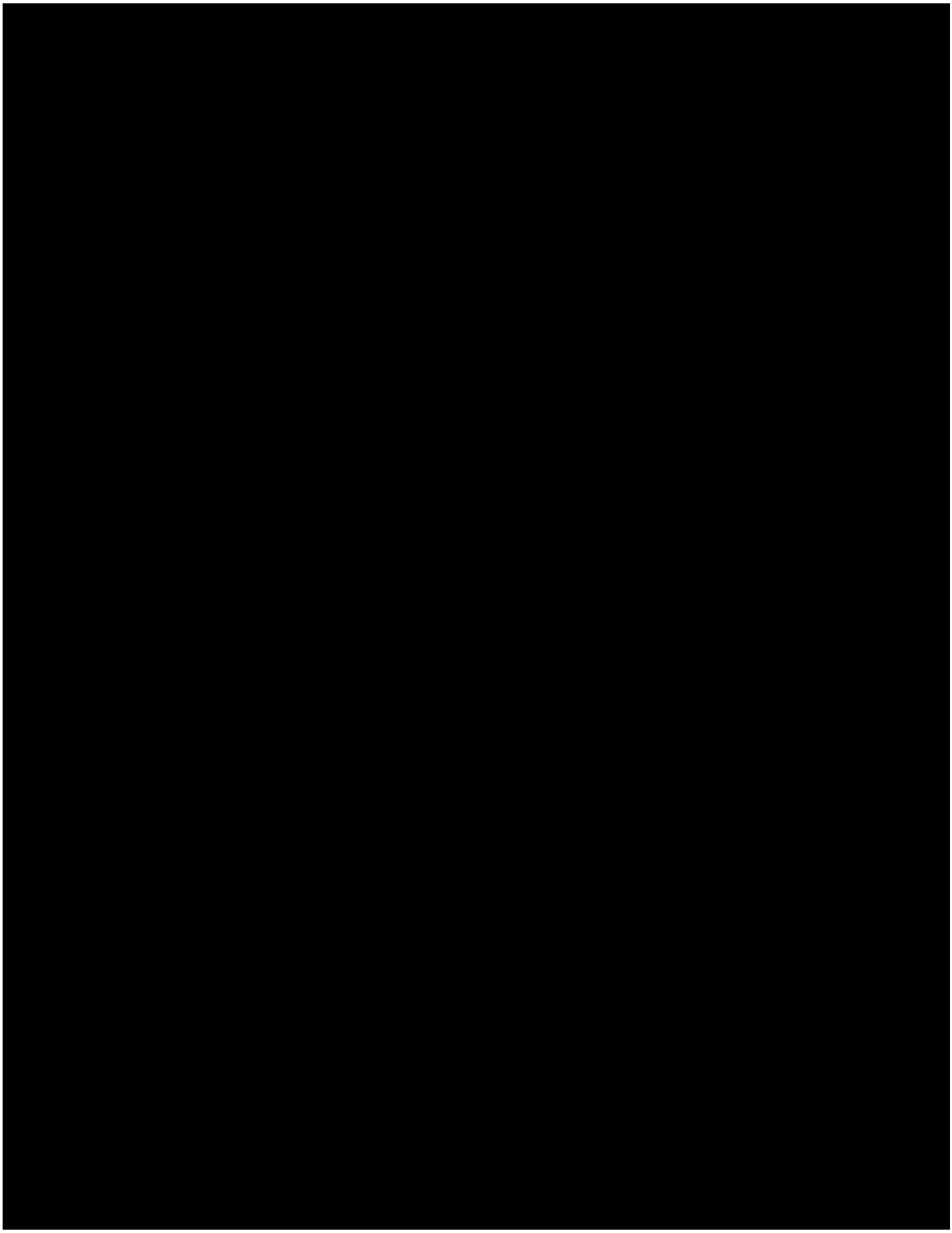


 WP/20/190

IMF Working Paper

Middle East and Central Asia Department

Intangible Investment and Low Inflation: A Framework and Some Evidence[1]

Prepared by Subir Lall and Li Zeng

September, 2020

Abstract

Intangible investment is growing as a share of economic activity. We present a simple framework incorporating its distinguishing characteristic of generally greater scalability and lower marginal costs than tangible investment. We show evidence that this may have contributed to more elastic aggregate supply in recent years, which is consistent with lower inflation and a flattening of the Phillips curve. This framework also highlights the channels through which technological change, a large constituent of intangible investment, may be leading to wage stagnation and greater market concentration.

JEL Classification Numbers: E22, E31, O34, D40

Keywords: Technological change, inflation, unemployment, market concentration.

Author's E-Mail Address: SLall@imf.org; LZeng@imf.org

[1] We thank Jihad Azour, Bas Bakker, Selim Elekdag, Nikoloz Gigineishvili, Javier Hamann, Michelle Hassine, Deniz Igan, Mico Mrkaic, S. Sankaraguruswamy, Yu Shi and seminar participants at the IMF.

Contents

I. INTRODUCTION

Following the Global Financial Crisis (GFC) of 2007-08, there has been a lively debate among economists about a number of prominent features of the subsequent recovery. An important question for macroeconomists and policymakers has been why despite the massive macroeconomic stimulus that was injected at the time, many economies have struggled to achieve their inflation goals even as full employment was eventually restored. While monetary policy remained highly accommodative across most advanced economies, inflation remained largely below (or near) the target despite full employment and closed output gaps.[2] A related question is why despite historically low unemployment, wage pressures did not emerge in any significant way. This has sometimes been linked to the declining bargaining power of labor, the increasing concentration and monopolistic positions of firms in both "tech" and "non-tech" sectors, and structural changes that have led to redistribution of income from capital to labor.

In this paper, we present a simple framework to argue that the rise of intangible investment across advanced—and increasingly emerging—economies can plausibly explain many macroeconomic relationships observed over the past decade. For purposes of this analysis, intangible investment refers to the nonphysical investment in the production of economic output. While software is a prominent and well-known example of intangible investment, other examples such as branding, production and managerial processes, and training also have a meaningful impact on the functioning of the economy. This type of investment is becoming a rising share of total investment and in some economies already exceeds the share of tangible investment.

We focus on the properties of intangible investment that are different from conventional tangible investment (for example, "plants and equipment" or hardware) and that can modify the conventional understanding of macroeconomic equilibria and shocks. We argue that the underlying structural changes that intangible investments embody, while in train since at least the 1990s, are still at an early stage of transforming economies. Despite that these changes are still at an early stage both within and across countries, we present both time series and panel data evidence that the rise of intangible investment is already having a measurable impact on macroeconomic relationships. In particular, this paper's conceptual and empirical focus is on the changing relationship between output, inflation and unemployment. The paper also discusses the implications of the conceptual framework on understanding inequality and wage stagnation, the rise of monopolistic power, financing investment, and taxation of investment, which is the focus of parallel work.

This paper is structured as follows. The next section describes a few economic phenomena that have puzzled economists and policymakers over the past decade and the related literature.

[2] The analysis in this paper refers to the period prior to the onset of the Covid-19 pandemic of 2020.

Section III uses the simple Aggregate Supply-Aggregate Demand (AS-AD) framework to illustrate how persistently low inflation would be represented in such a framework and argues that a more elastic aggregate supply curve than in the past would be conceptually consistent with the empirical observations. Section IV provides more rigorous empirical support to the proposition that aggregate supply curves may be more elastic than is traditionally assumed. The subsequent section discusses the rise of intangible investment and the unique properties that differentiate it from tangible investment. Section VI provides empirical evidence supporting the paper's main thesis that intangible investment can help explain low inflation. The final section discusses some addition implications of the proposed framework and topics of parallel research.

II. A Few Important Macroeconomic Puzzles

A major economic question since the global financial crisis has been about the causes underlying low inflation. Even as output gaps closed since the crisis and unemployment recovered to record low levels prior to the onset of the Covid-19 related downturn in 2020, inflation in some cases remained stubbornly below the pre-crisis norm of advanced economies and central banks' target. More recently, emerging markets also began to experience low inflation.[3] Explanations regarding low inflation have focused on demographic changes, technological changes, globalization, the expansion of central bank independence and inflation targeting, as well as Fisherian low interest rate-low inflation relationships.[4] A related strand of the literature has tried to explain the breakdown of the relationship between unemployment and inflation since the 1990s.[5] This literature has not achieved consensus on the causes for the so-called flattening of the Philipps curve, and consequently little guidance for the likely relationship in the future.

In terms of explanations for why technological progress in particular leads to lower inflation, numerous explanations have been offered. Then Federal Reserve Chairman Alan Greenspan in congressional testimony suggested that technological progress has suppressed unit labor costs and increased productivity (2005). In general, the discussion of technology has centered around three aspects: the price of information and communication technology (ICT) inputs has declined, leading to a decline of overall inflation due to the weight of ICT in the index; technology has had an impact through competition and market structure due to the ability to compare prices worldwide instantaneously and transparently; and technological change suppresses wage

[3] See Ha, Kose and Ohnsorge (2019) for a comprehensive review of the experience of emerging and developing economies.

[4] Sanchez and Kim (2018) discuss several hypotheses put forward in the literature and policy discussions including notably that technological progress may have helped lower inflation by suppressing unit labor costs and elevating productivity growth. Other explanations they discuss include demographic transition, globalization, the expansion of central bank independence and inflation targeting, and a Fisherian low interest rates-low inflation nexus.

[5] See Gagnon and Collins (2019) for a discussion and a review of the main hypotheses for why the Phillips curve relationship may appear to have broken down.

growth.[6] One shortcoming with these explanations is that no single good theoretical framework has emerged on why technological progress has had such a big impact on inflation, even as its impact on productivity and output growth remains elusive.

The suppression of wage growth across many countries over past decades has been associated with high and rising inequality in both advanced and emerging economies. This has been increasingly linked to technological change in empirical studies.[7] Other explanations for rising inequality included the weaker bargaining power of labor[8], the rise of artificial intelligence and automation[9]. Moreover, explanations including weaker bargaining power of labor are highly plausible for a range of countries, but the deeper underlying systematic driver of this reduced power remains less clear i.e. possibly due to country-specific legislation, ability of firms to shift production offshore, or the threat of substituting human labor with technology.

In summary, while low inflation, an increasing disconnect between unemployment and inflation, and high and rising inequality are well established, incorporating the structural changes in economies that lead to this outcome in a simple stylized macroeconomic framework that would apply to a broad group of economies have proved elusive.[10] The next section attempts to illustrate how persistently low inflation might conceptually present itself in a macroeconomic framework that also allows for shocks.

III. CAN THE AS-AD FRAMEWORK STILL EXPLAIN LOW INFLATION?

Counter-cyclical macroeconomic policies can often be well interpreted under the simple and standard AS-AD framework (Figure 1). In this framework, the ideal equilibrium for the economy is point E^*, where the vertical long-term supply curve LS, which indicates the potential output Y^*, intercepts with both the downward sloping aggregate demand (AD) curve and the upward sloping short-term aggregate supply (AS) curve. A large negative aggregate demand shock

[6] Lv, Liu and Xu (2019) find evidence that technological progress and globalization have helped reduce inflation in the United States. Autor et al link the rise of superstar firms to wage suppression.

[7] Jaumotte, Lall and Papageorgiou (2008, 2013) find that globalization had much less of a role to play than earlier studies had suggested. Instead, technological change can exacerbate inequality by increasing the wages of those with complementary skills much more tangibly.

[8] Bental and Demougin (2010) demonstrate how the institutional design of labor market bargaining can reduce the labor share of national income. Stansbury and Summers (2020) explain sluggish wage growth, lower inflation and a declining share of labor income in the United States through reduced worker power which they estimate using a rent-sharing parameter between workers and shareholders.

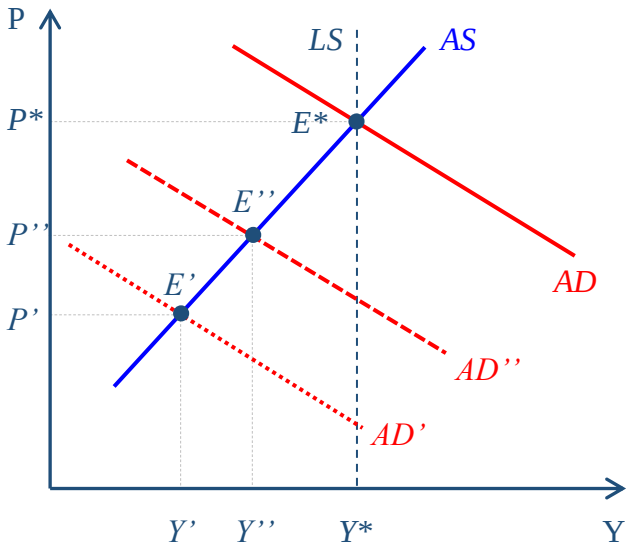
[9] Leduc and Liu (2019) find evidence of automation contributing substantially to the decline in the share of labor income in the United States.

[10] Farhi and Gourio (2018) extend a neoclassical growth model and using US data identify a role for monopoly power in explaining some of these trends in the United States.

would knock the economy into recession (*E'*), where output (*Y'*) and price (*P'*) both fall far below the potential or target levels. In this situation, counter-cyclical macro measures, including loose monetary policy and/or fiscal stimulus, would help to lift the economy out of recession by boosting the aggregate demand. If the economy only goes partially back (*E''*) towards the long-term equilibrium, it is often an indication of continued needs for accommodative macro policy support.

Persistent low inflation, however, has been a puzzling inconsistency between the AS-AD model and many economies' actual experience in recent years. Figure 1 suggests that, when the economy recovers from a severe downturn, inflation should rise back to its pre-crisis equilibrium level as growth approaches the potential. Nonetheless, what happened in many countries since the GFC is that, while stimulus measures have helped to narrow or even close the negative output gap, inflation has remained stubbornly low. Some researchers worry that macro economics has entered an uncharted territory, with important discussions such as whether inflation targeting is still an appropriate policy framework left unanchored.

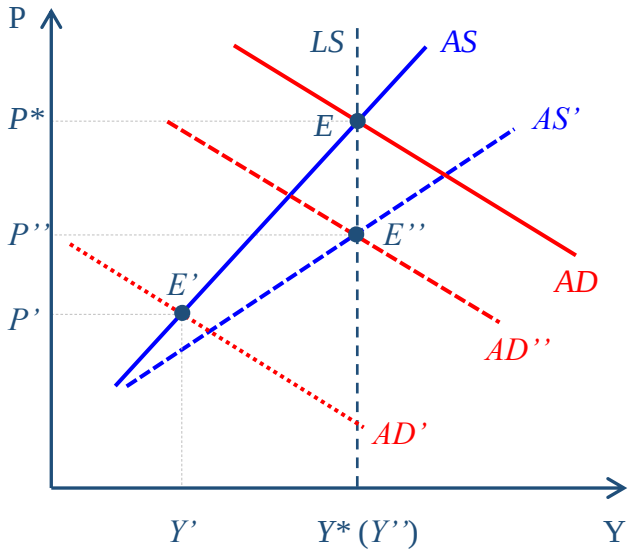
Figure 1. The AS-AD Framework



Is the AS-AD framework really outdated? No. In fact, its discrepancy with the recent reality can be largely reconciled with a simple tweak: supply side changes. In Figure 2, in addition to (a) the initial shock that shifted the aggregate demand from *AD* to *AD'* and (b) the subsequent policy stimulus that pushed it back to *AD''*, it is also assumed that the aggregate supply curve has flattened in the meanwhile, from *AS* to *AS'*. With this modification where the economy's short term supply function is more elastic, price level *P''* would remain well below its pre-crisis equilibrium *P**, even when the output gap is fully closed—*Y''* is the same as *Y**.

Introducing supply side changes not only helps the AS-AD model better fit reality, but also brings profound policy implications. While the dynamics illustrated in Figure 1 cannot square persistent low inflation with a closed output gap, adding supply side changes solves the puzzle, at least theoretically. The natural questions to ask next would be: (a) whether the short-term AS curve has indeed become more elastic in recent years; and (b) if so, what the underlying driving factors have been. Before empirically addressing these questions, however, it is worth first highlight some key policy implications of the adjusted AS-AD analysis:

Figure 2. The AS-AD Framework with Flattened AS Curve



1) Low inflation could be a new long-term equilibrium. Note that in Figure 2, *E''* is not only the intersection of the AD curve *AD''* and the short-term AS curve *AS'*, but also their intersection with the long-term aggregate supply curve *LS*. This suggests that, rather than indicating slack or imbalance in the economy, the lower price level *P''* is a new long-term equilibrium.

2) A path of stagnation to inflation target? The analysis does not directly answer the question whether the inflation target, set at *P**, is still a proper policy anchor, but it does shed more light on likely paths through which the economy could hit the inflation target.

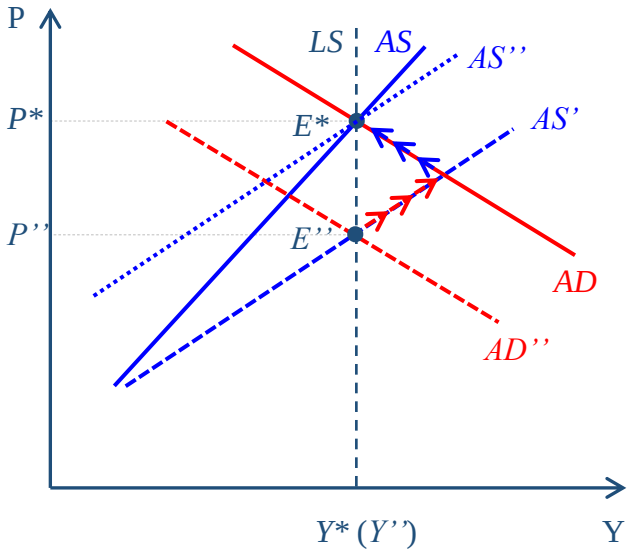
   The path illustrated in Figure 3 has two phases, the *expansion* indicated by the red arrows and the *stagnation* indicated by the blue arrows. At *E''*, since inflation is still below the target level, committed policy makers will continue with supportive measures, which not only pushes growth beyond the potential but also leads to higher inflation (*expansion*). If the policy makers have perfect foresight, policy stance should turn neutral once the aggregate demand curve reaches *AD*. What happens next is that, as growth stays above the potential and as near-term price rigidity diminishes over time, inflation will gradually rise to the target level *P** while the aggregate supply curve shifts from *AS'* to *AS''*. At this stage following the *expansion*, inflation will keep rising but growth will slow (*stagnation*).

   This contrasts Figure 1 where the economy from *E''* would reach the inflation target through continued expansion – rising inflation accompanied by faster growth.

3) Achieve the inflation target yet avoid stagnation? There are indeed such possibilities, for instance, the path shown in Figure 4. If potential growth rises to $Y^{\#}$, either due to the flattening of the AS curve or not, continued policy support could eventually move the AD curve from *AD''* to $AD^{\#}$. In this case, the new long-term supply curve $LS^{\#}$, the AD curve $AD^{\#}$ and the short-term AS curve *AS'* will together settle the economy at the new long-term equilibrium $E^{\#}$, with target level of inflation *P** but higher growth $Y^{\#}$ than before.

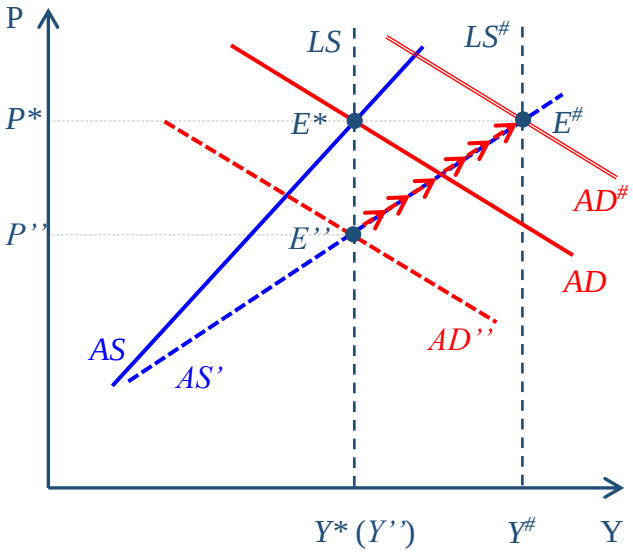
The different likely paths to achieving inflation target highlights a critical judgement for policy makers, that is, whether and how potential growth has changed over time. We will defer further discussions on this, including the consequence of misjudgment, to the final section where we revisit policy issues while also considering the empirical findings presented in the next two parts.

Figure 3. Likely Path to Inflation Target: *Stagnation*



The initial aggregate demand shock was omitted for clarity.

Figure 4. Likely Path to Inflation Target: *Higher Potential Growth*



The initial aggregate demand shock was omitted for clarity.

IV. Empirical Support for More Elastic Aggregate Supply

The previous section demonstrates that by introducing a "flatter" AS curve, the AS-AD framework resolves a major puzzle observed in recent years, that is, persistent low inflation along with a narrowed or even closed output gap. Such an adjustment to the model is more than a theoretical tweak but, as shown below, captures actual macro development in many economies.

There is a large literature documenting the flattening of the Phillips curve, which is closely associated with a flattened AS curve in the AS-AD framework.[11] An influential study is IMF (2013). It finds that the slope of the Phillips curve has gradually flattened over the past several decades across a large sample of advanced economies. An earlier study, IMF (2006), is another cross-country study showing that sensitivity of prices to domestic economic cycle has declined over time. It suggests globalization as an important a driver underlying such developments. There have also been studies looking at individual economies, for instance, Blanchard (2016) and Ball and Mazumder (2010) focus on the US economy, while Iakova (2007) discusses the likely implications for UK monetary policies.[12]

It should be pointed out that the discussions surrounding the flattening of the Phillips curve have not been unequivocally settled. There are still counterarguments, often resting on the endogeneity among economic development, market expectations and macroeconomic policies, arguing that the Phillips curve has not flattened. A notable paper is McLeay and Tenreyro (2019). Aside from the degree of the AS curve flattening, no consensus has been reached either regarding the timing of the flattening and what might have been the underlying drivers.

Rather than attempting to settle this debate, the evidence below is intended to highlight the empirical relevance of a flattened AS curve given its policy significance.

- A visual illustration

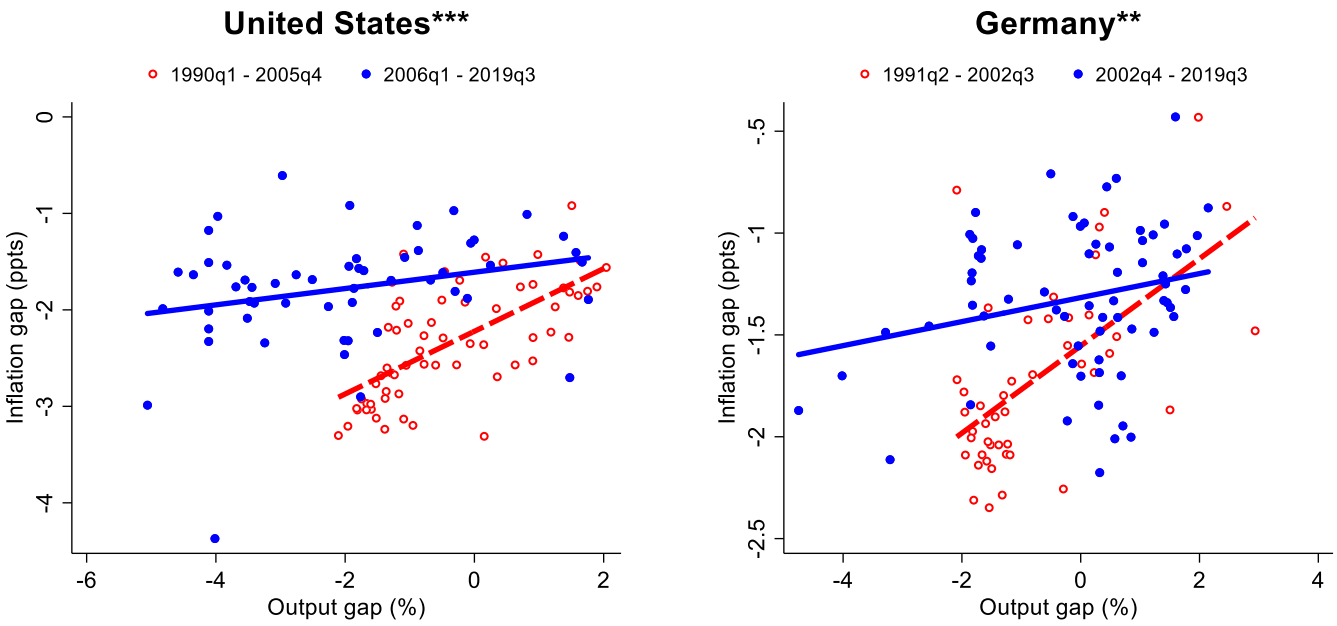
Figure 5 plots the inflation gap in the US and Germany against their respective output gap.[13] In both economies, the AS curve for the 1990s and early 2000s (the red dash line) was clearly steeper than the one for the latter period of the sample (the blue line). Similar charts for a larger set of countries are presented in Figure 6. While not universally the case (for instance, Japan and Mexico are two exceptions), a flattened AS curve to varying degrees is indeed observed in most economies.

[11] The conventional Phillips curve describes the negative relationship between wage inflation and unemployment. Assuming a stable Okun link between output growth and unemployment, the flattening of the Phillips curve then translates into a flatter AS curve in the AS-AD model. Since Roberts (1995) introduced the New Keynesian Phillips Curve (NKPC), there have also been many studies using such output-based variant of the Phillips curve, providing direct evidence on the flattening of the AS curve.

[12] Some other notable studies include: Roberts (2006)), Mishkin (2007), Kuttner and Robinson (2010), Coibion, Gorodnichenko and Koustas (2013), and Abbas, Bhattacharya and Sgro (2016). For a more complete survey of the literature, please see "The Formation of Expectations, Inflation and the Phillips Curve", Coibion, Gorodnichenko and Kamdar (2018).

[13] In this paper, we define Inflation gap = current inflation – long-term Consensus inflation forecast.

Figure 5. A visual illustration - The flattening of the AS curve



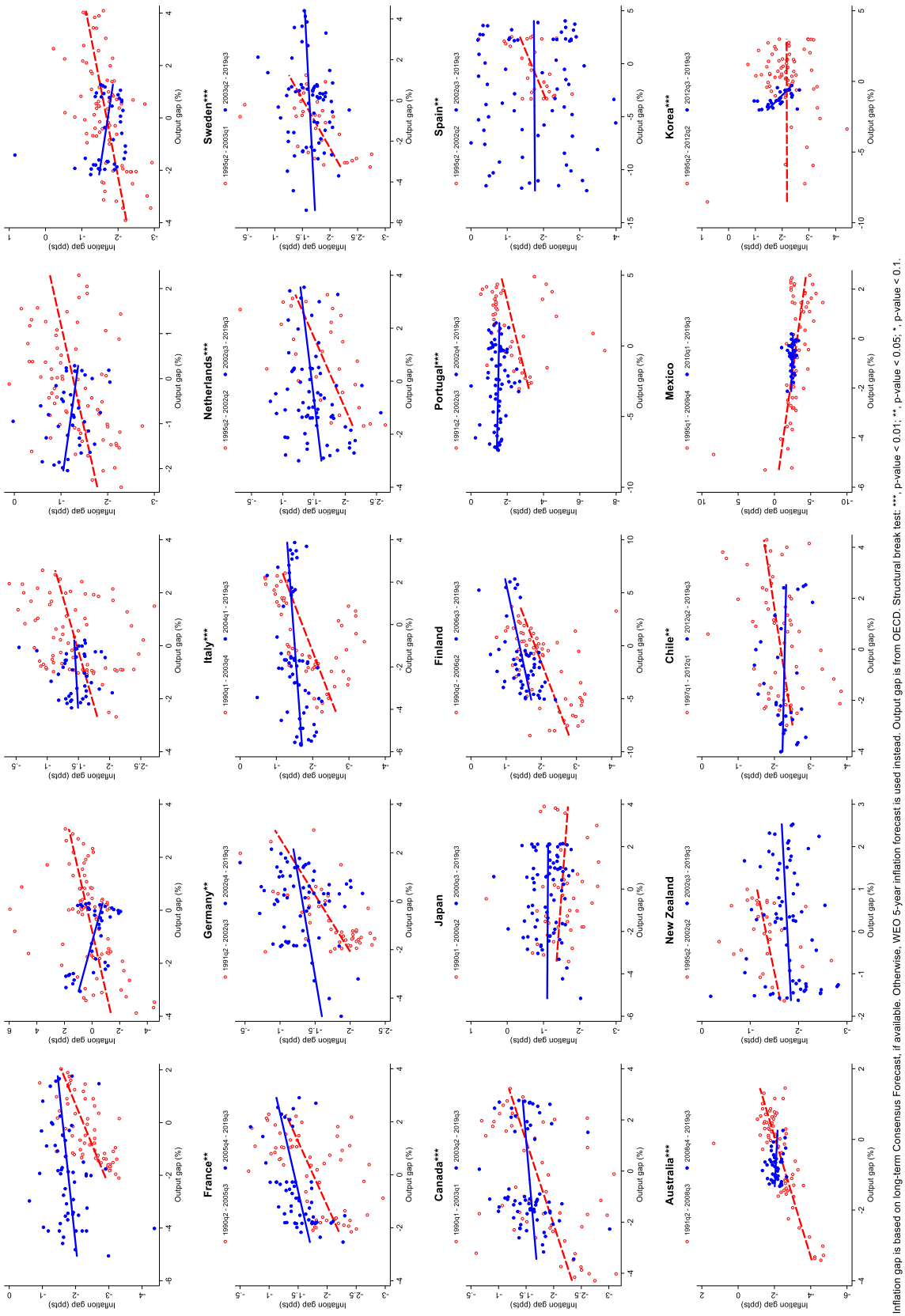
- With more econometric rigor

The regression and structural break test results underlying Figure 6 are presented in Table 1. Besides what is already visually clear, there are a couple of points to note:

- The flattening of the AS curve is statistically significant in most countries. In most cases (16 out of 20), the slope of the AS curve was positively significant in the first subsample period. It became smaller in the latter period or even turned negative in some cases, although none of the negative slope was significant. The flattening of the AS curve was statistically significant in 14 cases.

- The "structural breaks" in the AS curve were not synchronized across countries. In Figure 6, the break point for each economy is selected to maximize the difference in the AS curve slope for the two subsample periods. These break points vary across countries: While some of them coincided with the GFC, for instance, in the US and Australia, most of them did not. This is consistent with what will be discussed in the next section: Two major drivers of the flattening of the AS curve, in our view, are (a) globalization and (b) the rising importance of intangible capital in production. Both are long-term processes that did not take place in all countries at the same time or to even degrees.

Figure 6. A Visual Illustration: Flattening of the AS Curve



Inflation gap is based on long-term Consensus Forecast, if available. Otherwise, WEO 5-year inflation forecast is used instead. Output gap is from OECD. Structural break test: ***, p-value < 0.01; **, p-value < 0.05; *, p-value < 0.1.

Table 1. Structural break test on the flattening of the AS curve (a)

IFS code	Country	Before break	After break	P-value	Break point	Sample start	Sample end
111	**USA**	0.321***	0.081**	0.00	2005q4	1990q1	2019q3
112	**GBR**	0.441***	-0.521	0.00	2009q4	1990q1	2019q3
122	AUT	0.121***	0.021	0.29	2009q2	1990q2	2019q3
124	**BEL**	0.221***	-0.141	0.00	2009q3	1991q2	2019q3
128	**DNK**	0.141***	-0.111	0.00	2009q4	1990q2	2019q3
132	**FRA**	0.211***	0.111***	0.07	2005q3	1990q2	2019q3
134	**DEU**	0.211***	0.061**	0.03	2002q3	1991q2	2019q3
136	**ITA**	0.221***	0.041***	0.00	2003q4	1990q1	2019q3
138	**NLD**	0.191***	0.051**	0.01	2002q2	1995q2	2019q3
144	**SWE**	0.211***	0.021	0.00	2003q1	1995q2	2019q3
156	**CAN**	0.151***	0.041	0.01	2003q1	1990q1	2019q3
158	JPN	-0.041	0.001	0.82	2000q2	1990q1	2019q3
172	FIN	0.111***	0.071***	0.24	2006q2	1990q2	2019q3
182	**PRT**	0.191**	-0.021	0.01	2002q3	1991q2	2019q3
184	**ESP**	0.121***	0.001	0.02	2002q2	1995q2	2019q3
193	**AUS**	0.591***	-0.101	0.00	2008q3	1991q2	2019q3
196	NZL	0.181	0.051	0.42	2002q2	1995q2	2019q3
228	**CHL**	0.111***	-0.021	0.03	2012q1	1997q1	2019q3
273	MEX	-0.481	-0.111	0.10	2009q4	1995q1	2019q3
542	KOR	0.001	-0.531	0.00	2012q2	1995q2	2019q3

- Robustness check

The regression results with control of import prices (Table 2) are slightly stronger. Controlling import price inflation follows the literature to address the concern that, the volatility in headline inflation could at times be mainly driven by prices of imported commodities such as oil, instead of the domestic economic situation. Out of the 20 countries, 17 (compared with 16 in Table 1) now had positive and significant AS curve slope in the early subsample, and all of them showed significant flattening in the latter period (compared with 14 cases in Table 1).

The overall picture using alternative inflation and output gap measures stayed the same qualitatively, although the results for some individual economies were less robust. The baseline estimates used the output gap information from the OECD. For robustness check, the output gap from the WEO database was used as an alternative. The inflation gap in the baseline was computed based on the Consensus long-term forecast. Additional robustness tests were performed using the WEO 5-year inflation forecast.

Table 2. Structural break test on the flattening of the AS curve (b)

IFS code	Country	Before break	After break	P-value	Break point	Sample start	Sample end
111	**USA**	0.311***	0.041	0.00	2001q1	1990q1	2019q3
112	**GBR**	0.441***	-0.391	0.00	2009q4	1990q1	2019q3
122	**AUT**	0.091*	-0.141	0.00	2009q3	1990q2	2019q3
124	BEL	0.101	-0.151	0.02	2009q3	1991q2	2019q3
128	**DNK**	0.161***	-0.121	0.00	2009q1	1990q2	2019q3
132	**FRA**	0.191***	0.071***	0.02	2004q4	1990q2	2019q3
134	**DEU**	0.141***	-0.021	0.00	2009q1	1992q1	2019q3
136	**ITA**	0.251***	0.011	0.00	2004q1	1990q1	2019q3
138	**NLD**	0.181***	0.001	0.00	2002q2	1995q2	2019q3
144	**SWE**	0.221***	0.011	0.00	2003q1	1995q2	2019q3
156	**CAN**	0.151***	0.041	0.01	2001q2	1990q1	2019q3
158	JPN	-0.091	-0.041	0.53	2001q2	1990q1	2019q3
172	**FIN**	0.111***	-0.041	0.00	2009q4	1990q2	2019q3
182	**PRT**	0.251***	-0.031	0.00	2002q2	1991q2	2019q3
184	**ESP**	0.121***	0.001	0.04	2002q2	1995q2	2019q3
193	**AUS**	0.611***	-0.081	0.00	2008q3	1991q2	2019q3
196	**NZL**	0.401***	0.051	0.01	2002q2	1995q2	2019q3
228	**CHL**	0.131***	-0.021	0.01	2012q1	1997q1	2019q3
273	MEX	-0.311	-0.141	0.52	2009q4	1995q1	2019q3
542	**KOR**	0.061*	-0.521	0.00	2012q2	1995q2	2019q3

V. CAN INTANGIBLE INVESTMENT EXPLAIN THE AS CURVE FLATTENING?

Intangible investment is nonphysical investment undertaken by firms or the state in order to produce products. In their groundbreaking discussion of intangible investment and its impact on the economy, Haskel and Westlake (2018) (henceforth HW) cite examples of intangible investment that includes: software; databases; research and development; exploration; the creation of entertainment, literary or artistic originals; design; training; market research and branding; and business process reengineering. In contrast, prominent examples of tangible investment include Information and Communication Technology equipment such as computer hardware, as well as machinery and equipment. Based on this definition, there is significant overlap but not a complete mapping between what is referred to as "technological change" and "intangible investment." For example, while software is intangible investment, computer hardware or communications equipment is not. This is an important distinction in terms of the investment's economic properties. Thus, while the concept of intangible investment includes some aspects of technology, it excludes others. This distinction is, as will be discussed below, economically meaningful.

The key properties that Haskel and Westlake argue distinguishes intangible investment from tangible investment are sunkenness, scalability, synergies and spillovers. The key features are discussed below in brief with some examples, but HW provides a more detailed explanation and elaborate examples:

(a) Sunkenness: Intangible investments usually imply heavy sunk costs. That often derives from the fact that this type of investment is highly customized, and does not produce tangible standardized assets that could be sold off in a liquid secondary market. Often intangible investment is custom-produced for a very specific purpose and not easily sold (such as a brand).

(b) Scalability: Due to their nonphysical nature, intangible assets can be in more than one place at the same time. Just because they are being employed in one firm or production process does not preclude their being employed in another one. This makes intangible investment more scalable than tangible investment which cannot be as easily replicated.

(c) Synergies: Intangible investment often combines with other tangible and intangible investment to produce greater efficiencies or indeed new products. This is often seen in technology, such as when the combination of newly developed smartphones and apps can create new products such as ride-sharing. Similarly, investment in information technology by airlines has allowed for better price discrimination in airline seats and improving aircraft utilization.

(d) Spillovers: Many intangible assets are non-rivalrous in nature and also non-excludable. As a result, they often generate spillovers. Design is an example of such an investment that can near-simultaneously benefit many producers of similar products. Training is another example where the benefits may be felt widely even though the initial investment may take place in one firm.

HW argue that these properties have important economic consequences. While their focus of their analysis is on longer term consequences for how economies evolve, we instead focus on how intangible investment affects the short-term macroeconomic characteristics of an economy. This paper argues that the growing role of intangible investment—including but not restricted to that part of technological innovation that is intangible—is crucial to understanding how economies react to short-term fluctuations in demand and supply.

We focus on one property in particular of intangible capital, which is its scalability i.e. it can be deployed in two places or more for very little additional cost in order to produce more economic output. That is crucial to understanding that the marginal cost of an additional unit of intangible capital is lower than that for tangible capital. From an economist's perspective, it means that while the fixed cost of intangible investment is high, its but marginal cost is low.[14] Recalling that

[14] W. Brian Arthur (1996) pioneered the concept that knowledge-based sectors often exhibit increasing returns to scale. The scalability of intangible investment can be seen in this context as both a refinement and a broadening of his seminal insight.

the marginal cost translates into a firm's supply curve, with the same total cost, the firm that has more intangible investment will have a lower marginal cost. If more firms in the economy have these attributes, then aggregate supply in the economy would be expected to become more sensitive to prices i.e. more elastic.

VI. What Have Been Driving the Flattening of the AS Curve?

Section III argues that considering supply-side changes makes the AS-AD framework more flexible, which helps to reconcile the simultaneous observations of a closed output gap and lower inflation. Section IV provides empirical evidence that the AS curve has indeed flattened over time in many countries. In this section, we demonstrate that higher intangible investment is indeed associated with greater elasticity of an economy's aggregate supply function. This paper relies on the database on intangible investment developed by Corrado, Hulten and Sichel (2005, 2009), who pioneered the estimation of intangible investment starting with the United States in 2005.

Empirical evidence shows that globalization and rising importance of intangible capital can help to explain the flattening of the AS curve. The sample of this study covers all countries with available information from the Intangible Capital Database with the exception of Greece.[15] In the regressions presented below, the dependent variables are time series of the AS curve slope, estimated for each individual country using a 40-quarter rolling window. To test the robustness of the results, two measures of the AS curve slope are used, one with and the other without control for import price inflation in the estimation. The analysis first looks at the effects of the two macro trends separately for each individual economy. It then, still for each individual economy, considers the two factors simultaneously. The last part of the empirical analysis looks at cross-country evidence using panel regressions.

1) The higher the degree of global integration, the flatter the AS curve

In most countries, a higher degree of integration with the global economy is clearly associated with a flatter slope for the AS curve. In Table 3, the degree of globalization is proxied by each country's trade openness, that is, the ratio between total exports and imports of goods and services and GDP. Most of the estimated coefficients for trade openness are negative and significant. The only exceptions are Denmark and France, for which the coefficients are still negative, but insignificant. For the UK, the estimated coefficients are both negative as well, but only significant in one of the two specifications. To ensure the results were not simply driven by the GFC episode, all the regressions reported in Tables 3 to 6 were also estimated with observations from the 2008-09 period excluded. The results were either qualitatively the same or even stronger in some cases.

[15] The data is available at INTAN-invest website. Please see Corrado, Haskel, Jona-Lasinio and (2016) for more detailed introduction.

Table 3. The impact of trade openness on AS curve slope

AS curve slope without control for import price inflation

Countries	AUT	BEL	DEU	DNK	ESP	FIN	FRA	GBR	ITA	NLD	PRT	SWE	USA
Trade openness	-0.61***	-0.77***	-0.57***	-0.09	-1.03***	-0.31***	-0.25	-1.04***	-1.33***	-0.36***	-1.17***	-0.64***	-2.36***
N	76	72	72	76	68	76	76	76	76	76	72	76	76
r2	0.35	0.49	0.72	0.02	0.56	0.14	0.02	0.16	0.38	0.86	0.77	0.26	0.63

AS curve slope with control for import price inflation

Countries	AUT	BEL	DEU	DNK	ESP	FIN	FRA	GBR	ITA	NLD	PRT	SWE	USA
Trade openness	-0.99***	-0.71***	-0.60***	-0.15	-1.11***	-0.41***	-0.36	-0.1	-1.60***	-0.47***	-1.30***	-1.11***	-2.50***
N	73	72	69	76	68	73	73	73	73	73	72	73	73
r2	0.55	0.35	0.64	0.03	0.63	0.23	0.03	0.00	0.45	0.90	0.75	0.60	0.55

legend: * p<.1; ** p<.05; *** p<.01

2) The higher the shares of intangible capital, the flatter the AS curve

In Table 4, intangible capital in an economy is measured as a ratio to the stock of tangible capital. The results indicate that in all the sample countries, except the UK, higher shares of intangible capital are associated with flatter AS curves. Also note that in some countries such as Spain, Finland and the Netherlands, the fit of the model is quite high. The regressions are also estimated using an alternative measure of intangible capital, as percent share of GDP, producing results that are qualitative the same (not reported here).

Table 4. The impact of intangible capital on AS curve slope [1/]

AS curve slope without control for import price inflation

Countries	AUT	BEL	DEU	DNK	ESP	FIN	FRA	GBR	ITA	NLD	PRT	SWE	USA
Intangible capital	-0.83***	-2.83***	-1.98***	-0.46**	-3.27***	-0.92***	-2.28***	-0.01	-4.21***	-0.93***	-2.75***	-0.64**	-0.71***
N	64	60	60	64	56	64	64	64	64	64	60	64	64
r2	0.28	0.50	0.61	0.08	0.67	0.68	0.43	0.00	0.53	0.80	0.76	0.10	0.72

AS curve slope with control for import price inflation

Countries	AUT	BEL	DEU	DNK	ESP	FIN	FRA	GBR	ITA	NLD	PRT	SWE	USA
Intangible capital	-1.21***	-2.60***	-1.93***	-0.70***	-3.39***	-1.11***	-2.59***	3.09***	-4.89***	-1.17***	-3.16***	-1.59***	-0.75***
N	61	60	57	64	56	61	61	61	61	61	60	61	61
r2	0.42	0.34	0.43	0.11	0.71	0.74	0.38	0.19	0.55	0.83	0.81	0.39	0.53

1/ The intangible capital is measured by its ratio to tangible capital.
legend: * p<.1; ** p<.05; *** p<.01

3) Consider globalization and intangible capital together

The results in Table 5 generally support the notion that higher integration with the global economy and larger shares of intangible capital tend to make the AS curve flatter. There are two notable exceptions though, Denmark and the UK – the fitness of the model is low, and some estimated coefficients come with unexpected signs. In addition, the coefficients for intangible capital are insignificant in some regressions, for instance, in the cases of Austria and Belgium. This is likely due to the collinearity between the two regressor variables – although the mechanisms through which globalization and intangible capital affect the slope of the AS curve are different, both series have been rising over time (see Appendix Figures 1 and 2). The fact that the models including the two regressors have better adjusted fitness suggest that both of the two macro trends are helpful in explaining the flattening of the AS curve.

4) Cross-country evidence

Table 6 reports panel regressions including all sample countries and the results are quite strong. They show that from a cross-country perspective, higher integration with the global economy and larger shares of intangible capital are associated with flatter AS curves. All the regressions include country fixed effects, and those in columns (6) to (10) also include time dummies. The estimated coefficients all come with the expected signs and are highly significant in most cases.

Table 5. The impact of trade openness and intangible capital on AS curve slope [1/]

AS curve slope without control for import price inflation

Countries	AUT	BEL	DEU	DNK	ESP	FIN	FRA	GBR	ITA	NLD	PRT	SWE	USA
Trade openness	-0.75***	-0.81***	-0.45***	0.46***	-0.44**	-0.11*	-0.49*	-1.21***	-1.21***	-0.21***	-0.77***	-0.64***	-1.01***
Intangible capital	0.06	-0.79	-0.41	-1.54***	-2.51***	-0.86***	-1.63***	1.80**	-2.45***	-0.47***	-1.44***	-0.14	-0.47***
N	64	60	60	64	56	64	64	64	64	64	60	64	64
r2	0.43	0.62	0.68	0.26	0.71	0.69	0.47	0.10	0.65	0.90	0.82	0.28	0.76

AS curve slope with control for import price inflation

Countries	AUT	BEL	DEU	DNK	ESP	FIN	FRA	GBR	ITA	NLD	PRT	SWE	USA
Trade openness	-0.87***	-0.90***	-0.69***	0.52***	-0.54***	-0.20***	-0.77**	-1.76***	-1.22***	-0.28***	-0.48**	-0.96***	-1.54***
Intangible capital	-0.2	-0.32	0.57	-1.90***	-2.45***	-1.00***	-1.49**	5.92***	-3.02***	-0.50***	-2.34***	-0.80***	-0.36**
N	61	60	57	64	56	61	61	61	61	61	60	61	61
r2	0.57	0.46	0.58	0.25	0.76	0.78	0.44	0.31	0.65	0.93	0.83	0.69	0.60

1/ The intangible capital is measured by its ratio to tangible capital.
legend: * p<.1; ** p<.05; *** p<.01

Table 6. The impact of trade openness & intangible capital on AS curve slope, cross-country evidence [1/]

	Without time dummies					With time dummies				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Trade openness	-0.60***			-0.43***	-0.43***	-0.19***			-0.11**	-0.09*
Intangible capital 1		-1.08***		-0.63***			-0.27***		-0.25**	
Intangible capital 2			-0.51***		-0.31***			-0.37***		-0.36***
N	968	812	812	812	812	968	812	812	812	812
r2	0.32	0.30	0.31	0.39	0.40	0.49	0.51	0.53	0.51	0.53

1/ AS curve slopes estimated without control for import price inflation
legend: * p<.1; ** p<.05; *** p<.01

Why have globalization and rising shares of intangible capital made the AS curve in an economy flatter? Integration with the global economy and increasing importance of intangible capital are both profound macro trends. A common channel through which they affect an economy, however, is that they both tend to lower the marginal cost of production and therefore make producers more sensitive to price changes—the very essence of a flattened AS curve.

Globalization lowers the marginal cost of production by allowing producers in an economy to source their intermediate inputs globally**.** As a result, the production process of both goods and increasingly services can be broken down into constituent parts, and sourced to its most cost-efficient sources.[16] Since the potential suppliers are now global and more competitive, it would be reasonable to assume that adjusting production would not alter the marginal cost of production as much as if there is a less competitive domestic supply chain.

Intangible capital, on the other hand, tends to drive down marginal production cost because of its higher scalability. While this phenomenon is quite visible across a number of areas of the economy, a simple illustrative example is from video streaming. Once the sunk cost of producing content and server storage space has been undertaken, the cost of making the context available to more households in a larger number of countries is relatively low. Similarly, once pharmaceuticals or automobile driver assistance software have been developed and patented, they can be made available to manufacturers across markets for relatively low marginal cost.

It is important to realize that the relative importance of the two macro trends have probably evolved and will likely continue to evolve over time. On the one hand, while globalization may

[16] The onset of the Covid-19 crisis has doubtless strained these global supply chains, but the analysis in this paper refers to the decades prior to this recent shock.

have matured at least for the near term, what is being seen in intangible capital in the past two decades could just be a beginning of its acceleration. Facilitated both by the ease of transmission of information and communication across borders, and the property of synergies, intangible capital investment appears to be spreading across both sectors within a country and across borders. Even conventional well-established products and services are seeing an increase in their intangible component. Arguably, this trend will increase over time as more "brick and mortar" businesses see a rise in their intangible components.[17] This would suggest that over time, the economy will be dominated more and more by production processes that take advantage of intangible investment and often producing goods and services that themselves also embed a high degree of intangible components.

VII. CONCLUSIONS

In this paper, we argue that economies have become more elastic in their ability to supply goods and services without triggering historical degrees of changes in economywide prices. This is due to the rising importance of intangible investment as a share of total investment in economies across the world, in addition to greater global integration. Intangible investment, which includes investments in certain types of technology but also improvements in business processes, economic competencies and branding, are distinct from tangible investment typified by plants and equipment, in that they are more scalable, have more synergies, and have other defining features.

While the role of technological change, some aspects of which are important subcomponent of intangible investment, in contributing to an economy's potential growth remain a matter of intense academic research, our contribution focuses instead on the short-term macroeconomic properties of intangible investment. We remain agnostic about the impact of these changes on long term growth, but argue that nevertheless a higher degree of intangible investment embeds a greater degree of scalability in production. In turn, this implies that economic output can increase or decrease more in response to shocks or even policy measures without necessarily exhibiting the same degree of price changes as has been in evidence in the past.

Conceptually, this transformation of short term economic relationships can be represented by the higher elasticity of short term economic aggregate supply curves in the conventional AS-AD framework. A greater degree of intangible investment in an economy is empirically associated with a "flatter" AS curve in a range of economies. However, this modification of the framework can remain agnostic about the impact of intangible investment on the economy's long term potential which is often represented by a vertical long term AS curve.

[17] With the onset of the Covid-19 pandemic and the lockdown, the ability for business meetings and education to be conducted virtually is another demonstration of how the size of these interactions can be scaled up with relatively little additional cost once the initial investment in technology is made.

Reevaluating short-term macroeconomic fluctuations with this perspective can help shed additional insight into a number of observed macroeconomic puzzles.[18] In terms of this paper's focus, the framework presented suggests that persistent low inflation even as an economy achieves full employment may be an outcome of the increasing elasticity of supply in the short term. In turn, this elasticity is due to the scalability of intangible investment which is becoming an ever-increasing share of total investment across economies. The framework shows that there may be multiple paths to achieving the inflation target for an economy. Increasing an economy's potential growth may be a way of achieving the inflation target with an overall higher increase in output than one that is potentially achieved by maintaining output above (lower) potential.

The framework remains agnostic about the impact of intangible investment on potential growth. In analytical terms, it focuses on the returns to scale parameters of the production function rather than the technological progress residual. As mentioned before, economists have not reached consensus on the impact of technological progress on potential growth, let alone on the other components of intangible investment which have been much less studied. Intangible capital could potentially lead to higher potential growth as well, but this work focuses on the lower marginal costs or production.

There are a number of additional implications of this framework that are the subject of future research:

First, because firms can use intangible capital more easily to scale up production without raising costs, this may create dynamics that lead to lower bargaining power for labor, lower wage responsiveness to changes in output (the flat Phillips curve) and a larger share of income going to capital. Labor that can be substituted by intangible capital would be most at risk, while labor that complements intangible capital may stand to gain. This could exacerbate inequality as the forces shaping manufacturing processes continue to evolve. The impact of intangible investment on labor income could help inform policy choices, including possible for redistribution policies.

Second, if intangible capital implies that returns to scale are improving continuously over time, this suggests that the cost structure of large incumbents is better than new entrants to a sector. It is possible that as a company grows, its monopolistic power is reinforced due to its better cost structure. Market concentration in this case may benefit consumers with lower prices and costs, but with possibly less competition or innovation in the sector. Indeed, as intangible investment rises, one could speculate that a greater concentration in sectors and generally lower competition would emerge naturally due to the larger market shares of firms with a more attractive cost structure. The full implications of this would need to be studied possibly at the sector level.

[18] Needless to say, there may also be additional potential explanations to explain these phenomena that are beyond the scope of this study.

The nature of financing would also be expected to change over time. Due to the higher fixed costs and ex ante risks of intangible investment, such investment appears better suited to internal financing by firms or equity-type sources such as venture capital. This could imply that over time, the role of such equity would increase while bank-based financing would be less important until the type of intangible investment has proven its usefulness and met the market test.

Another implication of this changing nature of investment is with regard to taxation. If monopolistic competition is a more likely outcome given the returns to scale properties of intangible investment, the ability to raise fiscal revenues, without stifling innovation and the low costs of such production, may need to be studied. Indeed, these revenues would become more important to compensate the type of labor that sees its ability to increase wages most at risk due to intangible investment. To put it succinctly, if technological progress favors a move away from perfect competition and also benefits consumers with lower prices, public policy may need to adapt to ensure that those adversely affected by this change can be supported through this transition.

In conclusion, the rising share of intangible investment has important implications for both short term fluctuations as well as longer term evolution of economies. In this paper, we present a simple framework and empirical evidence that sheds light on how intangible investment may be contributing to persistent low inflation that has been observed over the past decade. We also point to a number of other implications of rising intangible investment that are the subject of future research.

VIII. REFERENCES

Abbas, Syed K., Bhattacharya, Prasad Sankar, and Sgro, Pasquale, 2016. "The new Keynesian Phillips curve: An update on recent empirical advances," International Review of Economics and Finance, Elsevier, vol. 43(C), pages 378-403.

Arthur, W. Brian, 1996 "Increasing Returns and the New World Of Business," Harvard Business Review, July-August, available at https://hbr.org/1996/07/increasing-returns-and-the-new-world-of-business.

Ball, Laurence and Sandeep Mazumder, 2011. "Inflation Dynamics and the Great Recession," Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, vol. 42(1 (Spring), pages 337-405.

Bental, Benjamin and Demougin, Dominique, 2010. "Declining labor shares and bargaining power: An institutional explanation," Journal of Macroeconomics, Elsevier, vol. 32(1), pages 443-456, March.

Olivier Blanchard, 2016. "The Phillips Curve: Back to the '60s?" American Economic Review, American Economic Association, vol. 106(5), pages 31-34, May.

Olivier Coibion, Yuriy Gorodnichenko, and Dmitri Koustas, 2013. "Amerisclerosis? The Puzzle of Rising U.S. Unemployment Persistence," Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, vol. 44(2 (Fall)), pages 193-260.

Coibion, Olivier, Yuriy Gorodnichenko, and Rupal Kamdar. 2018. "The Formation of Expectations, Inflation, and the Phillips Curve." Journal of Economic Literature, 56 (4): 1447-91.

C. Corrado, J. Haskel, C. Jona-Lasinio, M. Iommi (2016). “Intangible investment in the EU and US before and since the Great Recession and its contribution to productivity growth,” in “Investment and Investment Finance in Europe”, Chapter 2, p. 73-102, European Investment Bank Report, November 2016.

Carol Corrado, Charles Hulten, and Daniel Sichel, 2005. "Measuring Capital and Technology: An Expanded Framework," NBER Chapters, in: Measuring Capital in the New Economy, pages 11-46, National Bureau of Economic Research, Inc.

Carol Corrado, Charles Hulten, and Daniel Sichel, 2009. "Intangible Capital and U.S. Economic Growth," Review of Income and Wealth, International Association for Research in Income and Wealth, vol. 55(3), pages 661-685, September.

Emmanuel Farhi and Francois Gourio, 2018. "Accounting for Macro-Finance Trends: Market Power, Intangibles, and Risk Premia," Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, vol. 49(2 (Fall)), pages 147-250.

Joseph E. Gagnon and Christopher G. Collins, 2019. "Low Inflation Bends the Phillips Curve," Working Paper Series WP19-6, Peterson Institute for International Economics.

Alan Greenspan, Testimony Before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, Federal Reserve Board's semiannual Monetary Policy Report to the Congress, February 16, 2005

Jongrim Ha, M. Ayhan Kose, and Franziska Ohnsorge, 2019. "Inflation in Emerging and Developing Economies," World Bank Publications, The World Bank, number 30657, August.

Haskel, Jonathan, and Stian Westlake. Capitalism without Capital: The Rise of the Intangible Economy. Princeton; Oxford: Princeton University Press, 2018. Accessed August 17, 2020.

Dora Iakova, 2007. “Flattening of the Phillips Curve: Implications for Monetary Policy”, IMF Working Paper, WP/07/76, IMF.

IMF, 2006. “How Has Globalization Affected Inflation” Work Economic Outlook, Chapter 3, IMF, April.

IMF, 2013. “The Dog that Didn’t Bark: Has Inflation Been Muzzled or Was It Just Sleeping?” Work Economic Outlook, Chapter 3, IMF, April.

Florence Jaumotte, Subir Lall, and Chris Papageorgiou, 2008. "Rising Income Inequality; Technology, or Trade and Financial Globalization?" IMF Working Papers 08/185, International Monetary Fund.

Florence Jaumotte, Subir Lall, and Chris Papageorgiou, 2013. "Rising Income Inequality: Technology, or Trade and Financial Globalization?" IMF Economic Review, Palgrave Macmillan;International Monetary Fund, vol. 61(2), pages 271-309, June.

Hee Sung Kim and Juan M. Sanchez, 2018. "Why Is Inflation So Low?" The Regional Economist, Federal Reserve Bank of St. Louis, vol. 26(1).

Kuttner, Ken and Robinson, Tim, 2010. "Understanding the flattening Phillips curve," The North American Journal of Economics and Finance, Elsevier, vol. 21(2), pages 110-125, August.

Sylvain Leduc and Zheng Liu, 2019. "Are Workers Losing to Robots?" FRBSF Economic Letter, Federal Reserve Bank of San Francisco.

Lei Lv, Zhixin Liu, and Yingying Xu, 2019. "Technological progress, globalization and low-inflation: Evidence from the United States," PLOS ONE, Public Library of Science, vol. 14(4), pages 1-19, April.

McLeay, Michael and Silvana Tenreyro, 2019. “Optimal Inflation and the Identification of the Phillips Curve,” NBER Working Paper No. w25892, May.

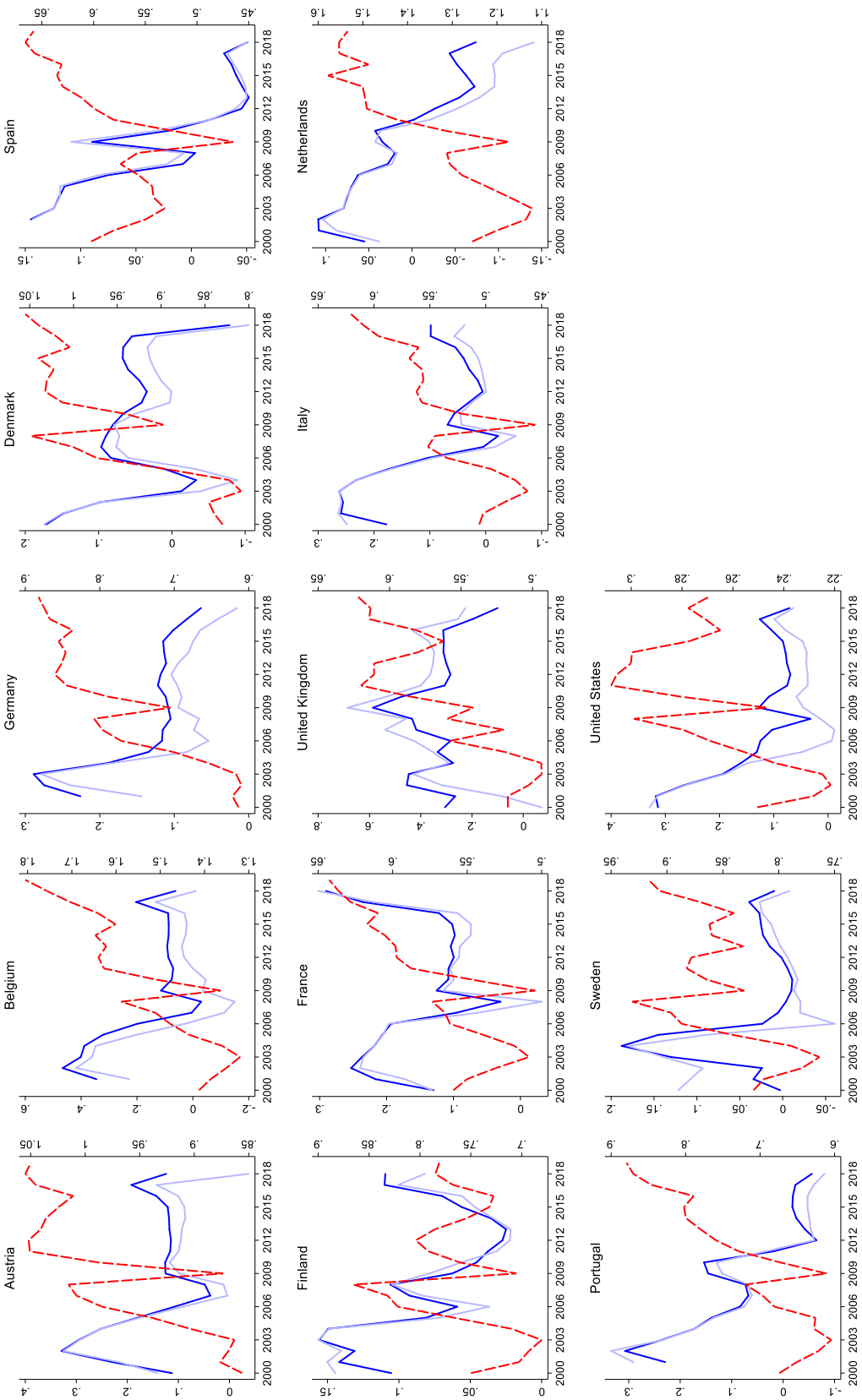
Frederic S. Mishkin, 2007. "Inflation Dynamics," International Finance, Blackwell Publishing, vol. 10(3), pages 317-334, December

Roberts, John M, 1995. "New Keynesian Economics and the Phillips Curve," Journal of Money, Credit and Banking, Blackwell Publishing, vol. 27(4), pages 975-984, November.

John M. Roberts, 2006. "Monetary Policy and Inflation Dynamics," International Journal of Central Banking, International Journal of Central Banking, vol. 2(3), September.

Anna Stansbury and Lawrence H. Summers, 2020. The Declining Worker Power Hypothesis: An Explanation for the Recent Evolution of the American Economy," NBER Working Papers 27193, National Bureau of Economic Research, Inc.

Appendix Figure 1. AS curve slopes estimated with 40-quarter rolling windows



Appendix Figure 2. Intangible capital over time