WORKING paper

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Global Value Chains and the Phillips Curve: a Challenge for Monetary Policy

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ABSTRACT

This paper studies how participation and position in Global Value Chains (GVCs) affect the slope of the Phillips Curve (PC) and, consequently, the ability of monetary policy to control inflation. Using data from the European Monetary Union (EMU) and value added measures of GVCs, we show that, beyond the role of trade openness, higher participation leads to a flatter PC. This evidence is consistent with the theoretical literature emphasising how globalisation can reduce the sensitivity of prices to unemployment due to stronger strategic complementarities, to higher market power and to imperfect exchange rate pass through. On the other hand, the role of GVC position is not statistically significant.

Keywords: Monetary Policy, Global Value Chains, Phillips Curve, Price Stickiness, Variable Markups.

JEL classification: E32, F41, F62.

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NON-TECHNICAL SUMMARY

The Phillips Curve (PC) –the structural relationship between inflation and unemployment– is an important ingredient of macro-economic models and it plays a central role in monetary policy and the ability of central banks to influence prices. In fact a steep PC implies that the monetary authority can affect prices by triggering small movements of unemployment around its natural –non-inflationary– level. Vice-versa, if the PC is flat, monetary policy needs to strongly intervene on the economic slack to be able to move inflation towards its target. The paper investigates the pre-pandemic years, and draws some lessons on the post-Covid period.

In pre-pandemic years, both in the European Monetary Union and the U.S., the relationship between unemployment and prices has become weaker over time. The literature has deeply focused on the structural reasons behind the progressive flattening of the PC, e.g. technological change, labor market transformation, ageing population, inflation anchoring. This paper considers an important channel so far overlooked: the integration of the domestic production structure in Global Value Chains (GVCs) and the role that GVCs play for the transmission of monetary policy.

GVCs entail the international sharing of production, where its processes are broken down into various activities and tasks carried out across different borders. There are two important metrics measuring the effect of GVCs: participation and positioning. Participation in GVCs assesses the extent to which a country is integrated into international production networks. Positioning, on the other hand, refers to the specific activities it undertakes within the chain. For instance, a country participating in a GVC might engage in downstream activities such as the assembly of components or product distribution. Alternatively, it might specialise in upstream activities, such as producing raw materials.

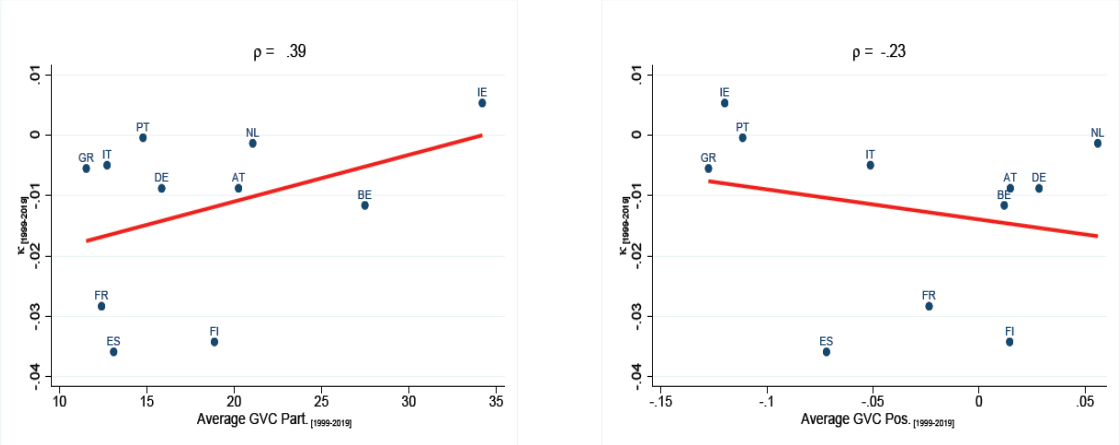
Theoretically, the presence of GVCs could push the slope of the PC either ways. It would *flatten the curve* if: (1) the use of international intermediate inputs is subject to imperfect exchange rate pass-through; (2) price rigidities accumulate at each step of the production chain; (3) the desired markup for domestic producers declines due to strategic complementarity; (4a) GVCs increase market power (enhancing the ability to adjust markups). On the other hand, it would result in a *steeper PC* if: (4b) firms would be pushed in the position of the production network with lower markups; (5) the increase in the number of varieties reduces firms' market shares. Our empirical analysis will allow us to asses which forces are predominating in the data.

To do so, we focus on a panel of 11 countries the European Monetary Union (EMU) and estimate the standard New Keynesian Phillips Curve (NKPC) augmented with GVCs indicators of participation and position for periods before the Covid-19 crisis. We find that only the participation channel significantly affects the slope of the PC. In particular, higher participation leads to a flatter PC. This result is in line with the theory on imperfect pass-through, strategic complementarities and increased market power (i.e. channels (1), (3), (4a)). Through a back-of-the-envelope exercise, we claim that the participation channel accounts for 13% of the flattening of the PC in pre-Covid years. Conversely, we do not find any significant evidence for the GVC position channel. This could be due to the fact that, in this case, there are two opposing forces –(2) and (4b)– which are equally strong and therefore do not allow to find an average effect. However, the negative point estimates suggest that the higher is the position in the GVC, the steeper is the PC. This seems somehow supporting the theory of compounding effect of price stickiness at each step along the production chain.

Thereafter, we exploit the Covid-19 crisis to study how the exogenous variation in GVC participation and position, due to the pandemic shock, has affected the PC in recent years. The pandemic indeed led to a decline in participation of all countries, but resulted in heterogeneous changes in GVC

positions. We exploit this variation and confirm previous results: in the post-Covid years, the fall in GVC participation explains 8% of the recent steepening of the PC. GVC position does not play a significant role.

Figure 1 : The Slope of the Phillips Curve and GVC Measures



(a) GVC Participation (b) GVC Position

Note : Figure 1. (a) plots the mean GVC participation index over the slope of the Stock and Watson Phillips. In Figure 1.(b), the mean GVC position index is on the x-axis

Chaînes de valeur mondiales et courbe de Phillips : un défi pour la politique monétaire

RÉSUMÉ

Cet article étudie comment la participation et la position dans les chaînes de valeur mondiales (CVM) affectent la pente de la courbe de Phillips (CP) et, par conséquent, la capacité de la politique monétaire à contrôler l'inflation. En utilisant des données de l'Union monétaire européenne (UEM) et des mesures de la valeur ajoutée des chaînes de valeur mondiales, nous montrons que, au-delà du rôle de l'ouverture commerciale, une plus grande participation conduit à une courbe de Phillips plus plate. Ces données sont cohérentes avec la littérature théorique qui souligne que la mondialisation peut réduire la sensibilité des prix au chômage en raison de complémentarités stratégiques plus fortes, d'un pouvoir de marché plus élevé et d'une transmission imparfaite des taux de change. D'autre part, le rôle de la position dans les chaînes de valeur mondiales n'est pas statistiquement significatif.

Mots-clés : Politique monétaire, chaînes de valeur mondiales, courbe de Phillips, rigidité des prix, marges variables.

1 Introduction

The shape, the slope and even the existence itself of the Phillips Curve –the relationship between inflation and unemployment– is currently under scrutiny. Alongside being an important ingredient of macroeconomic models, the Phillips curve (PC) retains its central role in understanding the effects of macroeconomic policies. In particular, the existence and the slope of the PC is key for the ability of central banks to influence inflation. A steep PC in fact, implies that the monetary authority can affect prices by triggering small movements of unemployment around its natural –non-inflationary– level. Vice-versa, if the PC is flat, monetary policy needs to strongly intervene on the economic slack to be able to move inflation towards its target.

Both for Europe and for the U.S, economists argue that the slope of the PC has always been relatively flat and/or that it has progressively weakened, in particular in the decade following the Great Recession (GR) - see Blanchard (2016) and Moretti *et al.* (2019) among many others. However, after the Covid-19 crisis, the PC seems to be back and in good shape. In fact, when considering the PC specification from Stock and Watson (2019) and estimating the slope of the curve for the first 11 countries that joined the EMU (the focus of our paper),[a] we find that the PC was indeed alive, albeit with a modest slope, from 1999 until the GR. After that, it experienced a severe flattening, while, following the Covid-19 pandemic crisis, it has exhibited a significant steepening (see Table A.1 in Appendix A).

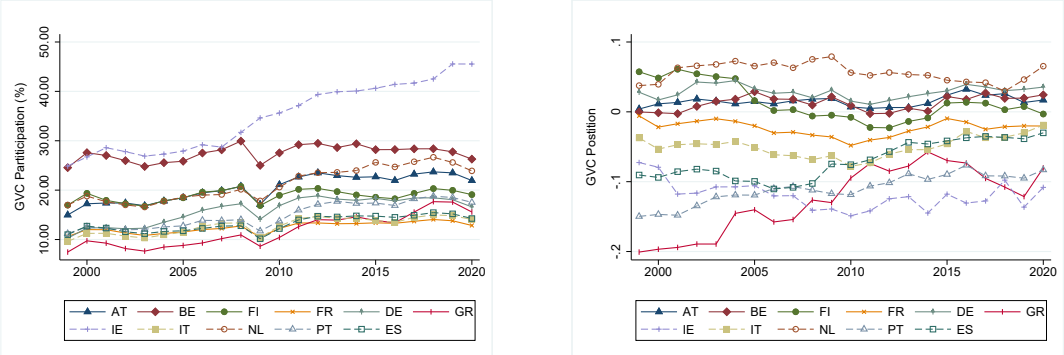
This paper contributes to the literature aimed at shedding light on these dynamics. Previous studies explaining changes in the slope of the PC over time attribute them to two main factors: inflation anchoring and structural changes in the economy. In this paper, we focus on the latter. In particular, we investigate the role of an important structural change that has characterised all economies since the 1990s: the integration of the domestic production structure in Global Value Chains (GVCs).

GVCs entail the international sharing of production, where its processes are broken down into various activities and tasks carried out across different borders. Two are the important metrics measuring GVCs: participation and positioning. Participation in GVCs assesses the extent to which a country is integrated into international production networks. We will focus on GVC-related output measures which evaluate how much a country contributes to the value-added creation within global supply chains (Borin *et al.*, 2021). Positioning, on the other hand, refers to the specific activities it undertakes within the chain. For instance, a

[a] Although Luxembourg was among the first countries to join the EMU, we exclude it from our sample for data availability.

country participating in a GVC might engage in downstream activities such as the assembly of components or product distribution (backward participation). Alternatively, it might specialise in upstream activities, such as producing raw materials (forward participation). We are going to focus on a metric summarising the overall position of the country within the GVCs, measured as the difference between forward and backward participation (Borin *et al.*, 2021).

The involvement and positioning of a country within GVCs extend beyond the mere implications of openness or trade: it entails a deep structural change in the composition and organisation of domestic production and price setting. In fact, by affecting the environment in which firms decide their own prices, GVCs play a crucial role in shaping the relationship between prices and economic slack, as described by the PC, and thus the entire supply side of the economy.



(a) GVC Participation (b) GVC Position

Note: Panel (a) plots GVC participation between 1999 and 2020. GVC participation is measured as the share of gross output depending on connections with more than one country. Panel (b) plots GVC position, a measure ranging from -1 to +1 and expressing respectively whether a country is at the bottom or at the top of the GVC.

Figure 1: GVC Participation and Position

Theoretically, the presence of GVCs could push the slope of the PC either ways. It would flatten the curve if, for example, (1) the use of international intermediate inputs is subject to imperfect exchange rate pass-through (Monacelli, 2007) and/or (2) price rigidities accumulate at each step of the production chain (Rubbo, 2023) and/or (3) the desired markup for domestic producers declines due to strategic complementarity (Sbordone, 2007; Guerrieri *et al.*, 2010) and/or (4a) GVCs increase market power (enhancing the ability to adjust markups). On the other hand, it would result in a steeper PC if, for example, (4b) firms would be pushed in the position of the production network with lower markups

(Battiati *et al.*, 2021) and/or (5) the increase in the number of varieties reduces firms' market shares (Benigno and Faia, 2016).

This paper aims at investigating empirically the implications of GVCs for the PC. Focusing both on participation and position within GVCs, we shade light on the importance of these opposing forces. In fact, by analysing the role of participation, we can understand if channels (1), (3), (4a) and (5) are present and which force is stronger. For example, if the PC is flatter for countries more involved in GVCs, this would imply that imperfect exchange rate pass-through, strategic complementarities and higher market power are there and stronger than the potential effect of increased varieties. Moreover, focusing on the country position in GVCs, we can test the presence and strength of mechanisms (2) and (4b). On one hand, economies positioned downward in the production structure (closer to the final good) should have a flatter PC due to accumulating rigidities at each step of the chain (Rubbo, 2023). On the other hand, downstream firms could have lower markups (as found for France, Germany, Italy and Spain by Battiati *et al.*, 2021), reducing the possibility of limiting fluctuations of prices in response to changes in marginal costs. Therefore, accounting for the type of participation allows us to understand if and how these are relevant forces for the price setting elasticity to marginal costs.

We leverage on recent data on GVCs participation and GVCs position from Mancini *et al.* (2024a). These are GVC-output measures encompassing the chain activities traced in value-added (VA) and final goods, accounting also for all the exchanges of inputs within the intermediates stages of production. For our purpose, these measures have clear advantages with respect to standard trade-related indicators. In fact, first, GVCs trade-indicators may understate the importance of GVCs for services and upstream manufacturing that do not actively participate in exports. Second, they are subject to overstatement in countries/sectors whose export constitutes a small share of overall domestic output.

As Figure 1 shows, EMU countries exhibit heterogeneous participation and position into GVCs between 1999 and 2020. In Panel (a) of Figure 1, we plot GVC participation VA-shares across EMU countries. A general upward trend can be observed for most countries with a slight dip around the global financial crisis (2008-2009) followed by a subsequent recovery. Panel (b) shows the GVC position VA-measure, which ranges from -1 (closest to the final good) to +1 (furthest from the final good). This indicator reflects, respectively, whether a country occupies a downstream or upstream position in global value chains. These series highlight the heterogeneity across EMU countries, with core economies like Germany maintaining leadership in upstream roles, while other countries exhibit more modest or mixed patterns in both GVC participation and position. We exploit this cross-country

heterogeneity to test whether these two channels affect the PC.

First, we start by augmenting the standard New Keynesian Phillips Curve (NKPC) with these GVC's indicators. We estimate it on core inflation for the EMU11 from 1999 to the Covid-19 crisis. By instrumenting all endogenous variables, like the unemployment gap, with monetary policy shocks, we find that only the participation channel significantly affects the slope of the PC. In particular, higher participation leads to a flatter PC. This result, as mentioned earlier, is in line with the theory on imperfect pass-through, strategic complementarities and increased market power (i.e. channels (1), (3), (4a) seem to be stronger than channel (5)). Through a back-of-the-envelope exercise, we claim that the participation channel accounts for 13% of the flattening of the PC in pre-Covid years. Conversely, we do not find any significant evidence for the GVC position channel. This could be due to the fact that, in this case, there are two opposing forces –(2) and (4b)– which are equally strong and therefore do not allow to find an average effect. However, the negative point estimates suggest that the higher is the position in the GVC, the steeper is the PC. This seems somehow supporting the theory of compounding effect of price stickiness at each step along the production chain.

Our analysis does not stop here and tries to fill a gap in the literature. In fact, previous research on this topic focused just on tradable prices. The motivation for that choice was that those prices should be more effective in revealing the influence of global factors on the domestic economy. Guerrieri *et al.* (2010), for example, find that foreign competition, by reducing the desired markups of domestic producers, lowers the inflation rate and the slope of the PC for tradable goods, leaving for future research the use of measures of domestic inflation, e.g non-tradable inflation, that could potentially magnify these effects. However, GVCs are increasingly important in the production of non-tradable goods, in particular services. In light of this, we decide to investigate the unexplored role of positioning and participation in GVCs when considering non-tradable inflation.

The focus on non-tradable prices is crucial for several reasons. First, it allows to disentangle the effect of GVCs from openness to trade. In fact, as non-tradables are sold only domestically, the elasticity of their prices to the economic slack can be imputed to changes in marginal costs and their production structure, and not directly to international competition. Second, the surge in demand for services has altered their significance in calculating inflation. In fact, core inflation itself, a critical metric for central bank decisions, is heavily influenced by the prices of services as their importance is increasing.[b] Third,

[b] In the euro area, the weight of services in core inflation has increased by approximately 10 percentage points since the introduction of the single currency in 1999. Similarly, in the United States, services now

non-tradable prices usually exhibit greater stickiness compared to tradable ones and price rigidity obviously is crucial for the real effects of monetary policy. For example, Altissimo *et al.* (2005) and Dhyne *et al.* (2006) find that firms which produce non-tradable goods have more rigid prices. They also provide evidence of downward consumer price stickiness in the services sector, possibly linked to downward wage rigidity. Forth, non-tradable goods are increasingly important as intermediate inputs in the production of both tradable and non-tradable goods (referred to as "servicification"). Consequently, sticky service prices have a broader impact on the economy through their effect on firms' marginal costs. The "servicification" trend has the potential to further diminish the short-term impact of monetary policy impulses on inflation.

In light of this argument, we estimate a Regional Phillips curve á la Hazell *et al.* (2022) using non-tradable prices. This has three main advantages also for the empirical identification of the PC: (i) non-tradable prices are more sensitive to regional unemployment than the aggregate core inflation; (ii) inflation expectations can be properly controlled for by using time fixed effects, as we focus on countries sharing the same monetary policy since 1999; (iii) other differences across regions, as long as these differences are constant over time, will be absorbed by country fixed effects.

When considering non-tradable prices, our results are confirmed: participation in GVCs decreases non-tradable prices' reaction to domestic slack, while the position within the GVCs does not play a significant role. Furthermore, we find that participation in GVCs has a negative and significant impact on the level of inflation. Through a back-of-the-envelope calculation, we find that the effect is magnified: GVCs participation accounts up to 32% of the observed flattening of the PC in pre-pandemic years. This exercise allows a strengthening of results by Guerrieri *et al.* (2010), as we find that foreign competition, by reducing the desired markups of domestic producers, lowers the inflation rate not only for tradable goods but also for non-tradables. This could be due to the broad use of non-tradables in the GVC or to the increasing complementarity between tradables and non-tradables (see Craighead (2024)).

Thereafter, we perform two robustness checks to corroborate our results. First, we exploit the Covid-19 crisis to study how the exogenous variation in GVC participation and position, due to the pandemic shock, has affected the PC in recent years. The pandemic indeed led to a decline in participation of all countries, but resulted in heterogeneous changes in GVC positions. We exploit this variation and confirm previous results: in the post-Covid years, the fall in GVC participation explains 8% of the recent steepening of the PC. GVC

constitute three-quarters of the core CPI basket.

position does not play a significant role. Finally, we make sure that GVC participation is not simply capturing openness to trade. In fact, by including both GVC measures and trade openness in the empirical models, our results are confirmed.

For example, in April 2024, the ECB faced a challenging decision regarding whether to begin to decrease policy rates or not. In fact, despite high policy rates and falling headline inflation, core inflation and in particular service prices, were remaining persistently strong. High service inflation is in fact an important indicator of wage dynamics and therefore of labor market tightness. But then, do GVCs increase or decrease the sensitivity of core inflation to the domestic labor market? Does participation in GVCs have a direct impact on non-tradable prices? We believe addressing these questions is crucial for an appropriate monetary policy response.

Our paper is organised as follows. Section 2 presents the literature review. Section 3 introduces the conceptual framework. Section 4 presents data and the empirical analysis. Section 5 concludes.

2 Literature review

This paper relates to three strands of literature. The first one concerns global value chains, which documents the extent of countries' and industries' involvement in GVCs and the nature of their participation. Starting from the definition of GVCs (i.e. trade must cross at least two country borders) proposed by Hummels *et al.* (2001), many studies have undertaken the challenging task of evaluating the extent to which GVCs are present in trade and in output.

We closely follow Borin and Mancini (2015), who provided a quantitative assessment of trade crossing at least two borders, and Borin and Mancini (2023), who proposed a comprehensive methodology for value-added accounting of trade flows at the aggregate, bilateral, and sectoral levels. Antras and Chor (2022) provide a review and critical evaluation of differences across GVCs indicators.

Our paper also closely relates to the recent literature questioning if GVCs are increasing or decreasing output volatility. The debate concludes that there is no an easy answer as many factors come at play. What matters is the nature of the shock (see Acemoglu *et al.* (2015) and Carvalho and Tahbaz-Salehi (2019)), the position of the country in the GVCs (Ferrari (2022), Borin *et al.* (2021)) and the substituability of factors of production (Barrot and Sauvagnat (2016) and Baqaee and Farhi (2019)). During the recent Covid-19 pandemic crisis, Bonadio *et al.* (2021) show that lockdowns had worse economic consequences on coun-

tries with lower GVC participation, while Berthou and Stumpner (2022) find that GVCs synchronized the business cycle across countries and hence transmitted shocks across borders. More recently, Ascari *et al.* (2024) show that shocks to global supply chain pressures were the dominant driver of euro area inflation in 2022, and that these shocks have a highly persistent and hump-shaped impact on inflation. Closely connected to this literature, our paper uses the findings of those studies that cope with shocks propagation in a production network, like for example Boehm *et al.* (2019), Carvalho *et al.* (2021), Dhyne *et al.* (2021) and Rubbo (2023).

The second strand of literature explores the flattening of the PC, employing both empirical and theoretical approaches. On the empirical front, numerous studies on both sides of the Atlantic investigate this phenomenon. In the U.S, according to Blanchard (2016), Murphy (2018), and Powell (2018), the PC remains extant, but its slope started to flatten as early as the 1980s, coinciding with more anchored inflation expectations. Similarly, Hooper *et al.* (2020), Fitzgerald *et al.* (2022), and Mavroeidis *et al.* (2014) support this trend. McLeay and Tenreyro (2020) extend this observation to the state and city levels, noting a stronger correlation between unemployment and inflation in aggregate time series. Del Negro *et al.* (2020) present evidence suggesting that the flattening began in the 90s, accompanied by a progressive flattening of the aggregate supply curve. Additionally, Portier *et al.* (2020) and Portier *et al.* (2023) show that the PC has been quite flat in the last two decades.

In the European context, Ball and Mazumder (2021), Moretti *et al.* (2019), Deroose *et al.* (2017), and Berson *et al.* (2018) indicate that the PC flattened after the 2008 financial crisis. However, they emphasise that the structural relationship between price dynamics and economic slack variables, including unemployment, persists. In contrast, Giannone *et al.* (2014) contend that the PC was steeper during the GR, while Ciccarelli *et al.* (2017) propose that the disconnect between prices and unemployment emerged after 2012, attributing it to both structural and cyclical factors affecting aggregate demand.

Across both continents, the prevalent explanation for the Phillips Curve flattening is the increased importance of inflation expectations over past inflation in explaining current price dynamics. This shift is attributed to the more firmly anchored inflation expectations by the Fed and the ECB, as evident in works from Roberts (2006) and Bernanke (2007) to Ng *et al.* (2018) and Hazell *et al.* (2022) for the U.S. and from Draghi (2015) to Bobeica and Jarociński (2019) for Europe.

Alternative explanations for the flattening delve into structural changes, such as demographic shifts and technological advancements in economic fundamentals (see, among others,

Daly *et al.* (2016), Yoon *et al.* (2018), Pfajfar and Santoro (2008), and Bruine de Bruin *et al.* (2010)). Regarding technology, Mincer and Danninger (2000), Jorgenson (2001), Akerlof *et al.* (1996) and others argue that technological innovation, digitalization, automation, and ICT contribute to the long-term downward trend in inflation. Additionally, a growing body of literature attributes PC flattening to labour market dynamics and characteristics (see, among others, Ball and Mazumder (2011), Daly and Hobijn (2014), Benigno and Ricci (2011), Faccini and Melosi (2023), Petrosky-Nadeau *et al.* (2020), Lombardi *et al.* (2023) and Siena and Zago (2022, 2024)). Real factors have also been shown to play an important role on the slope of the PC. In particular, strategic complementarities in price-setting, arising from firm-specific capital and/or labour (see, among others, Sveen and Weinke (2005, 2007), Altig *et al.* (2011), Giuli and Tancioni (2012) and Madeira (2015)) and endogenous demand elasticities (Kimball (1995) and Eichenbaum and Fisher (2007)). Lastly, but strongly connected to our work, there is the literature connecting the slope of the PC to international strategic complentarities and openness. In line with Sbordone (2007), Guerrieri *et al.* (2010), Benigno and Faia (2016), Guilloux-Nefussi (2020), Lodge *et al.* (2021) and Hottman and Reyes-Heroles (2024), we show that international forces are important drivers of the slope of the PC. However, differently from them, we show that the crucial driver are GVCs and not only openness to trade. Similar results are found, for the UK, in a recent paper by Aquilante *et al.* (2024) that shows that higher GVC integration into EMEs (only) flattens the PC.

We also refer to a third strand of literature showing the interrelationship between endogenous market structures, strategic interaction and variable markups. Etro and Colciago (2010) show how markups vary counter-cyclically due to entry on competition while Colciago and Rossi (2015) show how strategic interactions among producers lead varying price markups. We borrow from this literature the conceptual framework and extend it to an international setting.

3 Conceptual Framework

In this section, we rely on the existing theoretical literature to construct a conceptual framework to guide our empirical analysis of the role of GVCs on the functioning of the supply side of the economy. The presence of GVCs could push the sensitivity of inflation to economic slack (i.e. the slope of the PC) either ways. We identified five main channels in the literature through which GVCs can influence the slope of the PC. While these theories were not originally formulated to explicitly account for GVC participation, their reasoning can

be extended to include GVCs. We first explain the five channels in details. Afterwards, we show how using both measures of participation and position within GVCs in the estimation of the PC can help disentangling some of these operative channels.

(1) *Imperfect exchange rate pass-through.* GVCs are backward and forward exchange of intermediate and final goods crossing at least two borders. This implies that transactions in different currencies are at the core of every GVCs, even within a monetary union. In fact, each EMU-11 country has different baskets of imports and exports of tradable goods and services, from/to countries which price their products not in euro (Comunale and Kunovac, 2017). But producers are not changing prices at the speed of exchange rate movements, creating the so-called imperfect exchange rate pass-through, which will be different across countries depending on GVC participation and position. This, as shown by Monacelli (2007) for imports, implies that the elasticity of inflation to unemployment depends on the share of GVCs in total consumption/production. In particular, an increase in participation contributes to an increase in real rigidities, as consumers and firms are more subject to imperfect price movements. As a result, the PC flattens as GVCs participation increases. Formally, Monacelli (2007) shows that the Phillips curve has the following form:

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + (1-\lambda)(1-\phi)\xi x_t + \chi_t \tag{1}$$

where π_t is consumer price inflation, $E_t\pi_{t+1}$ is inflation expectation, ξ is the slope of the domestic Phillips curve, as in the typical Calvo-Yun model (i.e. $\xi = \frac{(1-\theta\beta)/(1-\theta)}{\theta}$, where θ is the Calvo parameter and β the discount factor), and x_t is a function of the marginal cost. It is easy to see that, in this case, the elasticity of inflation to economic slack $(1-\lambda)(1-\phi)\xi$ depends on λ and ϕ, which are measuring, respectively, the degree of openness in both consumption and production imports. An increase in either λ or ϕ corresponds to a flattening of the PC. Therefore, increase in participation to GVCs should flatten the Phillips curve.

(2) *Compounding rigidities at each step of the production network.* GVCs can be interpreted as production networks where the final product is the outcome of different production steps made across different borders. Rubbo (2023) shows, in a closed economy framework, that production networks have a mitigating effect on the slope of the PC. In economies characterised by multiple sectors and intermediate inputs, the responsiveness of inflation to changes in economic conditions is moderated, due to the compounding of nominal rigidities at each step of the chain. In a GVC context, this theory would imply that countries

more downstream should have a PC which is flatter than countries at the beginning of the network (i.e. upstream).

(3) *Strategic complementarities and international competition.* Regarding the competitive environment, economic theory has long recognised (see, for example, Woodford (2003)) that the stronger strategic complementarity (i.e the extent a firm considers the behaviour of other firms in its own decisions.), the weaker the relationship between inflation and the marginal costs (the flatter the PC). Sbordone (2007) shows that increased variety of goods fosters competition, leading to more elastic demand curves and reducing desired mark-ups, setting up a force that would flatten the PC. Also focusing on increased competition, Guerrieri *et al.* (2010) show that in a New Keynesian model in which firms face an elasticity of demand that depends on its price relative to its competitors, the following PC arises:

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \xi \left[(1 - \Psi) x_t + \Psi \phi p_{M,t} \right] \tag{2}$$

where $p_{M,t}$ represents import prices relative to domestic prices. Therefore, $\xi * (1 - \Psi)$ is the response of inflation to fluctuations in marginal costs and Ψ controls the variations of the desired markups (i.e. the strategic response of firms) in response to increased international competition. A higher value of Ψ has a double effect: it reduces the sensitivity to real marginal costs, while it raises the reaction of domestic prices to import prices. The rise in foreign competition, which lowers import prices, diminishes the desired markups of domestic producers, thereby exerting downward pressure on the inflation rate for domestic goods. Participation to GVCs can be seen as a measure of domestic firm openness and exposure to foreign competition. Therefore, following Guerrieri *et al.* (2010), increased GVC participation should be associated with lower inflation levels and a flatter PC.

(4) *Market power and network structure.* This channel focuses on how international openness affects firms' network and market structure. In fact, depending if GVCs favors larger, more productive firms over smaller, less productive ones or viceversa, market power –and therefore markups– can change in presence of GVCs. Participation in GVCs is shown to increase average markups for firms in advanced economies (while the opposite is true in developing economies), as highlighted in the World Development Report 2020. This would imply that higher participation flattens the PC –channel (4a). However, in addition, Ascari *et al.* (2023) shows that market power depends on the positioning of the firm in the GVCs, with very different implication across countries. Focusing on France, Germany, Italy and Spain (a subset of our countries), Battiati *et al.* (2021) find in Europe, unlike in the

US, that markups are negatively correlated with GVC backward participation. Therefore, among EMU-11, downward countries should exhibit a steeper PC, as their price elasticity to marginal cost would be higher –channel (4b).

(5) *Price elasticity and markups.* Increasing the variety of goods available affects the price elasiticty of the demand for both final and intermediate goods. As shown by Benigno and Faia (2016) and Guilloux-Nefussi (2020), firms internalise their influence on the sectoral output when setting their optimal plans. Therefore, the price-elasticity of demand plays a crucial role as it determines the desired markup, which is a function of the market share. Larger variety of goods can result in lower market share (Benigno and Faia, 2016). Therefore, firms become less prone to absorb marginal cost shocks by decreasing their desired markup, implying higher sensitivity of price adjustment to changes in marginal cost. As a result, GVCs, by introducing more varieties of final and domestic goods can steepen the PC.

Summarising, the effect of GVCs on the slope of the PC is ultimately an empirical question. Using theory to guide the empirical analysis, we are going to use both participation and position within GVCs to shade light on the relative importance of the above mechanisms. Analysing the role of participation, we can understand if any combination of channels (1), (3), (4a) – which push towards a flattening of the PC– is stronger than the effect of channel (5) – which would imply a steeper PC. Turning to the role of country position in GVCs, we can test the presence and strength of channels (2) and (4b), affecting the slope in opposite ways.[c]

4 Empirical Analysis

4.1 Data

Our focus is on the first eleven countries joining the European Monetary Union from the introduction of the single currency in 1999 (EMU11): Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain.[d] Focusing on EMU11

[c]For example, regarding participation, if the PC is flatter for countries more deeply involved in GVCs, this would suggest that imperfect pass-through and/or strategic complementarities and/or increased market power are there and stronger than the potential effect of increased varieties. On the other hand, when considering position, while economies positioned downward in the production process (closer to the final good) should have a flatter PC due to the accumulation of rigidities at each step of the chain, firms positioned downward could have lower markups, which could increase the elasticity of prices to changes in marginal costs.

[d]For data availability and reliability, we exclude Luxembourg.

countries from 1999q1 onwards allows the estimation of the PC over the longest time-span. This alleviates concerns about inflation expectations, as all countries are subject to the same monetary policy ruled by a common central bank with a specific and common mandate on inflation.

Data come from five main sources. The series for participation and position in GVCs come from Mancini *et al.* (2024a) and are available at yearly frequency. We mainly focus on measures related to output and not only trade. This is to properly account for all the activities within the global supply network, even those corresponding to non-tradable goods such as services. As explained in Borin *et al.* (2021), "looking only at GVC trade understates the actual extent of GVCs by around US$10 trillion, as GVC trade amounts to about $10 trillion, while GVC output to about $20 trillion". We express the participation of a country to the GVC as the share of gross output depending on connections with more than one country. Borin *et al.* (2021) provides also a measure of position in GVCs. Through a score ranging from -1 to $+1$, this measure tells whether a country is overall located at the bottom (-1) or at the top of the GVC (+1). Being at the bottom (top) of the GVC means that a country is fully dependent (independent) on all passages and transformation of intermediary goods through the GVC. Both GVC measures are available only at yearly frequency between 1995 and 2020.

We use quarterly unemployment data for the population aged 15-75 from the OECD Data Warehouse. The natural level of unemployment (NAIRU) is taken from the most recent OECD Economic Outlook, for which these data are available (May 2021). We us the NAIRU and the rate of unemployment to construct the quarterly unemployment gap. We use the Eurostat data to build country-specific quarterly series of core inflation, i.e. the year-on-year percentage change in the Consumer Price Index (CPI), energy and food prices excluded. From the ECB Data Warehouse, we build series of non-tradable inflation. In order to do so, we follow Siena (2021) and use the year-on-year change in the GDP deflator of non-tradable sectors. From this source, we also built the relative non-tradable prices. We consider these series from 1999q1 up to 2023q4. Finally, we use data from the ECB Survey of Professional Forecasters that provides information on expected CPI inflation by country. All series are at quarterly frequency. Appendix B reports details on the construction of each variable along with figures for all series and countries in the sample.

4.2 Participation and position in GVC across EMU countries

Figure 1, Panel (a) shows that all eleven EMU members participated in GVCs between 1999 and 2020, albeit with significant heterogeneity in both the level and evolution of

participation across countries. For instance, in 1999, Greece had the lowest percentage (7.46%) of GVCs value-added shares embedded in each unit of gross output produced. On the other hand, Belgium and Ireland had the highest observed participation (24%) in the same period. All countries experienced a positive increase in participation over time, particularly pronounced for Greece and Ireland. Moreover, almost all countries experienced two major slowdowns. The first one occurred during and just after the Great Recession. As discussed in Cigna *et al.* (2022), the speed of growth in GVC participation has slowed in post-recession years partly due to the increase in low GVCs sectors, such as construction and services. However, in Europe GVCs have maintained a strong regional dimension, as visible in Figure 1. The second slowdown in GVCs participation is in 2020, when the Covid-19 pandemic hit Europe.[e]

Figure 1, Panel (b) plots the evolution of the position of each EMU11 country in GVCs. Here, heterogeneity in levels and dynamics is even more marked. For example, Portugal, Spain and Greece moved upstream in the GVC between 1999 and 2020. Conversely, other countries, such as Ireland and Finland, have moved downstream in their position within GVCs. The position of all other countries remained roughly the same, despite fluctuations over time around the same initial level.

In the next sections, we are going to exploit this heterogeneity to account for the role of GVCs on the slope of the PC. In particular, first we are going to use both series of GVC participation and position to study whether they contributed effectively to changes in the slope of the PC in the long run, i.e. until the Covid-19 Crisis. We will then leverage the Covid-19 shock as a natural experiment to investigate how recent shifts in the PC dynamics can be explained by variations in GVC participation and position resulting from the global pandemic shock. Finally, in the last sub-section, we check that the measures of GVC participation are not simply capturing francoopenness to trade.

4.3 The Slope of the Phillips Curve and GVC

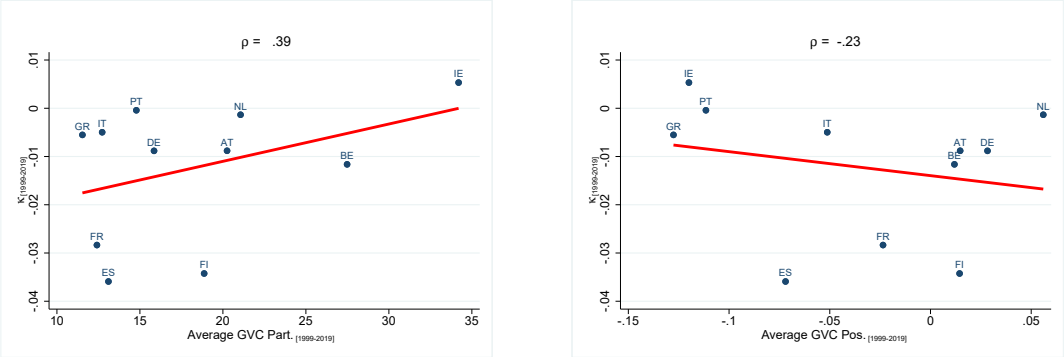
Do participation and position in GVCs matter for the relationship between price dynamics and unemployment? In order to check this point, we start by plotting the cross-country correlation between the slope of the Stock and Watson PC and the mean value of GVC participation and position. The slope of the Stock and Watson PC is estimated for each

[e]This, as showed by Ascari *et al.* (2023), was also due to strong sectoral reallocation and GVCs restructuring.

country over the 1999q1-2019q4 window (see Appendix A for details).[f] The country specific mean-level of GVC participation and position are calculated over the same periods.

Panel (a) in Figure 2 shows a positive correlation between the slope of the PC and the average level in participation to the GVC. In other words, countries with higher contribution of the GVC to their home-production are the same with a flatter PC. This first-hand evidence is consistent with all the theories showing that an increase in GVCs participation flattens the PC (see Section 3). On the other hand, Panel (b) in Figure 2 shows that there is a negative correlation between the slope and the (average) position of a country within the GVC. That is, countries at the top (bottom) of the GVC exhibit a steeper (flatter) PC. This evidence is more in line with theories suggesting that a change in the supply structure depends on the position in the production network.

Yet, it is important to move from correlations to a causal analysis in order to assess to which extent the two dimensions of the GVC (participation vs. position) matter for the PC. This is an empirical challenge as there are several sources of endogeneity. First, the estimates of the PC could be biased as there are factors that can influence both unemployment and inflation at the same time (e.g. supply shocks). Second, there are other long-run and structural factors that might have influenced the slope of the PC and GVCs contemporaneously such that their relationship is spurious.



(a) GVC Participation (b) GVC Position

Note: Figure (a) plots the mean GVC participation index over the slope of the Stock and Watson Phillips Curve. In Figure (b), the mean GVC position index is on the x-axis.

Figure 2: Global Value Chain and the Phillips Curve

[f] Building on Stock and Watson (2019), for each country we estimate the following model: $\Delta\pi_{i,t}^{Core} = \alpha + \kappa_i \hat{u}_{i,t} + \varepsilon_{i,t}$, where the $\Delta\pi_{i,t}^{Core}$ is the difference between the moving average of core inflation measured between t and $t-3$ and the moving average of core inflation measure between $t-4$ and $t-7$. α is the constant term. $\hat{u}_{i,t}$ in the percentage deviation of the moving average of unemployment, measured between t and $t-3$, and the NAIRU. See Appendix A for details.

4.4 GVCs Participation vs. Position

This section exploits the cross-country variation in the participation and position in GVCs to test whether these are important determinants of the slope of the PC. We use the New Keynesian Framework to study if GVCs affect the PC as predicted by the theory. By estimating an augmented New Keynesian Phillips Curve (NKPC) for core inflation and using both GVC position and participation measures, we can test which theoretical channel matters the most for the recent observed dynamics of the PC.

Thereafter, we follow the most recent developments in the empirical literature on the PC estimation and consider the regional framework á la Hazell *et al.* (2022), using non-tradable inflation. This exercise is not only helps corroborate our results, but also shows the importance of GVCs for non-tradable price dynamics, an intuition that has been suggested but not explored in Guerrieri *et al.* (2010).

Both analysis are conducted initially for periods before the Covid-19 Crisis. In particular, given different variable definitions across the empirical models, for consistency between the New Keynesian and the regional PC estimation, we consider observations from 2002q1 up to 2018q4. Later on, we extend the sample and use the pandemic as a natural experiment to validate our results and rationalise recent PC dynamics.

To conclude the analysis, we do some robustness checks. The most important is to assure that our GVC participation measure is not simply capturing trade openness.

4.4.1 Core Inflation - The New Keynesian Framework

Empirical Model Consider the following augmented NKPC:

$$\begin{aligned}\pi_{i,t}^{Core} = \alpha_i + \kappa \hat{u}_{i,t} + \gamma_1 \mathbb{E}(\pi_{i,t+4}) + X'_{i,t}\gamma_2 \\ + \sum_{j=\{part.,pos.\}} \left\{ \kappa_j \hat{u}_{i,t} GVC^j_{i,t-4} + \delta_j GVC^j_{i,t-4} \right\} \\ + \kappa_{GR} \hat{u}_{i,t} \times After_{GR} + \delta_{GR} After_{GR} + \varepsilon_{i,t} \end{aligned} \tag{3}$$

where $\pi_{i,t}^{Core}$ is the year-on-year core inflation observed in country i at time t; α_i is the country i fixed-effect; $\hat{u}_{i,t}$ is the unemployment gap, i.e. the percentage deviation of unemployment from the NAIRU; $\mathbb{E}(\pi_{i,t+4})$ is the level of inflation expected in country i one year from now; $X_{i,t}$ controls for the country-specific import price index, a dummy variable indicating whether the country i is in a business cycle phase of expansion or recession[g], and

[g]Following Siena and Zago (2024), we use CEPR business cycle dates to identify the expansion before the Great Recession (GR), the GR, the expansion following the GR but before the Sovereign Debt Crisis

a year dummy to net out other potential contemporaneous and common event affecting our country-specific GVCs measures (expressed at early frequency).[h] $GVC^{part.}_{i,t-4}$ expresses to which extent a country participates to GVCs, i.e. the share of value-added created through global supply chains. We consider the 4^{th} lag of this variable to reduce endogeneity. Similarly, $GVC^{pos.}_{i,t-4}$ captures the top-vs.-bottom position of the country in the GVC and it is expressed as a score ranging between -1 and $+1$. $After_{GR}$ is a dummy taking value one for periods after the GR, according to CEPR business cycle dates. $\varepsilon_{i,t}$ is the error term.

In words, the first line of equation (3) is the baseline NKPC; the second line takes into account the role of GVCs participation and position both for the slope of the PC and the level of inflation; the third line controls for recent dynamics in the PC following the GR as done in Siena and Zago (2024), i.e. we control for a structural break in the slope of the PC in post-recession years. In light of this, we use the augmented PC of equation (3) to test whether GVC participation and position matter for the slope of the PC and how. Formally, we want to test

$$H_0 : \kappa_j = 0, \;\; \forall j = \{part., pos.\}.$$

However, this hypothesis cannot be tested via Ordinary Least Square (OLS). In fact, these estimates would be biased as supply shocks can contemporaneously affect the unemployment gap, inflation and inflation expectations. Therefore, all unemployment gaps and their interactions, and inflation expectations should be instrumented. For the unemployment gap and all its interactions, we use aggregate off-the-shelf high-frequency monetary policy shocks for the Euro Area (mps_t) from Altavilla *et al.* (2019). In this paper, monetary policy surprises are identified as exogenous/unexpected changes in the 3-month Overnight Index Swap occurred during the monetary policy communication window. We select those shocks that are not correlated with the stock market to separate them from information shocks (see Jarociński and Karadi, 2020). We sum these shocks at quarterly frequency and use mps_{t-k}, $mps_{t-k} \times After_{i,c}$, $mps_{t-k} \times GVC^{j}_{i,t-4}$, for $j \in \{part., pos.\}$ and $k \in \{2, .., 6\}$ as instruments for the unemployment gap and all its interaction terms. On the other hand, we instrument country-specific inflation expectations with the lag of the aggregate inflation expectations for the EMU11 (i.e. the average of lagged inflation expectations across countries). The fact that these instruments are common across all countries and that the MP surprises are quarterly aggregation of high frequency shocks could potentially be a threat

(SDC), the SDC and periods after the SDC.

[h] Yearly GVC data is merged with quarterly data without any interpolation, i.e. GVC measures take the same value for four consecutive quarters within the same year and country. Using interpolation methods to transform the GVC measures from yearly to quarterly does not significantly affect the results of our empirical analysis.

for our identification. Despite this, these instruments are sufficiently relevant (Wald F-stat = 14.50) and valid (Sargan-Hansen statistic = 7.10; p-value = 0.96)[i] Moreover, under this specification, the model does not exhibit cross-sectional dependence[j].

	(1) π^{Core}	(2) π^{Core}	(3) π^{Core}	(4) π^{Core}	(5) π^{Core}
$\hat{u}$	-0.0081**	-0.0321***	-0.0075	-0.0544**	-0.0605***
	(0.0035)	(0.0070)	(0.0118)	(0.0216)	(0.0220)
$\hat{u} \times GVC_{part.}$		0.0007***		0.0007***	0.0005**
		(0.0002)		(0.0002)	(0.0002)
$GVC_{part.}$		-0.0203		-0.0569	0.0340
		(0.0198)		(0.0416)	(0.0699)
$\hat{u} \times GVC_{pos.}$			0.0109	-0.1982	-0.0570
			(0.0984)	(0.1543)	(0.1777)
$GVC_{pos.}$			-0.7755	-1.9539	-6.0901*
			(1.0748)	(1.7852)	(3.1181)
Observations	748	748	748	748	748
Country Fe	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Post-GR break	No	No	No	No	Yes
Time Fe	No	No	No	No	No
IV	MP	MP	MP	MP	MP

Note: The variable of interest in column (1)-(5) is core inflation measured as the year-on-year change in CPI inflation (energy and food excluded). $\hat{u}$ is the percentage deviation of unemployment from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses. *, **, *** indicate significance at 90%, 95% and 99%.

Table 1: The New Keynesian Phillips Curve and GVCs

Results Table 1 shows two-stage least-square estimates of model (3). As shown in column (1), we find that the PC has overall a small negative slope equal to -0.008. When controlling for the role of GVC participation in column (2), the curve is instead steeper

[i] See Appendix C for first-stage statistics.

[j] The average cross-sectional correlation of the error (across panel groups) is small (0.16) and the Frees statistic is below the critical value, i.e. $0.27 < Q_{0.01} \approx Z_{0.01}$. In other words, we cannot reject the null hypothesis of crossectional independence (see De Hoyos and Sarafidis (2006)).

(-0.03). However, the estimate $\kappa_{part.}$ for the interaction term $\hat{u} \times GVC^{part.}$ is positive and significant. In other words, countries with higher participation in the GVC exhibit a flatter NKPC. In column (3), we control for the role of $GVC^{pos.}$ alone. The point estimate of the slope of the PC is now closer to that found in column (1), while GVC position surprisingly has a positive effect on the slope. Yet, all estimates are not significantly different from zero, suggesting that not only does GVC position play no role, but the inclusion of this control also increases the standard errors for the estimate of the slope estimate.[k] In column (4), we control for both GVC participation and position. Now, the estimate of the slope κ is significantly different from zero and slightly bigger than what found in column (2). The estimate of $\kappa_{part.}$ remains significant and unchanged with respect to what previously found. Despite the fact that now the estimate of $\kappa_{pos.}$ is negative, there is again no significant evidence that the GVC position matters for the slope of the PC. In column (5), we control for the post-GR structural break in the slope of the PC, as documented in Siena and Zago (2024). Under this further check, the results remain (roughly) unchanged.

In light of this evidence, we can derive two conclusions. First, (1) imperfect exchange rate pass-through and/or (2) strategic complementarities and/or (4a) higher market power are stronger than the potential effect of (5) increased varieties. Second, as positioning does not statistically affect the slope of the PC, we can either conclude that countries upward and downward behave similarly, or, more likely, that the two opposing forces (i.e. (3) more compounding rigidities (Rubbo, 2023) and (4b) lower markups as we go downstream Battiati *et al.* (2021)) offset each other. Further analysis, using sectoral decompositions, could shed more light on the role of GVCs positioning.

To conclude, only participation matters for the slope of the New Keynesian PC. In particular, according to the estimates of column (5), as the average value for $GVC_{part.}$ is 18% (see Appendix B.1), participation in the GVC accounts for $(18.7 * 0.0005/(0.0605 + 18.7 * 0.0005)) \approx 13\%$ of the flattening of the PC witnessed in the pre-Covid years.

4.4.2 Non-tradable Inflation - The Regional Framework

By focusing only on tradable prices, Guerrieri *et al.* (2010) present empirical evidence of the flattening of the U.S. PC as the share of imports increases. In the previous section, we extended this analysis to EMU11 countries and found a significant role of GVCs in affecting also core inflation, a broader measure that encompasses non-tradable prices as well. Here,

[k] In presence of supply shocks in specific sectors, a bad position over the GVC can reflect into price and inflation dynamics in a way that local conditions may result less statistically relevant for inflation.

we further develop this finding. We explore whether our results hold true when we only use non-tradable prices, which are generally considered to be primarily influenced by domestic factors. However, GVCs are increasingly important in the production of non-tradable goods, in particular services. In light of this, we decide to investigate the unexplored role of positioning and participation in GVCs when considering non-tradable inflation. Additionally, focusing on non-tradable prices allows to better disentangle the effect of GVCs from openness to trade. In fact, as non-tradables are sold only domestically (but use also tradable goods as intermediate inputs), the elasticity of their prices to the economic slack can be imputed to changes in marginal costs and their production structure, and not directly to international competition.

Empirical Model We follow the most recent developments in the literature and consider the regional PC of Hazell *et al.* (2022) using non-tradable prices, applied to the euro area as in Siena and Zago (2024). Estimating a regional PC has several advantages: i) using non-tradable (NT) prices reduces the bias due to inflationary spillovers from one country to another; ii) variation in long-run inflation expectations (due to the behaviour of the central bank) can be controlled for by using time fixed effects; (iii) other differences across regions, as long as these differences are constant over time, will be absorbed by country fixed effects. Given this empirical setup, we augment the baseline regional PC as discussed in the previous section. Formally, we consider the following equation:

$$\begin{aligned}\pi_{i,t}^{NT} = \alpha_i + \xi_t + \kappa \hat{u}_{i,t} + \gamma_1 \overline{p}_{i,t}^{NT} + X_{i,t}' \gamma_2 \\ + \sum_{j=\{part.,pos.\}} \left\{ \kappa_j \hat{u}_{i,t} GVC_{i,t-4}^{j} + \delta_j GVC_{i,t-4}^{j} \right\} \\ + \kappa_{GR} \hat{u}_{i,t} \times After_{GR} + \delta_{GR} After_{GR} + \varepsilon_{i,t} \end{aligned} \tag{4}$$

where $\pi_{i,t}^{NT}$ is non-tradable inflation in country i at time t, measured as the year-on-year percentage change of the GDP deflator for non-tradable sectors (see Siena, 2021). ξ_t is the time fixed effect, which captures common changes in monetary policy across EMU members (see Hazell *et al.*, 2022). Following Hazell *et al.* (2022), now $\hat{u}_{i,t}$ is the discounted sum of four quarters of future unemployment in deviation from its long-run equilibrium level (NAIRU), and $p_{i,T}^{NT}$ is the 4-quarter discounted sum of future levels of non-tradable prices (relative to the overall price level). All the rest is the same as defined for the NKPC with the exception of $X_{i,t}$ which does not include import prices.

Also in this case, we cannot use OLS for estimation. Hence, we rely on internal instru-

mental variables (IVs). In particular, we use $\hat{u}_{i,t-4}$, $\hat{u}_{i,t-4} \times GVC^{j}_{i,t-4}$ and $\hat{u}_{i,t-4} \times After_{GR}$ as instruments for the unemployment gap and all its interaction terms. On the other hand, we instrument country-specific relative non-tradable prices with their fourth lag ($\overline{p}^{NT}_{i,t-4}$). This set of instrument results to be relevant (Wald F-stat = 47.34)[l] and, under this specification, the model does not exhibit cross-sectional dependence.[m]

Results In column (1) of Table 2, we present the results from the regional PC. The slope is negative, relatively small (-0.012) and significant. In column (2), we control for the role of GVC participation both on the level of inflation and, more importantly, on the slope of the PC. Also in this case we find that the slope is larger (-0.028), and GVC participation plays a significant role in the flattening of the PC. In column (3) we control for GVC position alone. Differently from the corresponding results for the NKPC, in this case the slope of the PC is significant whereas the point estimate of $\kappa_{pos.}$ is negative and not significant. When controlling for GVC participation and position at the same time, we confirm that position in the GVC does not play any significant role whereas pariticipation does. When controlling for a structural break in the PC in post-GR (column (5)), results do not change. Differently from the case with core inflation, when we use NT prices, participation in GVCs has always a negative and significant impact on the level of inflation: for every level of unemployment the PC shifts downwards.

Also in this set-up, our results are in line with theories (see section 3) of imperfect pass-through, strategic complementarities and increased market power: the more a country is integrated in the GVC, the flatter is its PC. According to the estimates of column (5), the contribution of this channel to the pre-pandemic flattening of the PC is $18.7{*}0.0008/(0.032+18.7*0.0008) \approx 32\%$. Positioning, on the other hand, does not statistically affect the slope of the PC. As mentioned in the previous paragraph, this could well be due to equally strong opposing forces, cancelling the average effect.

As sensed in Guerrieri *et al.* (2010), using non-tradable inflation indeed magnifies the effect of participation in the GVCs on the slope of the PC. The intuition behind this is that non-tradable prices usually exhibit greater stickiness compared to tradable ones, for two reasons. Firstly, firms producing non-tradable goods employ higher shares of labour than those producing tradable goods, leading to more rigid pricing structures (see Altissimo *et al.* (2006); Alvarez and Shimer (2011); Dhyne *et al.* (2021)). Secondly, the lower level

[l] See Appendix C for first-stage statistics.

[m] The average cross-sectional correlation of the error (across panel groups) is small (0.25) and the Frees statistic is below the critical value, i.e. $0.79 < Q_{0.01} \approx Z_{0.01}$. In other words, we cannot reject the null hypothesis of cross-sectional independence (see De Hoyos and Sarafidis (2006)).

	(1) π^{NT}	(2) π^{NT}	(3) π^{NT}	(4) π^{NT}	(5) π^{NT}
$\hat{u}$	-0.0120***	-0.0281***	-0.0189***	-0.0334***	-0.0319**
	(0.0038)	(0.0040)	(0.0048)	(0.0096)	(0.0133)
$\hat{u} \times GVC_{part.}$		0.0009***		0.0008***	0.0008***
		(0.0001)		(0.0002)	(0.0002)
$GVC_{part.}$		-0.5249**		-0.5810**	-0.6076**
		(0.2504)		(0.2947)	(0.2867)
$\hat{u} \times GVC_{pos.}$			-0.0707	-0.0531	-0.0557
			(0.0617)	(0.0592)	(0.0563)
$GVC_{pos.}$			12.9549	15.4676	17.2247
			(18.6807)	(20.2432)	(20.8298)
Observations	748	748	748	748	748
Country Fe	Yes	Yes	Yes	Yes	yes
Controls	Yes	Yes	Yes	Yes	Yes
Post-GR break	No	No	No	no	Yes
Time Fe	Yes	Yes	Yes	Yes	Yes
IV	Int.	Int.	Int.	Int.	Int.

Note: The variable of interest in column (1)-to-(5) is non-tradable inflation measured as the year-on-year percentage change of non-tradable prices. $\hat{u}$ is the 4-quarters discounted sum of future unemployment in deviation from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses are clustered at country-level. *, **, *** indicate significance at 90%, 95% and 99%.

Table 2: The Regional Phillips Curve and GVCs

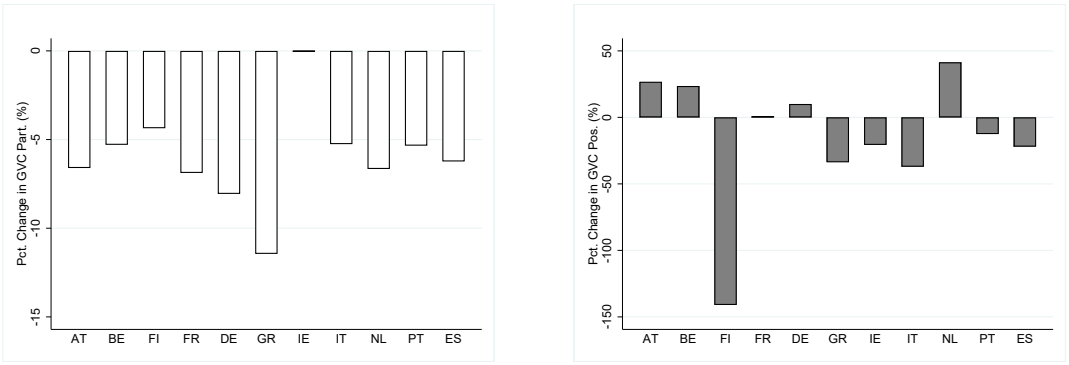
of competition for non-tradable goods may enable service firms to adjust their prices less frequently.

This result allows a strengthening of Guerrieri *et al.* (2010) because GVCs make the inflation rate more rigid not only for tradable goods but even for, more sticky, non-tradable goods. This could be due to the broader use of non-tradables in the GVC or to the increasing complementarity between tradables and non-tradables (see Craighead, 2024).

In Appendix D.1, we verify that these results hold also when using other measures of positioning in GVCs. Following Antràs *et al.* (2012), Fally (2012) and Antràs and Chor (2013), we consider two standard indexes computed using the inter-country input output

tables: upstreamness and downstreamness. The former measures the distance of a country's production from the final demand. Farther it is positioned within a GVCs from the final use, higher its indicator will be. On the other hand, downstreamess of a country measures the distance of the country from the factors of production. We use these measures from 1999 to 2020 applied to the OECD TiVA Input-Output tables, as in Mancini *et al.* (2024b). We find that all our results are robust when using these two alternative indicators of positioning. Only participation matters for the slope of the Phillips Curve. As a further robustness check, in Appendix D.2 we follow Bernardini *et al.* (2020) and control if our results hold true also when considering the effect of recent local recessions and their implications for the slope of the PC and level of inflation. In this case as well, the effect of GVC participation on the slope remains. Finally, in Appendix D.3 we re-estimate equation (3) with producer price inflation as dependent variable. This is an important exercise as ultimately GVCs affect the competitiveness and price adjustments of producers. Hence, if our evidence holds for core inflation and non-tradable inflation, it should be true also when considering producer price inflation as dependent variable. This is the case: only GVCs participation matters for the slope of the PC and leads to flattening; on the other hand, GVC position does not have any significant effect.

4.5 Covid-19 as a shock to GVCs



(a) GVC Participation (b) GVC Position

Note: Panel (a) plots the percentage change in GVC participation between 2019 and 2020, i.e. the year of the Covid-19 recession according to CEPR business cycle dates. GVC participation is measured as the share of gross output depending on connections with more than one country. Similarly, Figure Panel (b) plots the percentage change in GVC position between 2019 and 2020. This measure ranges from -1 to $+1$ and expresses respectively whether a country is at the bottom or at the top of the GVC.

Figure 3: Change in GVC Participation and Position due do Covid-19

Here we exploit the Covid-19 crisis to study how exogenous variations in our GVC measures influence the PC in post-pandemic periods. To do so, first we build the percentage change in $GVC^{part.}$ and $GVC^{pos.}$ between the end of 2019 and the end of 2020. Panel (a) of Figure 3 shows that all countries experienced a decline in GVC participation, as the Covid-19 pandemic and the following social and work restrictions led to the collapse of the GVC through interruption of production, trade, etc.. The average decline in participation due to the pandemic shock is -5.5%,[n] with Ireland experiencing the smallest change while Greece the largest. On the other hand, the effect of the pandemic shock on the country position in the GVC is more heterogeneous. As plotted in Figure 3, Panel (b), countries like Austria, Belgium, Germany and the Netherlands experienced an upstream movement in the GVC, whereas all the other countries moved downstream. The average change in position is -13%, with Finland being the country that moved downstream the most, while the Netherlands being the one that moved upstream the most.

Once endowed with these exogenous changes, we can use them to understand to which extent countries experiencing larger variation in participation and position during the Covid-19 crisis also witnessed changes in the PC and in which direction.

Here we estimate only the Regional Phillips Curve.[o] Our specification now is:

$$\pi_{i,t}^{NT} = \alpha_i + \xi_t + \kappa \hat{u}_{i,t} + \gamma_1 \overline{p}_{i,t}^{NT} + \sum_{j=\{part.,pos.\}} \left\{ \kappa_j \Delta GVC_{i,Covid}^{j} \times After_{Covid} \times \hat{u}_{i,t} \right\} + \kappa_{GR} After_{Covid} \times \hat{u}_{i,t} + \delta_{GR} After_{Covid} + \varepsilon_{i,t} \quad (5)$$

where the novelty is the variable $After_{Covid}$, which takes value one for periods after the Covid-19 recession according to CEPR business cycle dates. In other words, this model studies how the changes in participation and position in the GVCs due to the Covid-19 shock affect the post-Covid slope of the PC, once netting out other potential sources of structural change in the relationship between unemployment and inflation. Variables and instruments are defined as in Section 4.4.2.[p] The analysis now also covers the period 2020-2022.

As Table 3 shows, coherently with the results of section 4.4.2, also in this case we find that the pre-Covid slope is very small. Again only participation in GVC matters for the recent change in slope, with $\kappa_{part.}$ being positive and significant. Conversely, although

[n] See Appendix B.2 for summary statistics.

[o] This is due to the fact that, with only 12 quarters of observations available after the beginning of the pandemic, the instrumentation of the NKPC with core inflation results weak.

[p] See Appendix C for first stage statistics.

	(1) π^{NT}
$\hat{u}$	-0.0104***
	(0.0011)
$\hat{u} \times After_{covid} \times \Delta GVC_{part.}$	0.0144**
	(0.0067)
$After_{covid} \times \Delta GVC_{part.}$	-3.3756**
	(1.5153)
$\hat{u} \times After_{covid} \times \Delta GVC_{pos.}$	-0.0003
	(0.0003)
$After_{covid} \times \Delta GVC_{pos.}$	0.0910
	(0.0864)
Observations	924
Country Fe	Yes
Controls	Yes
Post-GR break	Yes
Time Fe	Yes
IV	Int.

Note: In column (1), the variable of interest is non-tradable inflation. $\Delta GVC^{part.}$ is the percentage change of $GVC^{part.}$ between 2019 and 2020, i.e. the year of the Covid-19 recession according to CEPR business cycle dates. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $\Delta GVC^{pos.}$ is the percentage change of $GVC^{pos.}$ between 2019 and 2020. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2022q4. Standard errors in parentheses. *, **, *** indicate significance at 90%, 95% and 99%.

Table 3: The Covid-19 GVC shock and the PC

negative, $\kappa_{pos.}$ is not significant.

Doing the same back-of-the-envelope calculation as before, we find that –for the average decline in participation equal to 6.1% (see Appendix B.2)– the participation channel accounts for $0.061 * 0.0144/(0.0104 + 0.061 * 0.0144) \approx 8\%$ of the recent steepening of the PC.

To sum up, by exploiting the Covid-19 pandemic, we confirm the results from the previous section: the GVC participation channel is important for the slope of the PC and it contributes to its flattening. On the other hand, GVC position does not play a significant role. These results are in line with the recent literature. For example, Ari *et al.* (2023)

document both the flattening of the Phillips curve in recent decades and post-Covid signs of its steepening. Using sectoral data from 24 advanced economies in Europe, they find, in line with Alfonso C *et al.* (2021), that the acceleration of e-commerce during the pandemic may have raised price flexibility. Additionally, they suggest that de-globalization may have made inflation more responsive to domestic economic conditions[q]

4.6 Robustness: GVCs and Openness to Trade

The results of sub-sections 4.4.1 and 4.4.2 are exposed to an important critique: the measure of GVCs participation could potentially just capture the openness to trade of a country rather than the peculiarities of its international production network. In fact, as shown in Appendix B.6.4, there is a small but significant correlation (roughly equal to 0.20) between openness to trade and GVCs participation (whereas there is no correlation between openness and GVCs position). This rises a red flag, as the imputed role of GVCs participation for the PC could be –to a certain extent– simply a by-product of international trade.

To investigate this point, here we augment both the NKPC of equation (3) and the regional PC of equation (4) with a measure of openness to trade to check if our main results hold. In particular, we use data from the World Bank on World Development Indicators and build a standard measure of openness ($Openness_{i,t}$) as the sum of total import and exports over GDP (see Appendix B.5). Hence, to both empirical models (3) and (4), we add the interaction term $\hat{u}_{i,t} \times Openness_{i,t-4}$ and the variable $Openness_{i,t}$ alone. These two elements will control respectively for the role of openness to trade on the slope of the PC and on the level of (core or non-tradable) inflation.

We begin by considering the NKPC with core inflation. As in Section 4.4.1, we instrument the unemployment gap and its interactions with monetary policy shocks alone and interacted with the measure of openness at $t-4$. Table 4 shows results.[r]

As shown in column (1) of Table 4, our previous findings are confirmed. Despite controlling for the role of trade openness, only participation in GVCs, and not positioning, matters for the slope of the PC. Moreover, trade openness has a contemporaneous and significant effect on the slope as well: the higher the openness to trade the steeper is the NKPC. By using theese estimates, also here we can do a back-of-the-envelope calculation

[q]See Razin (2020) who contends that trade globalization has reversed its course since the global financial crisis. A similar dynamics of the PC is present in the US. Benigno and Eggertsson (2023), observing that labor shortages are often accompanied by inflationary spikes, incorporate labor market tightness as an explanatory variable in the Phillips Curve and find that the rise in labor shortages, such as the one experienced after the COVID-19 crisis, caused the PC to become non-linear, with the slope becoming steeper than usual.

[r]See Appendix C for first-stage statistics.

	(1) π^{Core}	(2) π^{Core}	(3) π^{Core}	(4) π^{Core}
$\hat{u}$	-0.0493***	-0.0559***	-0.0446***	-0.0404***
	(0.0136)	(0.0175)	(0.0086)	(0.0128)
$\hat{u} \times GVC_{part.}$	0.0047***	0.0006**	0.0050***	
	(0.0014)	(0.0002)	(0.0010)	
$GVC_{part.}$	-0.0670	-0.1255**	-0.0595**	
	(0.0424)	(0.0489)	(0.0284)	
$\hat{u} \times GVC_{pos.}$	-0.0542	-0.3289**		0.0638
	(0.1355)	(0.1291)		(0.1045)
$GVC_{pos.}$	-1.7827	-0.4212		-8.8331***
	(1.4762)	(1.8308)		(3.1460)
$\hat{u} \times Openness$	-0.0007***		-0.0008***	-0.0000
	(0.0002)		(0.0002)	(0.0000)
$Openness$	0.0145***	0.0056	0.0146***	0.0159***
	(0.0048)	(0.0049)	(0.0041)	(0.0060)
Observations	748	748	748	748
Country Fe	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Post-GR break	Yes	Yes	Yes	Yes
Time Fe	No	No	No	No
IV	MP	MP	MP	MP

Note: The variable of interest in column (1)-to-(4) is respectively core inflation. $\hat{u}$ is the percentage deviation of the unemployment rate from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. *Openness* is the sum of imports and exports divided by GDP. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses. *, **, *** indicate significance at 90%, 95% and 99%.

Table 4: Openness to Trade and GVCs in the NKPC with core inflation

to quantify the impact of GVC participation on the flattening of the NKCP. As the mean value of *Openness* is 92.94%[s], we can say that the net effect of GVC participation on the slope of the PC (netting out the effect of openness to trade) is $[18.6 * (0.0047) + 92.94 * (-0.0007)]/[0.0493 + 92.94 * (0.0007) + 18.6 * (0.0047)] \approx 11\%$.

In column (2)-to-(4), we further check the robustness of these results by investigating more in detail the role played by trade. In column (2), we drop the interaction term $\hat{u} \times$ *Openness* to check if international trade alone affects the role played by GVCs participation on the slope of the PC. In this case, the slope results are slightly larger, while the impact

[s]See Appendix B.3.

of GVC participation on the slope is much smaller. Moreover, for the first time, the effect of GVCs position on the slope is significant. This indicates that ignoring the effect of trade on the slope of the PC would lead to underestimate the role of GVC participation and to overestimate the role of GVC position. In column (3) and (4) we respectively drop $\hat{u} \times GVC_{pos.}$, $GVC_{pos.}$ and $\hat{u} \times GVC_{part.}$, $GVC_{part.}$ while continuing to control for both $\hat{u} \times Openness$ and $Openness$. This allows to better understand the influence of trade on each GVC channel. In line with the results of column (1), again we find that –once netting out the effect of trade– only GVCs participation matters.

Table 5 shows results for the regional PC, where –similarly to Section 4.4.2– we instrument the new interaction term with $\hat{u}_{i,t-4} \times Openness_{i,t-4}$.[t] Column (1) confirms the results of the previous sections: only GVC participation matters for the slope of the regional PC. In this case openness to trade does not have any significant effect. This, as explained in the introduction, confirms the rational of using non tradable prices for estimating the effects of GVCs on the PC: it allows to separate the effects of GVCs from openness. When doing the usual back-of-the-envelope calculation, we find that GVC participation contributes to the flattening of the regional PC by $[18.7 * (0.0018) + 92.94 * (-0.0002)]/[0.0339 + 92.94 * (0.0002) + 18.7 * (0.0018)] \approx 17\%$.

In column (2)-to-(4) we further investigate the role of openness for the regional PC. As from column (2), not including the interaction term $\hat{u} \times Openness$ will underestimate the role of GVC participation on the role of the PC. When studying participation and positioning separately in column (3) and (4), we find that only GVCs participation matters for the slope of the regional PC.

The comparison between Tables 4 and 5 provides additional insights regarding the interaction between GVC participation and openness. In particular, using core inflation (the NK framework), openness affects the PC slope only if GVC participation is considered: openness alone might not capture all the nuances of inflationary dynamics without considering how countries are integrated into GVCs. In fact, participation in GVCs means that a country not only trades internationally but is also integrated into a global production network. This influences production costs, prices, and thus inflation dynamics. Core inflation is more influenced by production costs that better reflect participation in GVCs.

On the other hand, when considering non-tradable prices (the Regional framework), openness affects the slope only if GVC participation is not considered. This supports the idea that non-tradable prices are affected by the international production network but not by

[t] See Appendix C for first-stage statistics.

	(1) π^{NT}	(2) π^{NT}	(3) π^{NT}	(4) π^{NT}
$\hat{u}$	-0.0339**	-0.0321**	-0.0288**	-0.0248**
	(0.0135)	(0.0143)	(0.0120)	(0.0123)
$\hat{u} \times GVC_{part.}$	0.0018***	0.0009***	0.0018**	
	(0.0006)	(0.0002)	(0.0007)	
$GVC_{part.}$	-0.8525***	-0.5931**	-0.7826***	
	(0.2418)	(0.2987)	(0.2524)	
$\hat{u} \times GVC_{pos.}$	-0.0525	-0.0504		-0.0246
	(0.0516)	(0.0559)		(0.0440)
$GVC_{pos.}$	17.6976	17.3126		8.4888
	(20.1517)	(21.8408)		(15.5116)
$\hat{u} \times Openness$	-0.0002		-0.0002	0.0001***
	(0.0001)		(0.0001)	(0.0000)
$Openness$	0.0386	-0.0203	0.0479	-0.0823*
	(0.0488)	(0.0293)	(0.0464)	(0.0468)
Observations	748	748	748	748
Country Fe	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Post-GR break	Yes	Yes	Yes	Yes
Time Fe	Yes	Yes	Yes	Yes
IV	Int.	Int.	Int.	Int.

Note: The variable of interest in column (1)-to-(4) is non-tradable inflation. $\hat{u}$ is the 4-quarters discounted sum of future unemployment in deviation from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. *Openness* is the sum of imports and exports divided by GDP. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses are clustered at country-level. *, **, *** indicate significance at 90%, 95% and 99%.

Table 5: Openness to Trade and GVCs in the Regional PC

trade openness per-se. However, if GVC participation is omitted, the measure of openness partially captures this international supply chain effect. Summarising, the relevance of openness and GVC participation for the slope of the Phillips Curve varies depending on the type of price used in the analysis: GVC participation seems to play a crucial role for more stable prices related to international production costs, while for NT prices, economic openness is not relevant, when GVC participation is included.

In Appendix D.1, we provide further robustness checks that confirm the role of GVC participation. We show that only participation matters also when using different measures of positioning, in particular the upstreamness and downstreamness of Antràs *et al.* (2012)

and Antràs and Chor (2013), while controlling for the openness to trade at the same time. In Appendix D.4, we keep on taking into account for the role of openness to trade and control for the interaction between $GVC_{part.}$ and $GVC_{pos.}$ and its effect on both the level of inflation and on the slope of the PC. This helps to understand whether $GVC_{part.}$ has still a significant effect on the slope for countries with similar levels of $GVC_{pos.}$ (and viceversa). This is a way of testing the theoretical channel for which, given the same level of GVCs participation, countries in different positions within the GVCs could have different slope of the PC (see channel (4b) in Section 3). We don't find statistical evidence of this channel.

Finally, in Appendix D.5 we use an identifying equation similar to equation (3) and (4) – where we omit all the GVCs variables– to check the direct effect of openness to trade on the slope of the PC. When dropping GVC position and participation from the controls, openness to trade has a significant effect and leads to a flattening of the PC. Yet, this effect is smaller than the estimated effect of GVC participation.

5 Conclusions

The role of Global Value Chains (GVCs) for the structure of the economy and its implication for monetary policy is only partially understood. In this paper we investigate the role of two channels through which GVCs can affect the slope of the Phillips Curve and, consequently, the transmission of monetary policy shocks. The two channels are GVCs participation and position, which capture respectively to which extent a country relies on GVCs for production and whether they are located upstream or downstream in the chain of production of the final good. Our analysis focus on 11 EMU countries. We first estimate a NKPC for periods before the Covid-19 recession, and find that both channels operate as the theory predicts: higher participation leads to a flattening of the PC, whereas an upper position in the GVC lead to a steepening. Yet, only the first channel is statistically significant. Through a back-of-the-envelope calculation, we find that the participation channel accounts for 15% of the flattening in pre-Covid years. Thereafter, we repeat the same analysis using the empirical set-up of Hazell *et al.* (2022), which estimate a regional PC with non-tradable prices. This exercise is important since, through the rise of the service economy, non-tradable prices play a higher role in core inflation. Moreover, they allow a better estimation of the slope of the PC as they correlate more with country-level unemployment. Also under this setup, our results are confirmed: only participation matters, while the position within GVCs does not affect the slope of the PC. Under this empirical set up, the role of participation is magnified and accounts up to 32% of the flattening of the PC in pre-Covid years. While

insignificance of GVC position may challenge recent literature suggesting a compounding effect of price stickiness at each step along the production chain, the participation channel enables a reassessment of the theory proposing that foreign competition, by reducing the desired markups of domestic producers, decreases the inflation rate. This holds not only for tradable goods (as in Guerrieri *et al.* (2010)), but, and even more so, also for non-tradables. Finally, we extend our analysis to post Covid-19 periods. In particular, we exploit the Covid-19 pandemic as a natural experiment to valuate the exogenous variation in GVC participation and position. Also in this case, we confirm previous results: it is only GVC participation that matters for the slope. In particular, the collapse in GVCs participation due to the Covid-19 shock can explain 8.4% of the steepening of the PC observed in post-pandemic years. We think this findings have important implications for monetary policy and for a better understanding on how monetary policy can be effective.

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APPENDIX (not for publication)

A The Stock & Watson Phillips Curve

The Stock & Watson correlation across countries and throughout time. In this section, we use the empirical framework of Stock and Watson (2019) and their variables definition to study the evolution of the Phillips Curve (correlation) across countries and throughout time. In particular, we focus on the evolution of the Phillips Curve (PC) before the Great Recession (GR), after the GR and after the Covid-19 crisis across eleven countries (EMU11): Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. For this sample of countries, we consider data spanning from 1999q1 to 2023q4 at quarterly frequency. With this purpose in mind, we consider the following estimating equation:

$$\begin{aligned}\Delta\pi_{i,t}^{Core} = \alpha_i + \kappa_1 \hat{u}_{i,t} \\ + \kappa_2 \hat{u}_{i,t} \times \mathbb{I}(After_{GR}) + \kappa_3 \hat{u}_{i,t} \times \mathbb{I}(After_{Covid}) \\ + \mathbb{I}(After_{GR}) + \mathbb{I}(After_{Covid}) + \varepsilon_{i,t}\end{aligned} \tag{A.1}$$

where the $\Delta\pi_{i,t}^{Core}$ is the difference between the moving average of core inflation measured between t and $t-3$ and the moving average of core inflation measure between $t-4$ and $t-7$. α_i is the country fixed effect. $\hat{u}_{i,t}$ in the percentage deviation of the moving average of unemployment, measured between t and $t-3$, and the NAIRU.[u] The dummy $I(After_{GR})$ and $I(After_{Covid})$ takes value one respectively for periods after the GR and the Covid-19 recession according to CEPR business cycle dates. $\varepsilon_{i,t}$ is the error term. In words, the first line of equation (A.1) is the standard Stock & Watson PC. The second line studies how the slope of the PC evolves after the GR and after the Covid-19 Crisis. The third line of the model controls for changes on the level of inflation in the corresponding periods. Table A.1 shows results. Before the GR, the slope of the PC was significant and relatively small. When considering periods after the GR (but before the Covid-19 crisis), we witness a flattening: the slope of the PC moves from -0.014 to $-0.0140 + 0.0125 = -0.0015$. In words, just after the GR, there was a severe flattening of the PC, as highlighted in Siena and Zago (2024). Conversely, when considering periods after the Covid-19 crisis, we see that the PC experienced a steepening. In fact, in recent years, the estimated slope of the PC is equal to $-0.0140 + 0.0125 - 0.0855 = -0.087$.

[u] See Appendix B for further details on data and variables construction.

To sum up, the PC changed from being (slightly) negatively sloped before the GR to basically disappear until the Covid-19 crisis, after which the estimated PC results to be strongly negatively sloped.

	(1) $\Delta\pi^{Core}$
$\hat{u}$	-0.0140***
	(0.0037)
$\hat{u} \times \mathbb{I}(After_{GR})$	0.0125***
	(0.0045)
$\hat{u} \times \mathbb{I}(After_{Covid})$	-0.0855***
	(0.0075)

Note: Table A.1 reports the Phillips Curve Correlation estimated using a panel composed by the countries that joined the EMU before 2002 (Luxembourg excluded). The dummy $I(After_{GR})$ and $I(After_{Covid})$ takes value one respectively for periods after the Great Recession and the Covid-19 recession according to CEPR business cycle dates. Standard errors in parentheses. *, **, *** indicate significance at 90%, 95% and 99%.

Table A.1: The Price Phillips Curve across the EMU11 and GVC

The Stock & Watson correlation for each country. In this section, we discuss how to estimate the slopes of the PC used in the scatter-plots of Section 4.3. We follow the empirical framework and variables definition of Stock and Watson (2019) and estimate the following equation for each country i in the sample:

$$\Delta\pi_{i,t}^{Core} = \alpha + \kappa_i \hat{u}_{i,t} + \varepsilon_{i,t}. \tag{A.2}$$

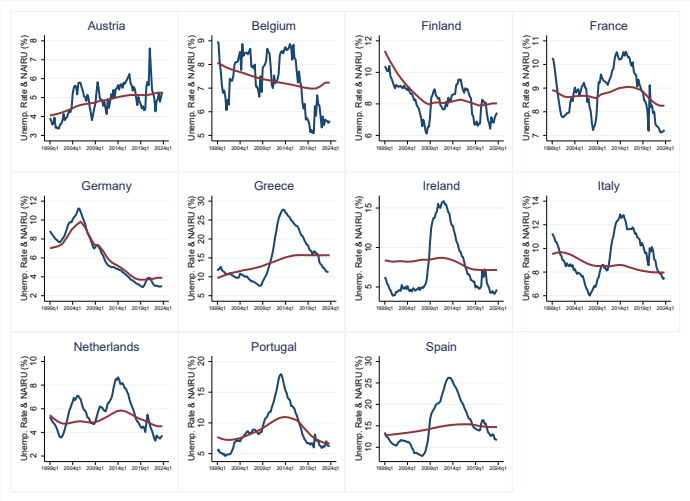
α is the (country-specific) constant term. All other variables are defined as above. For each country, we estimate κ_i between 1999q1 and 2019q4.

B Data

B.1 Unemployment Data

We consider unemployment data from the OECD Data Warehouse, which provides quarterly series of the unemployment rate for population in the 15-74 age bracket by country. Hence, we consider data for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. We refer to this group of countries that joined the European Monetary Union already before the introduction of the single currency (1999q1) as EMI11. The OECD Economic Outlook provides the Non-accelerating Inflation Rate of

Unemployment (NAIRU). We use the Economic Outlook from May 2021, which is the last outlook providing estimates of the NAIRU up to 2022 at yearly frequency for the same group of countries. We interpolate the yearly NAIRU and build quarterly series. As the values of the NAIRU for 2023 are not provided, for each country we assume that the level of the NAIRU in 2023 is equal to the level at 2022q4. Figure B.1 plots the unemployment rate and the NAIRU for each country between 1999q1 and 2023q4.

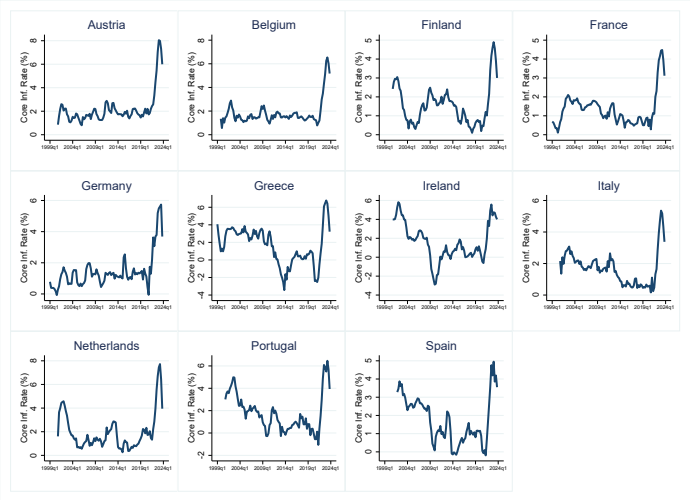


Note: The figure plots the unemployment rate and NAIRU for each country that joined the EMU before 1999 (Luxembourg excluded). Data is at quarterly frequency and comes from the OECD.

Figure B.1: Unemployment and NAIRU by EMU11 country

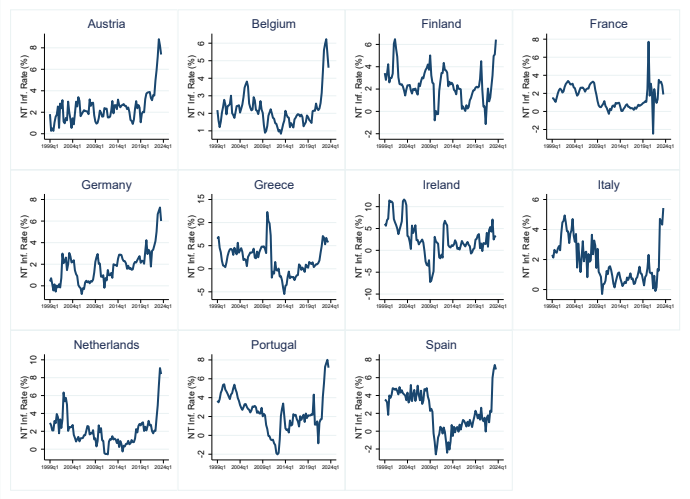
B.2 Inflation Data by EMU11 country

The OECD provides headline core inflation rates (energy and food prices excluded from the HICP) at quarterly frequency for each country of the EMU11. In addition, we follow Siena (2021) and use Eurostat data to build non-tradable inflation from the GDP deflator of non-tradable sectors. Figures B.2 and B.3 plot the different inflation rates for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain between 1999q1 and 2023q4.



Note: The figure plots the year-on-year core inflation rate (i.e. HICP inflation with food and energy excluded) for each country that joined the EMU before 1999. Data is at quarterly frequency and comes from the OECD.

Figure B.2: Core Inflation by EMU11 country



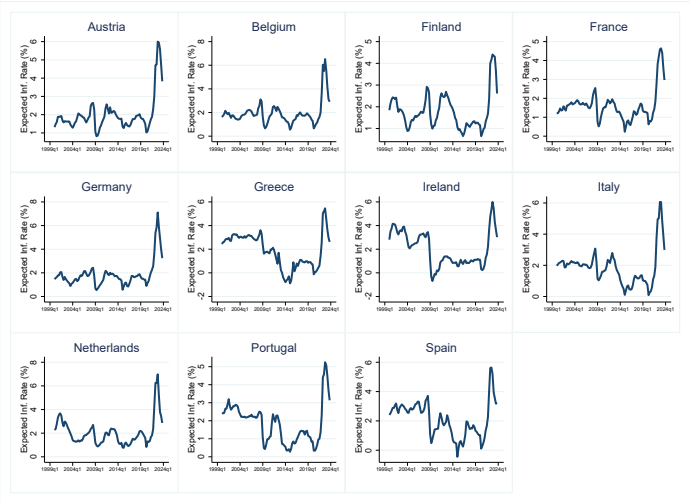
Note: The figure plots the year-on-year non-tradable inflation rate for each country that joined the EMU before 1999 (Luxembourg excluded). Data is at quarterly frequency and comes from Eurostat.

Figure B.3: Non-tradable Inflation by EMU11 country

B.3 Inflation Expectations

We use data from the ECB Survey of Professional Forecasters that provides information on expected level of CPI inflation in four quarters from now. Figure B.4 plots the different indexes for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands,

Portugal and Spain between 1999q1 and 2023q4.



Note: The figure plots the expected level of core inflation in one year for each country that joined the EMU before 1999 (Luxembourg excluded). Data is at quarterly frequency and comes from ECB Survey of Professional Forecasters.

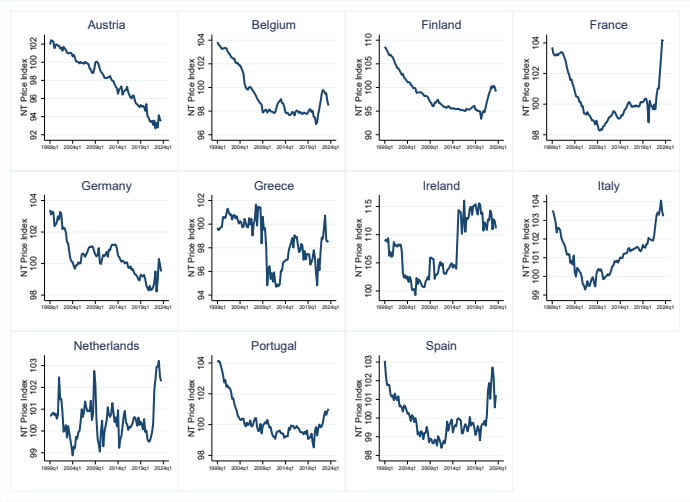
Figure B.4: Core Inflation Expectations by EMU11 country

B.4 Non-tradable Price Indexes by EMU11 country

The non-tradable price index is built using the GDP deflator for non-tradable as in Siena (2021). Data comes from Eurostat and is at quarterly frequency. Figure B.5 plots the different indexes for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain between 1999q1 and 2023q4.

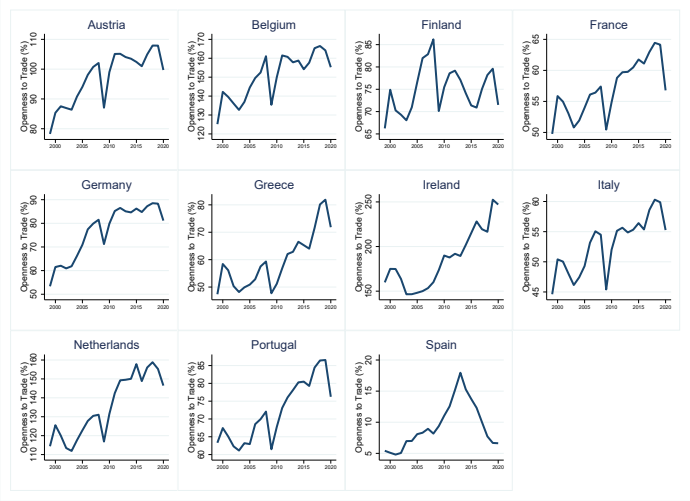
B.5 Openness to Trade

We use data from World Bank on World Development Indicators and build a common measure of openness to trade as the sum of total import and export, divided by GDP. Hence, we consider data for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. This group of countries, which joined the European Monetary Union prior to the introduction of the single currency (1999q1), is referred to as EMU11. This data is available only at yearly frequency. Figure B.6 plots the series for each country.



Note: The figure plots the non-tradable price index for each country that joined the EMU before 1999 (Luxembourg excluded). Data is at quarterly frequency and comes from Eurostat.

Figure B.5: Non-tradable Price Index by EMU11 country



Note: The figure plots the series for a measure of openness to trade (the sum of total import and export normalised by GDP) for each country that joined the EMU before 1999 (Luxembourg excluded). Data is at yearly frequency and comes from the World Bank.

Figure B.6: Openness to Trade by EMU11 country

B.6 Summary Statistics for GVC Participation, GVC Position and Openness to Trade

B.6.1 $GVC^{part.}$ and $GVC^{pos.}$

Our measures of GVC participation and position are at yearly frequency and come from Mancini *et al.* (2024a). Table B.1 below reports summary statistics for $GVC^{part.}$ and $GVC^{pos.}$. The sample is composed of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain for years between 1999 and 2018. It is important to note that this yearly-frequency data is merged with the quarterly-frequency panel dataset used in Section 4 without any specific interpolation. In other words, within each country and year, our GVC measures remain constant for four consecutive quarters. Using interpolation methods to transform the GVC series from yearly to quarterly frequency does not significantly change the results of our empirical analysis.

$GVC^{part.}$		$GVC^{pos.}$	
Mean	*Std.Dev*	*Mean*	*Std.Dev*
18.66	7.41	-0.03	0.06

Table B.1: Summary Statistics

B.6.2 $\Delta GVC^{part.}$ and $\Delta GVC^{pos.}$

Table B.2 reports summary statistics for $\Delta GVC^{part.}$ and $\Delta GVC^{pos.}$, i.e. the change in GVC participation and position experienced by each country in the sample between 2019 and 2020 due to the Covid-19 shock. The sample is composed of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain.

$\Delta GVC^{part.}$		$\Delta GVC^{pos.}$	
Mean	*Std.Dev*	*Mean*	*Std.Dev*
-6.01	2.74	-14.95	49.11

Table B.2: Summary Statistics

B.6.3 *Openness*

Table B.3 below reports summary statistics for *Openness*. The sample is composed of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal

and Spain for years between 1999 and 2018.

Openness	
Mean	*Std.Dev*
92.94	43.52

Table B.3: Summary Statistics

B.6.4 *Openness* vs GVC Measures

In Section 4.6, we study the role of GVC participation and position while also taking into account the role of openness to trade. Since openness can influence the role played by GVCs for a country, it is convenient here to check to which extent openness correlates with our GVCs measures in order to exclude the presence of strong collinearity among the main independent variables in the analysis of Section 4.6. To do this, we consider the average within country OLS correlation between openness to trade and GVC participation and position. Table B.4 shows results. While our measure of GVC position is not correlated with openness, there is a statistically significant (but relatively small) correlation between openness and GVC participation: when openness increases by 1 unit, GVC participation increases by 0.19.

	(1)	(2)
	$GVC_{part.}$	$GVC_{pos.}$
Openness	0.1940***	-0.0003
	(24.92)	(-1.27)

Note: $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. *Openness* is the sum of imports and exports divided by GDP. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses are clustered at country-level. *, **, *** indicate significance at 90%, 95% and 99%.

Table B.4: Average within-country correlation between Openness to Trade and GVCs measure

C Instrumental Variables Tests and Statistics

C.1 Statistics for Table 1 and 2

Here, we report statistics from the first-stage regressions underlying the results of Table 1 and Table 2 along with tests for the endogeneity of the instrumented variables.

For the estimation of the NKPC, we have 17 instruments (i.e. 4 lags of monetary policy shocks and their interactions along with the lag of aggregate inflation expectations for the EMU) for 5 endogenous variables. The first column of Table C.1 reports first-stage statistics for the NKPC (column (5) of Table 1). The instruments result sufficiently strong to instrument separately the unemployment gap and expected inflation (first row of Table C.1). As monetary policy shocks are common to all countries, they tend to be weak instruments. For this reason, we look at the Anderson-Rubin F-test for weak instrument robust inference which tells us that our set of IVs is sufficiently relevant for the NKPC, as the corresponding F-stat is 14.50 (second row of Table C.1). Along with this, we report also the Sargan-Hansen J-stat (with p-value in parenthesis) for the validity of the instruments: as we cannot reject the null hypothesis, we conclude that the monetary policy shocks are valid instruments. Finally, we report also the Hausman statistic for endogeneity of the instrumented variable: variables are indeed endogenous.

The second column of Table C.1 reports statistics from column (4) of Table 2 where we use internal instruments (i.e. the forth lag of the unemployment gap and all its interaction along with the moving average of past expected inflation). The instruments effectively explain the main endogenous variables and are overall relevant for the identifying equation (Cragg-Donald F-stat=47.20). No Sargan-Hansen J statistic is reported as, in this case, our model is perfectly identified (p.i.). The instrumented variables are weakly endogenous.

	(1)		(2)	
Instrument	MP		Int.	
	$\hat{u}$	$\mathbb{E}(\pi)$	$\sum_{s=1}^{4}\beta^s\hat{u}_{t+s}$	$\sum_{s=1}^{4}\beta^s p^{NT}_{t+s}$
F	22.34	21.99	302.65	146.69
Wald F-Stat	14.50		47.34	
Sargan-Hansen J	7.17 (0.96)		p.i.	
Hausman	25.51 (0.00)		6.97 (0.14)	

Table C.1: First-Stage Statistics of Table 1 and 2

C.2 Statistics for Table 3

Table C.2 reports statistics from column (1) of Table 3 where we use internal instruments (i.e. the forth lag of the unemployment gap and all its interaction along with the moving average of past expected inflation) to instrument the five endogenous variables. Hence, our model is perfectly identified (p.i.). The instruments effectively explain the main endogenous variables and are overall relevant for the identifying equation.

	(1)	
Instrument	Int.	
	$\sum_{s=1}^{4} \beta^s \hat{u}_{t+s}$	$\sum_{s=1}^{4} \beta^s p_{t+s}^{NT}$
F	302.04	454.71
Wald F-Stat	30.66	
Sargan-Hansen J	p.i.	
Hausman	239.40 (0.00)	

Table C.2: First-Stage Statistics of Table 3

C.3 Statistics for Table 4 and 5

The first column of Table C.3 reports first-stage statistics for the NKPC (column (1) of Table 4) when the endogenous variables are 6 and the instruments are 21 (i.e. 4 lags of monetary policy shocks and their interactions along with the lag of aggregate inflation expectations for the EMU). The instruments result sufficiently strong to instrument separately the unemployment gap and expected inflation (first row of Table C.1). As monetary policy shocks are common to all countries, they tend to be weak instruments. For this reason, we look at the Anderson-Rubin F-test for weak instrument robust inference which tells us that our set of IVs is sufficiently relevant for the NKPC. Moreover the Sargan-Hansen test and the Hausman test confirm respectively that our monetary policy shocks are valid instruments for the endogenous variables.

Column (2) of Table C.3 reports statistics from column (1) of Table 5 where we use internal instruments (i.e. the forth lag of the unemployment gap and all its interaction along with the moving average of past expected inflation) to instrument the 6 endogenous variables. In this case, our model is perfectly identified. Instruments explain well the main endogenous variables, and overall they are relevant instruments for the identifying equation.

	(1)		(2)	
Instrument	MP		Int.	
	$\hat{u}$	$\mathbb{E}(\pi)$	$\sum_{s=1}^{4}\beta^s\hat{u}_{t+s}$	$\sum_{s=1}^{4}\beta^s p^{NT}_{t+s}$
F	22.22	24.97	253.11	234.82
Wald F-Stat	18.30		38.36	
Sargan-Hansen J	9.37 (0.98)		p.i.	
Hausman	10.61 (0.03)		5.39 (0.06)	

Table C.3: First-Stage Statistics of Table 4 and Table 5

D Further Robustness Checks

D.1 Different measures of positioning

In this section, we test the robustness of our result to other measures of positioning. In particular, we use upstreamness and downstreamness measures, computed with data from the OECD Tiva Inter-Country Input Output tables. Upstreamness of a country, proposed by Antràs *et al.* (2012), measures the distance of its productions from the final demand. Farther a country is positioned within a GVCs from the final use, higher will be its measure of upstreamness. On the other hand, downstreamess of a country, see Antràs and Chor (2013), measures the distance of the country from the factors of production. Endogenous variables are instrumented as done Section 4.4.2. Table D.1 shows the results employing non-tradable inflation and looking both at upstreamness, columns (1) and (3), and downstreamness, columns (2) and (4). In column (3) and (4) we control also for the role of openness to trade. Previous results are confirmed. Participation to GVCs flattens the slope of the PC, while positioning does not statistically matter.

D.2 Controlling for past business cycles

In this section, we check whether our results are robust when controlling for the influence of business cycles on the PC. In particular, we follow Bernardini *et al.* (2020) and create a business cycle dummy $bc_{i,t}$ that takes value one in periods in which there is a contraction of GDP for at least two quarters in country i. Then we augment the econometric model 3 and 4 of Section 4.4 with $bc_{i,t-4}$ and $\hat{u}_{i,t} \times bc_{i,t-4}$ in order to check if past downturns have a contemporaneous effect on the level of inflation and on the relationship between inflation and unemployment. In the NKPC and in the regional PC, the interaction term is

	(1) π^{NT}	(2) π^{NT}	(3) π^{NT}	(4) π^{NT}
$\hat{u}$	-0.0352**	-0.0361**	-0.0348	-0.0361
	(0.0159)	(0.0164)	(0.0358)	(0.0270)
$\hat{u} \times GVC_{part.}$	0.0008***	0.0007***	0.0017**	0.0016**
	(0.0002)	(0.0001)	(0.0007)	(0.0007)
$\hat{u} \times GVC_{Antras}$	0.0038	0.0073	0.0029	0.0062
	(0.0096)	(0.0088)	(0.0263)	(0.0154)
$GVC_{part.}$	-0.4255***	-0.4717***	-0.6996**	-0.7509***
	(0.1134)	(0.0980)	(0.3005)	(0.2801)
GVC_{Antras}	-6.6198*	6.0049	-5.1311	4.7940
	(3.6227)	(3.9242)	(5.6683)	(8.3882)
$\hat{u} \times Openness$			-0.0001	-0.0002
			(0.0001)	(0.0001)
$Opennes$			0.0505	0.0579
			(0.0447)	(0.0466)
Observations	748	748	748	748
Country Fe	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Post GR break	Yes	Yes	Yes	Yes
Time Fe	Yes	Yes	Yes	Yes
IV	Int.	Int.	Int.	Int.
Antras Measure	Upstream	Downstream	Upstream	Downstream
Wald F-stat	57.66	74.44	50.40	53.30
Sargan-Hansen J	p.i.	p.i.	p.i.	p.i.
Hausman	261.25 (0.00)	278.70 (0.00)	6.29 (0.04)	6.01(0.05)

Note: The variable of interest in column (1) to (4) is non-tradable inflation. $\hat{u}$ is the 4-quarters discounted sum of future unemployment in deviation from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{Antra.}$ is respectively the index of *upstreamness* Antràs *et al.* (2012) and *downstream* Antràs and Chor (2013). *Openness* is the sum of imports and exports divided by GDP. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses are clustered at country-level. *, **, *** indicate significance at 90%, 95% and 99%.

Table D.1: $GVC_{pos.}$ from Antràs *et al.* (2012); Antràs and Chor (2013)

instrumented as done in Section 4.4.1 and in Section 4.4.2. Table D.2 shows results. Both for the New Keynesian and regional Phillips Curve, results do not substantially change from those of section 4.4: only GVC participation matters for the slope, no matter recent downturns that might have influenced the Phillips Curve or inflation dynamics.

	(1) π^{Core}	(2) π^{NT}
$\hat{u}$	-0.0494**	-0.0355**
	(0.0197)	(0.0139)
$\hat{u} \times GVC_{part.}$	0.0007**	0.0011***
	(0.0003)	(0.0003)
$\hat{u} \times GVC_{pos.}$	-0.1831	-0.0359
	(0.1772)	(0.0557)
$\hat{u} \times bc$	0.0027	0.0106***
	(0.0084)	(0.0036)
$GVC_{part.}$	-0.0717	-0.6744**
	(0.0620)	(0.2870)
$GVC_{pos.}$	-0.9479	12.1530
	(2.6535)	(20.6054)
bc	-0.1183	-4.0872**
	(0.1594)	(1.6725)
Observations	748	748
Country Fe	Yes	Yes
Controls	Yes	Yes
Time Fe	No	Yes
IV	MP	Int.
Wald F-test	11.58	37.64
Sargan-Hansen J	19.35 (0.50)	p.i.
Hausman	17.90 (0.00)	3.90 (0.14)

Note: The variable of interest is consumer price inflation from the OECD. $\hat{u}$ is the percentage deviation of the unemployment rate from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. Following Bernardini *et al.* (2020), bc indicates quarters of economic contractions. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses (clustered at country level for the regional Phillips Curve). *, **, *** indicate significance at 90%, 95% and 99%.

Table D.2: The role of business cycles

D.3 The Phillips Curve with producer price inflation

We repeat the analysis of section 4.4.1 with producer price inflation (π^{PPI}) as the dependent variable. π^{PPI} is the year-on-year percentage change of the producer price index from the OECD data warehouse. All other variables and instrumentation remain the same as described in section 4.4.1. Results are shown in Table D.3. Although the instruments are not strong, this exercise is important as it confirms the importance of participation to GVC for the slope of the PC also when looking directly at producer price dynamics.

D.4 Controlling for the interaction of $GVC_{part.} \times GVC_{pos.}$

Here, we continue the series of robustness checks introduced in Section 4.6 by adding the interaction term $GVC_{part.} \times GVC_{pos.}$ and $GVC_{part.} \times GVC_{pos.} \times \hat{u}$ to both the NKPC and the regional PC while controlling also for the role of openness to trade. This is an important control since it allows to study how the $GVC_{part.}$ ($GVC_{pos.}$) affects the slope of the PC for countries with similar level of $GVC_{pos.}$ ($GVC_{part.}$). The endogenous variables are instrumented as done in Section 4.4.1 and in Section 4.4.2. Table D.4 shows results.

As from column (1), the introduction of the interaction term does not alter the overall findings presented in Section 4.6: also when controlling for similar levels of $GVC_{pos.}$, only $GVC_{part.}$ significantly flattens the NKPC. Notably, the interaction term $GVC_{part.} \times GVC_{pos.} \times \hat{u}$ is not significant although the positive point estimate suggests that –when considering core inflation– countries with similar participation in GVCs could experience an extra-flattening of the NKPC if they are positioned more upstream.

As from column (2), we again find that only $GVC_{part.}$ has a significant effect on the slope of the regional PC. However, when considering non-tradable inflation, the interaction term $GVC_{part.} \times GVC_{pos.} \times \hat{u}$ –although not significant– has a negative point estimate. In other words, when considering non-tradable prices, countries with similar participation in GVCs could experience a mitigated flattening of the PC if they are positioned further upstream.

These results suggest that, while participation in GVCs significantly flattens the Phillips Curve, a higher position of a country within the GVC can further diminish the relationship between unemployment and core inflation, while potentially strengthening it for non-tradable inflation.

	(1) π^{PPI}
$\hat{u}$	-0.1587*
	(0.0935)
$\hat{u} \times GVC_{part.}$	0.0040***
	(0.0013)
$GVC_{part.}$	-0.5288
	(0.3850)
$\hat{u} \times GVC_{pos.}$	-0.8694
	(0.9023)
$GVC_{pos.}$	30.7100
	(18.9867)
Observations	748
Country Fe	Yes
Controls	Yes
Post-GR break	Yes
Time Fe	No
IV	MP
Wald F-test	3.55
Sargan-Hansen J	29.96 (0.02)
Hausman	15.58 (0.00)

Note: The variable of interest is consumer price inflation from the OECD. $\hat{u}$ is the percentage deviation of the unemployment rate from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses. *, **, *** indicate significance at 90%, 95% and 99%.

Table D.3: The NKPC with Producer Price Inflation

	(1) π^{Core}	(2) π^{NT}
$\hat{u}$	-0.0523***	-0.0313***
	(0.0201)	(0.0102)
$\hat{u} \times GVC_{part.}$	0.0069***	0.0016**
	(0.0026)	(0.0008)
$GVC_{part.}$	-0.0955**	-0.7670***
	(0.0381)	(0.2610)
$\hat{u} \times GVC_{pos.}$	-0.0206	-0.0360
	(0.1468)	(0.0756)
$GVC_{pos.}$	3.3506	9.8725
	(2.4897)	(22.2194)
$\hat{u} \times GVC_{part.} \times GVC_{pos.}$	0.0090	-0.0011
	(0.0097)	(0.0040)
$GVC_{part.} \times GVC_{pos.}$	-0.4085***	0.5964
	(0.1529)	(1.2046)
$\hat{u} \times Openness$	-0.0009***	-0.0001**
	(0.0003)	(0.0001)
$Openness$	0.0189***	0.0351
	(0.0049)	(0.0277)
Observations	748	748
Country Fe	Yes	Yes
Controls	Yes	Yes
Post-GR break	Yes	Yes
Time Fe	No	Yes
IV	MP	Int.
Wald F-Stat	10.78	29.26
Sargan-Hansen J	13.96 (0.95)	p.i.
Hausman	33.80 (0.00)	266.54 (0.00)

Note: The variable of interest in column (1) and (2) is respectively core and non-tradable inflation. In column (1), $\hat{u}$ is the percentage deviation of the unemployment rate from the NAIRU. In column (2), $\hat{u}$ is the 4-quarters discounted sum of future unemployment in deviation from the NAIRU. $GVC^{part.}$ is the share of gross output depending on connections with more than one country. $GVC^{pos.}$ is an index ranging from -1 to $+1$ and it expresses respectively whether a country is at the bottom or at the top of the GVC. *Openness* is the sum of imports and exports divided by GDP. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses. *, **, *** indicate significance at 90%, 95% and 99%.

Table D.4: Controlling for the interaction $GVC_{part.} \times GVC_{pos.}$ and openness to trade

D.5 Testing the role of openness to trade in the PC

In this section, we focus exclusively on the role of openness to trade. Following the methodology and identifying equations described in Section 4.4.1 and 4.4.2, we consider only

Openness and *Openness* $\times \hat{u}$ in the standard setup of the NK and regional PC. Table D.5 shows the results. As from column one, we immediately see that instruments for the NKPC are not valid. Hence, we focus on the regional PC. Under the usual instrumentation (forth lags of the endogenous variables), we find that openness to trade flattens the PC. Yet, when comparing this effect to that found in Section 4.4.2, we can conclude that the role played by GVC participation in the flattening of the regional PC is substantially stronger.

	(1) π^{Core}	(2) π^{NT}
$\hat{u}$	-0.0733**	-0.0240**
	(0.0294)	(0.0108)
Openness $\times \hat{u}$	-0.0000	0.0001***
	(0.0001)	(0.0000)
Openness	0.0096	-0.0788**
	(0.0065)	(0.0372)
Observations	748	748
Country Fe	Yes	Yes
Controls	Yes	Yes
Time Fe	No	Yes
IV	MP	Int.
Wald F-Stat	1.57	108.34
Sargan-Hansen J	2.99 (0.99)	p.i.
Hausman	28.41 (0.00)	7.85 (0.09)

Note: The variable of interest in column (1) and (2) is respectively core and non-tradable inflation. In column (1), $\hat{u}$ is the percentage deviation of the unemployment rate from the NAIRU. In column (2), $\hat{u}$ is the 4-quarters discounted sum of future unemployment in deviation from the NAIRU. *Openness* is the sum of imports and exports divided by GDP. The sample is composed of all countries that joined the EMU before 2002 (Luxembourg excluded). Data is quarterly and spans from 2002q1 until 2018q4. Standard errors in parentheses (clustered at country level for the regional Phillips Curve). *, **, *** indicate significance at 90%, 95% and 99%.

Table D.5: The Role of Openness to Trade