growth against the unemployment rate. It reveals that dropping inflation expectations

have played an important role in explaining the relative stability of nominal wage growth in the face of dropping unemployment. Real wage growth, in contrast, has picked up from negative levels to reach a peak of 3.5 percent in the immediate aftermath of the crisis. Finally, 9.4 goes one step further and shows that the negative relationship between real wage growth and labor market slack seems alive and stable over time when due account of the large drop in the natural level of unemployment in Germany is taken. Figure 10.4 shows a clear and rather stable relationship between real wage growth and the unemployment gap measured as the deviations of unemployment from the NAIRU.

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