Don't Stop Believing: Inflation on a Gradual Journey Higher in Advanced Economies

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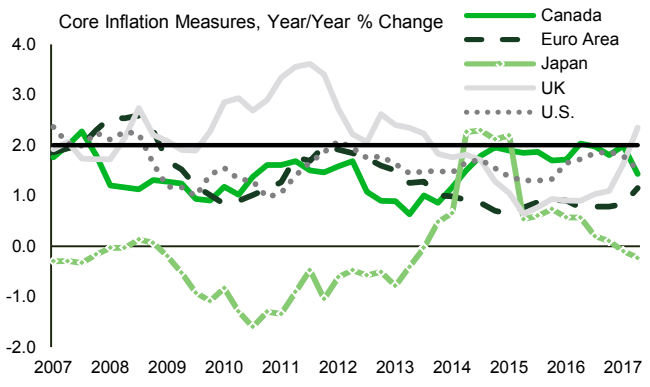
November 6, 2017

Highlights

- Above-trend economic growth and plunging unemployment rates in G5 economies all indicate that global economic slack is diminishing or has diminished. Yet inflation has persistently remained below target, puzzling central bankers eager to lift interest rates off the zero lower bound.
- A number of transitory and structural factors have been cited as key in keeping G5 inflation subdued. These include transitory factors such as exchange rate moves and structural factors, including digitization and evolution of global supply chains. Lastly, the issue of measurement errors has also been raised as an explanation. While some of these culprits may be more important than others, we don't believe that collectively they explain more than a small part of the inflation mystery.
- Instead, low inflation appears to largely reflect the both persistent economic slack post-crisis and a weaker, more drawn out relationship between capacity absorption and higher price/wage inflation.
- Accordingly, our model simulations reveal that higher inflation is just around the corner, especially in light of continued above-trend economic growth and lower unemployment rates across the G5.
- Given their uncertain and unobservable nature, estimated output or labor market gaps face significant limitations as "real-time" measures of excess capacity. For this reason, central banks are likely to increasingly shift their focus to more observable and higher frequency indicators of capacity pressures, notably wage growth, to guide monetary policy decisions. Mixed wage performances go a long way in explaining diverging central bank communications of late regarding the removal of post-crisis stimulus.

Getting to the root of the low inflation puzzle in advanced economies is proving to be a daunting task. There are too many moving parts and a plethora of factors that appear to be playing a role in keeping inflation below target in inflation-targeting advanced economies such as Canada, the U.S., UK, Euro Area, and Japan (collectively the G5) in the post crisis period (Chart 1). Inflation is generally believed to be positively correlated with the economic cycle. As the economy absorbs more inputs, the means of production including labor, become scarcer, thus bidding up wages and prices. Eventually, this process drives firms to raise prices to offset slimmer profit margins. But, the process this time around appears to be delayed relative to past cycles. Although output and employment gaps have either evaporated or will do so in coming quarters,

CHART 1: INFLATION PERSISTENTLY BELOW TARGET IN ALL G5 ECONOMIES



Source: National Statistical Agencies via Haver Analytics, TD Economics.

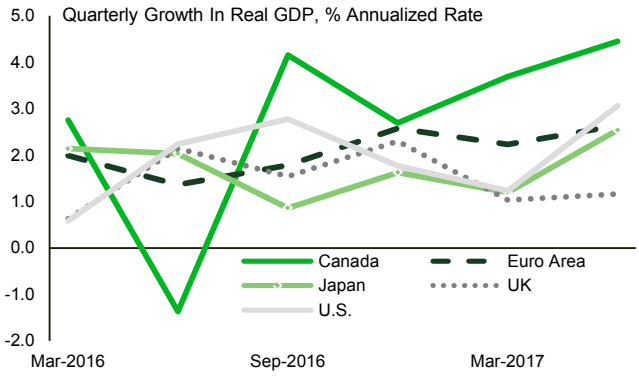
wage growth remains subdued for reasons not well understood at this mature phase of the economic cycle.[1]

Central bank research has attempted to explain this unusual weakness in wage and price growth. For example, the Federal Reserve attributes much of the persistence of below target inflation to idiosyncratic factors, and maintains a belief that as labor market slack diminishes, the resulting pop to wages will help push inflation back to target.[2] A similar narrative is being argued by other global central banks, who have generally adopted a belief that it's only a matter of time before tightening labor markets result in rising wages and price pressures more broadly.

On the surface it may seem that central bankers are clinging to an orthodox belief in the relationship between inflation and economic slack at a time when actual data argue against such a relationship holding. Indeed, not one of the G5 inflation-targeting economies has experienced inflation persistently at target since 2010 despite extraordinary measures undertaken by central banks to stimulate demand. Given this poor track record, why should markets believe central banks now when they proclaim that inflation will eventually move back to target?

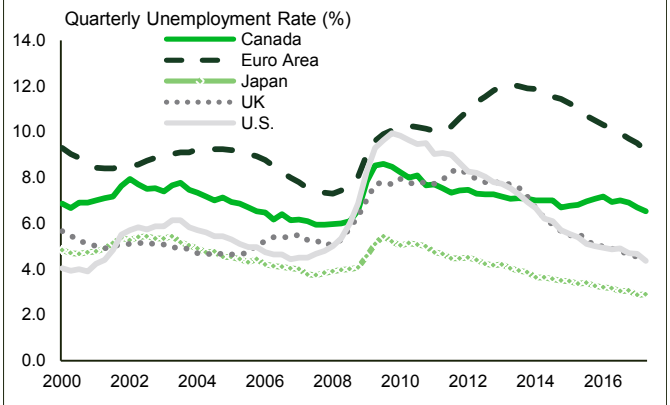
For one, there indeed is empirical evidence supporting this traditional belief in both the wage and price Phillips curves.[3] Our model simulations find that the historical relationship between labor market and economic slack with wages and prices likely is still at work even if there is corresponding evidence that it has lost some power over the past decade or so. And, while the strength of the relationship appears to vary by economy, our modelling exercise is consistent with G5 inflation beginning a slow trek higher in the coming months.

CHART 2: GROWTH HAS TICKED UP IN THE G5 ECONOMIES, ABSORBING SLACK



Source: National Statistical Agencies via Haver Analytics, OECD/European Commission/CBO, TD Economics.

CHART 3: UNEMPLOYMENT RATES PLUMBING NEW CYCLE LOWS



Source: National Statistical Agencies via Haver Analytics, TD Economics.

At the same time, however, model results rely on estimates of slack that are highly uncertain and difficult to measure. Central banks are well aware of this limitation. Instead, they appear to be increasingly relying on more observable and higher frequency labor market indicators such as unemployment and wage growth to guide monetary policy decisions. On that front, the story remains decidedly mixed across the G5, with the U.S. and UK showing more encouraging signs of wage pickup while Canada, Europe and Japan have been lagging behind. This provides a good explanation for the varying signals around the exit of post-crisis stimulus by G5 central bankers.

The Inflation Puzzle Explained

The recent string of economic outperformance in G5 economies has raised questions of when monetary policymakers will begin to remove the extraordinary stimulus that was put in place after the Great Recession (Chart 2).

Traditionally, growth in excess of trend and low unemployment rates have set the stage for higher price and wage inflation. However, inflation has persisted well below target in G5 economies after the

Great Recession. More concerning is the spate of below target inflation despite unemployment rates plumbing to new cycle lows (Chart 3).

These recent trends have raised concerns that maybe economists are wrong in their assertion about the link between economic slack and inflation. However, no economist worthy of the title would say that the Phillips curve is a universal law. Instead, the strength of this relationship waxes and wanes over economic cycles.[4] In addition to this cyclicality, the strength of this relationship varied across countries. Since the late 1990s, our simulations suggest that the impact on inflation from shrinking spare economic capacity has been highest in the Euro Area and UK, while somewhat less visible in the U.S., Canada, and Japan (Chart 4). This development could be chalked up to differences in economic and market structures from country to country.

Since the financial crisis, the Phillips curve relationship within G5 economies has clearly weakened compared to the pre-crisis period, but we would not go as far as to say that it has broken down. Furthermore, we currently appear to be at a point in the decade-long expansion where the relationship has reached a cyclical low. Our forecasts assume that this correlation holds or even strengthens in some regions over the next 12-18 months.

For much of the post-crisis period, weak inflation could simply be explained by the large amount of economic slack that had materialized after the massive negative shock to global demand during the Great Recession. But, over the past few years, the lack of visible price pressures as economies have recovered has put the focus on other inflation-dampening influences. These include:

1. Idiosyncratic factors;

2. Digitization and global supply chain innovations;

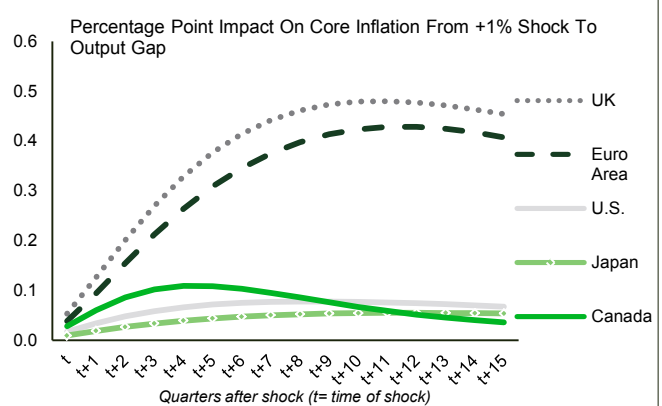
3. Measurement errors on economic slack;

4. Anemic wage growth.

Temporary and structural factors suppressing prices globally

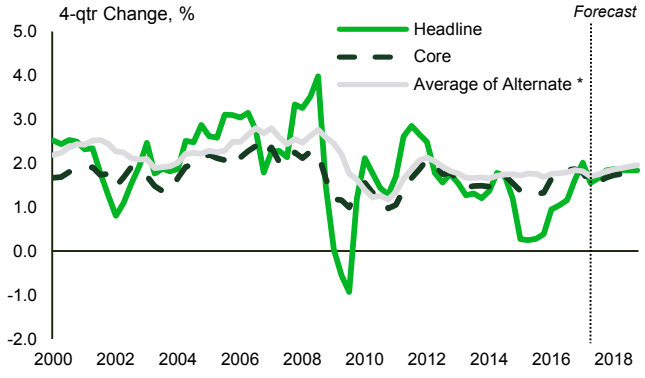
Pinning down the exact source of price weakness in each G5 economy is a very difficult exercise. In Canada, past declines in food and electricity prices have contributed to weak inflation prints in the first part of 2017, but have begun to fade. Similarly, weak

CHART 4: INFLATION RESPONSE TO CAPACITY PRESSURES IS WEAK AND VARIES GREATLY BY REGION



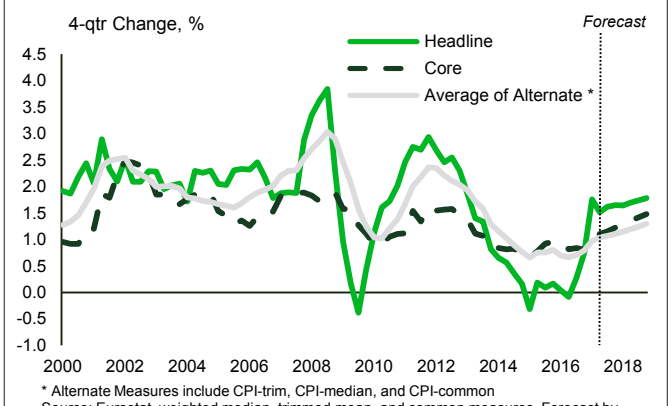
Source: TD Economics

CHART 5A: UNITED STATES INFLATION MEASURES



Source: BEA, weighted median, trimmed mean, and common measures. Forecast by TD Economics as of November 2017.

CHART 5B: EURO AREA INFLATION MEASURES



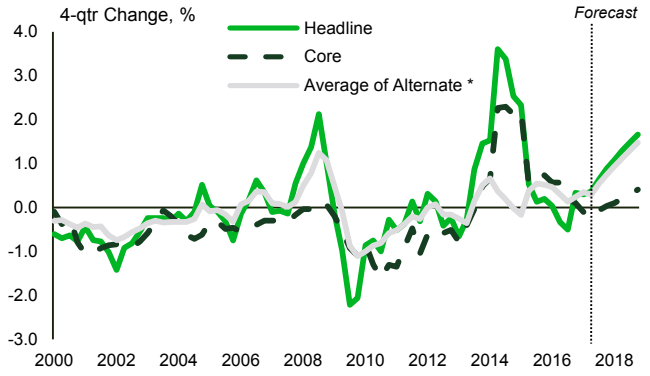
* Alternate Measures include CPI-trim, CPI-median, and CPI-common
Source: Eurostat, weighted median, trimmed mean, and common measures. Forecast by TD Economics as of November 2017.

inflation in the U.S. has been blamed on a number of transitory factors such as one off declines in communication and pharmaceutical prices, as well as import price weakness owing to a surge in the U.S. dollar in the preceding 12-month period. However, these short-term impacts have failed to diminish as 2017 has progressed. Underlying measures that strip out the most volatile price components, have continued to point to sub-2% inflation in both Canada and the U.S. (see Chart 5A – 5E).

Idiosyncratic factors are also playing a role in other regions as well. In Europe, the emphasis is less on areas of the consumer price basket per se, and more on the regional differences in the distribution of economic slack. Estimates of economic and labor market slack have largely diminished in the core regions of the Euro Area (Germany, France, Netherlands), while unemployment rates remain high by historical standards in the regions hit hardest by the Euro Crisis – namely Greece, Italy, Portugal, and Spain.

The UK has been somewhat of an outlier in this regard. Inflation has been running hotter than policymakers would like, and has largely been driven higher by the substantial depreciation in the pound against the euro and the U.S. dollar following the Brexit referendum. However, the pass-through to consumer prices from the pound's depreciation has largely played out, sending headline inflation to 3.0% lately. This currency-related upward move is likely to gradually fall out of inflation readings in coming months.

CHART 5D: JAPAN INFLATION MEASURES

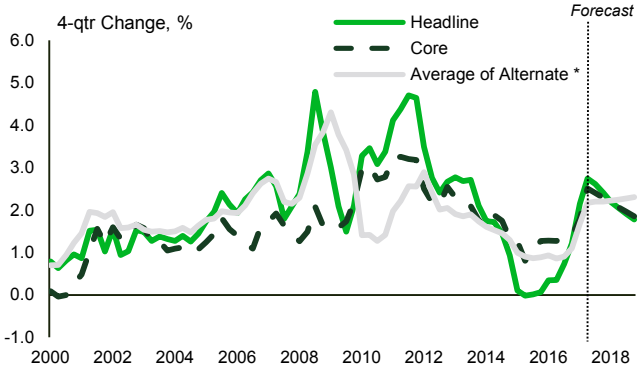


* Alternate Measures include CPI-trim, CPI-median, and CPI-common
Source: Official Statistics of Japan, weighted median, trimmed mean, and common measures. Forecast by TD Economics as of November 2017.

Aside from the transitory factors mentioned, the persistent weakness in underlying inflation across G5 economies suggests something more systematic is at play, possibly originating from a common global source. These include overcapacity in global industries, changing global value chains, and technologically driven supply shocks.

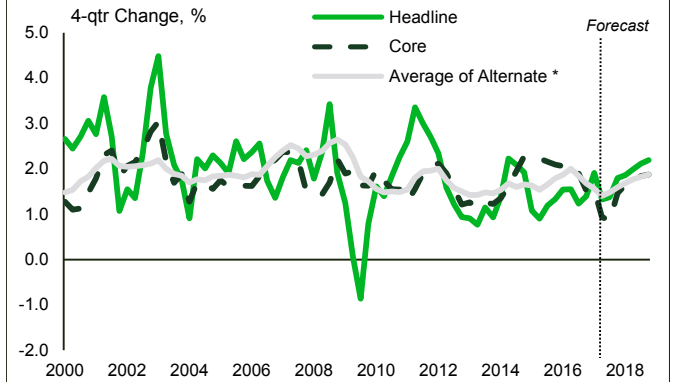
Breaking down headline inflation measures into goods versus services can help distinguish to what extent common global factors may be playing a role in suppressing price growth (Chart 6). Goods include tradables such as energy, food, and clothing, much of which is imported from abroad in finished form or contain a high amount of imported content, like automobiles. Given their high degree of tradability, goods are more likely to be impacted by common global factors. For example, China's accession into the WTO in 2001 meant that a wave of

CHART 5C: UNITED KINGDOM INFLATION MEASURES



* Alternate Measures include CPI-trim, CPI-median, and CPI-common
Source: Eurostat, weighted median, trimmed mean, and common measures. Forecast by TD Economics as of November 2017.

CHART 5E: CANADIAN INFLATION MEASURES



* Alternate Measures include CPI-trim, CPI-median, and CPI-common
Source: Statistics Canada, TD Economics.

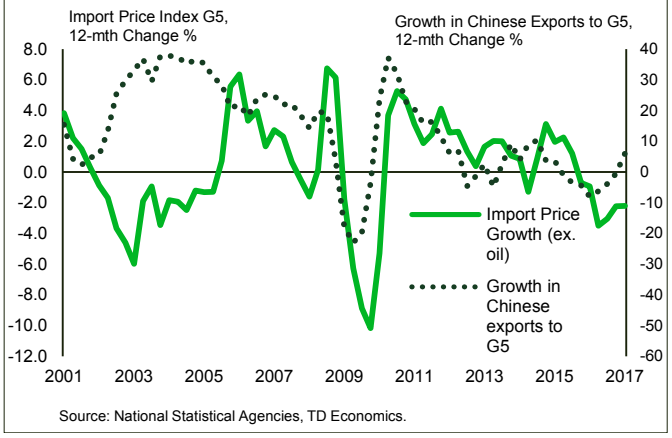
cheap goods from Asia found their way into global markets and helped create a deflationary impulse in goods prices around the world for the better part of the aughts (Chart 7).

In addition to changing global supply chains, goods prices are also more susceptible to pressures from technological innovation. Improved manufacturing techniques can reduce production costs globally. Moreover, falling input costs, such as the abundance of cheap energy owing to the shale gas revolution, can also facilitate a structural change in the domestic economy by making formerly expensive manufacturing industries feasible again in gas-rich regions such as North America.

Technological innovation, however, is not limited to manufacturing. E-commerce has risen in importance globally over the past decade, as the success of multinationals such as Amazon and Ali Baba prove. Although evidence of increased retail competition for most economies remains largely anecdotal, there is some evidence provided by the Billion Price project.[5] Price data gathered between 2014 and 2016 reveals increasing price competition between e-commerce players, such as eBay and Amazon, and multi-channel retailers, such as Walmart, and Canadian Tire. A high prevalence of online discounts in a country is assumed to be indicative of competitive retail price pressures (Chart 8). Since 2014, multi-channel retailers in Japan were more likely to provide discounted prices to online customers, followed by Brazil, Germany, and the U.S. On the other hand, Australia, Canada, China, and the UK were least likely to provide discounts. For the U.S., this data is consistent with what has and continues to be observed in the retail industry – consolidation and layoffs. Those nations with a low degree of online discounting over this period suggests a lack of penetration of online retail at the time of the survey, implying that online discounting, and consequently downward pressures on goods prices, will follow along with the upward trend toward online sales (Chart 9).

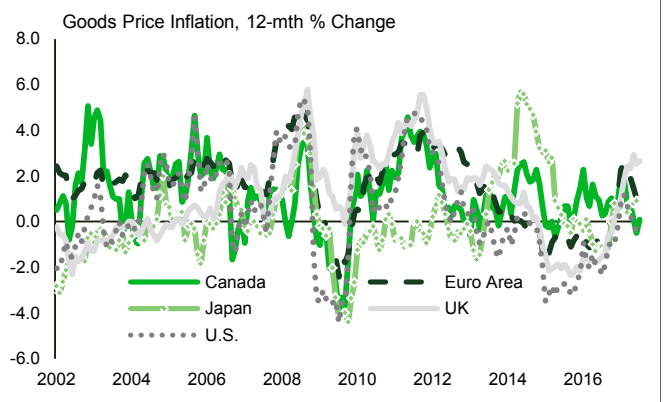
Unlike goods, services are less responsive to external factors and therefore are assumed to better reflect domestic economic conditions. Indeed, this measure appears to provide a less distorted picture of inflationary pressures in G5 economies, with services inflation running at or above target for the better part of the last decade (Chart 10). More specifically, steady and rising price pressures in ser-

CHART 7: CHINESE EXPORTING OF GOODS PRICE DEFLATION IN THE REARVIEW MIRROR



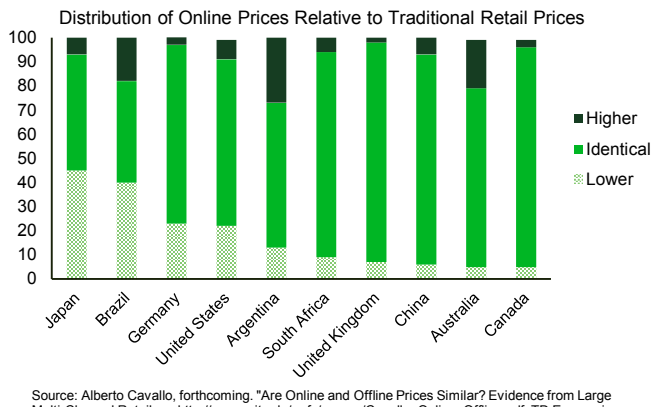
Source: National Statistical Agencies, TD Economics.

CHART 6: STRONG BOUTS OF DEFLATION/DISINFLATION IN GOODS



Source: BEA, Statistics Canada, Japan Statistics Bureau, Eurostat, TD Economics.

CHART 8: COMPETITION HEATING UP IN ONLINE RETAIL



Source: Alberto Cavallo, forthcoming. "Are Online and Offline Prices Similar? Evidence from Large Multi-Channel Retailers. http://www.mit.edu/~afc/papers/Cavallo_Online_Offline.pdf, TD Economics.

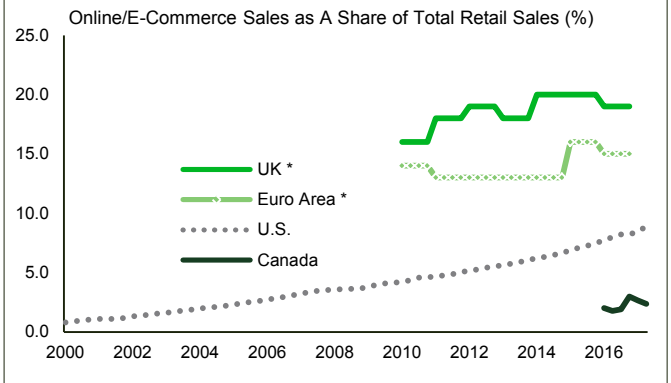
vices is consistent with the above trend economic performance in the G5 driven by robust growth in domestic demand.

Measuring how much these factors are weighing on price growth in each region is a difficult task. For example, the expansion in global supply has been a multi-decade phenomenon, suggesting that much of its effects on goods prices have largely been absorbed already in price indexes. As such, the ongoing global supply expansion is likely exerting a relatively small impact on current price dynamics. In contrast, e-commerce may be having more of a downward impact on G5 inflation in countries where online sales are more prominent, such as Japan. Additionally, technological quality improvements are notoriously difficult to translate into prices, leaving price indexes for high-tech goods and services prone to persistent, one-sided errors.

In response to concerns about mismeasurement, policymakers have developed inflation measures that sift through the survey data, removing idiosyncratic price movements in order to get at the underlying trend of price growth. As a result, these alternative inflation measures better represent the true underlying trend. Yet, even some of these trend inflation measures have exhibited signs of weakness for much of this year, suggesting measurement errors alone are insufficient to explain subdued price growth (see Charts 5A-E and Box 1 for a brief explanation of these underlying measures).

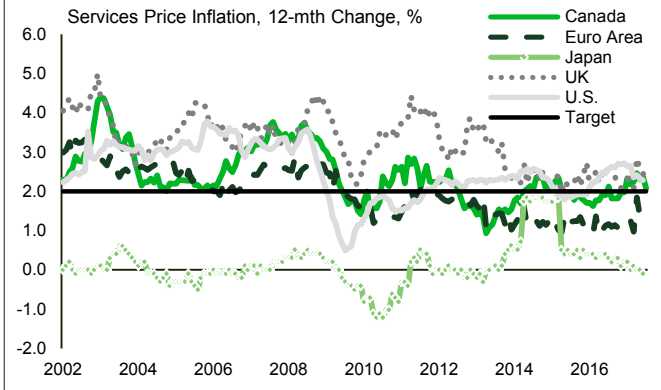
Overall, both systemic and idiosyncratic factors are

CHART 9: ONLINE SALES GROWTH RISING IN U.S. AND CANADA



* E-commerce share of total turnover of enterprise sales.
Source: BEA, Statistics Canada, Eurostat, TD Economics.

CHART 10: SERVICES INFLATION MORE STABLE, HOLDING NEAR TARGET



Source: BEA, Statistics Canada, Japan Statistics Bureau, Eurostat, TD Economics.

exerting some downward pressure on goods prices, and are likely to do so for some time. As such, policymakers will continue to ignore measures most affected by these factors, instead relying on inflation measures that aim to track the underlying trend.

Relationship between economic slack and prices has weakened but not gone away

Rather than idiosyncratic and structural factors, we believe that the absence of price pressures across the G5 largely boils down to the straight forward notion that inflation is taking longer to materialize than in past cycles. Indeed, in-house simulations, which are consistent with analysis released by G5 central banks, find the following:

- A low but statistically significant relationship between the output gap and headline as well as underlying measures of inflation since the late 1990s or early 2000 for the G5 economies (see Box 2 for details).
- Inflation measures that strip out more volatile components tend to show a stronger relationship with the output gap than headline inflation over the past two decades. Moreover, alternative underlying inflation measures also do a better job of forecasting inflation one to two years ahead.
- The Phillips Curve relationship is not static but ebbs and flows over time and not necessarily in tandem with the economic cycle. The apparent

breakdown recently suggests to us that the correlation in the G5 is currently at a cyclical low.

- Past periods of weak correlation between the output gap and inflation, such as in the 1990s, have proved to be temporary.

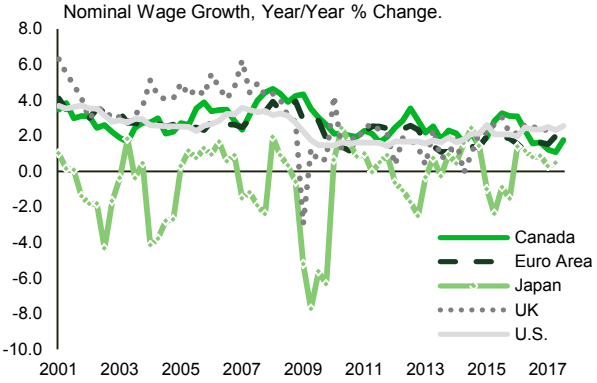
The inflation forecasts produced with these models, conditional on the expected evolution of output gaps suggest a firming of inflation in virtually all the G5 economies. At last count, output gaps were estimated to be essentially closed in Canada and the U.S. and open only slightly in the Eurozone.

At the same time, however, barring a sudden and significant strengthening in the cyclical Phillips Curve relationship (which we don't assume), the upward trek is expected to be very gradual. Even the recently downward revised forecasts by G5 central banks may be a tad optimistic. Core inflation is not expected to make material progress toward 2 per cent in the U.S. and Canada until late 2018, and not until 2020 for the Euro Area, UK, and Japan.

While these models do not necessarily capture the structural factors holding back price pressures, they do control for energy prices and exchange rate fluctuations. While energy prices provided a nice boost to inflation at the start of the year, their current level of $54 is little firmer from a year ago. Moreover, the outlook for oil is one of a gradual increase from current levels, suggesting a minor contribution to price growth.

CHART 11: WAGE GROWTH HAS REMAINED SUBDUED

Nominal Wage Growth, Year/Year % Change.



Source: National Statistical Agencies via Haver Analytics, TD Economics.

Similarly, while exchange rates previously provided a tailwind to inflation for Japan, Europe, and Canada, going forward the recent decline in the trade-weighted U.S. dollar suggests that exchange rates may instead exert a headwind on inflation in these regions.

Disappointing wage growth key to weak inflation

The recent inflation undershoot of G5 nations appears to result from a change in how long it takes for shrinking economic slack to translate into wage and price pressures. But, while central bankers appear to be justified in expecting inflation to rise going forward, model outputs are heavily contingent on the quality of the inputs. And in this regard, policymakers have generally had a difficult time in measuring economic slack in terms of the gap between output and its potential, with the latter being unobservable and subject to high bands of uncertainty.

As such, central banks have been showing an increased tendency to instead focus on more timely labor market indicators of economic slack, such as unemployment rates and wage growth, to gauge how quickly economic slack is diminishing.

Indeed, unemployment rates are currently at cyclical lows across the G5 (Chart 2). But, while this metric benefits from timeliness, there are limits to the usefulness of unemployment as a measure of economic slack. What matters is where the current setting stands relative to the trend rate consistent with full employment (i.e., natural rate of unemployment). On that count, central banks suffer similar measurement challenges as with the output gap.

Accordingly, the focus of central banks has increasingly shifted towards measures of wage growth. Similar to the unemployment rate, wage growth provides a timelier signal about the health of the labor market, and more importantly, is a good leading indicator on how inflation is expected to evolve.

Similar to other prices, wage growth has remained surprisingly tepid across the G5 (Chart 11). Although wages in the U.S. and UK have shown more upside, wage growth in Canada, Euro Area, and Japan has

struggled to gain momentum. Explanations for this weakness have generally hinged on the ongoing downward pressure exerted by past economic slack. Additionally, in the case of Euro Area and Japan, wage setting appears to be more of a backward rather than forward-looking process. There are reports that in the Euro Area unions avoid pushing too much in wage negotiations in fear of suffering employment losses once labor market reforms kick into gear.[6]

Another factor acting to hold back wage growth is weak productivity growth (Chart 12). It's no secret that throughout much of the developed world investment has disappointed in the aftermath of the Great Recession despite historically low interest rates. While some of this was likely related to the unwinding of pre-crisis overinvestment, other factors, including high hurdle rates, and economic uncertainty in terms of both response by policymakers and the rebound in the outlook, were found to be confounding factors in delaying new investment.[7]

Encouragingly, the recent above-trend performance of economic activity in G5 economies has been driven by domestic demand including business investment. Although it may take a few quarters, stronger business investment growth, if sustained, should help push up labor productivity growth, which in turn should help drive up wages.

Stronger wage growth in the pipeline

Similar to inflation, our models point to a gradual

firming in wage growth across the G5 in the months ahead, led by the U.S. Tightening labor markets will eventually give workers some ability to negotiate higher wages, pinching firm margins and leading to consume price pressures. But, until this transpires , and given the ongoing uncertainty around the impact of structural factors, central banks are likely to continue to lean toward caution as they contemplate monetary policy normalization. (see Table 1 for a summary of our inflation forecasts)

Moreover, after a summer when central banks were singing a similar tune with respect to removing crisis-era stimulus, expectations around the future path of monetary policy have diverged lately.

The Federal Reserve has communicated that it views the recent soft patch of inflation data as largely transitory, and remains on course to nudge up its overnight rate and gradually shrink its balance sheet. We expect to see three hikes between now and the end of 2018.

Similarly, the Bank of England is eager to raise interest rates to head off strong inflation related to past exchange rate depreciation. Inflation is expected to peak at the upper range of the 1% to 3% target in the fourth quarter of this year. Moreover, inflation is expected to remain at the upper end of the target range for much of 2018, leading to the expectation that the BoE will raise rates again in early 2018.

On the flip side, after implementing two rate hikes earlier this year, the Bank of Canada has signaled that it will be cautious about raising rates further in the near term partly reflecting a weak trend of wage growth. This has pushed back expectations of the next hike from later this year to early 2018. We have now reduced the amount of rate hikes by the end of next year from three to two (in Q1 and Q3). However, this view is highly contingent on growth returning to an above trend pace in the near term, and for wage and core inflation to continue to nudge higher.

Although inflation is unlikely to return to target until 2020 in the Euro Area, the ECB is committed to start the process of slowing the pace of additional accommodation early next year by reducing monthly

asset purchases. As with Canada, a tightening of monetary policy will occur only if the above-trend pace of growth continues together with a material firming in wage pressures. In our view this is unlikely to occur before mid-2019.

Japan will remain the outlier, as the Bank of Japan is likely to maintain an ultra-accommodative monetary policy stance in order to run the economy hot enough to put inflation on track toward its 2% target. As with the Euro Area, we don't expect a material uptick in wage or prices pressures before 2020.

Low inflation will ensure a gradual normalization of monetary policy

What's most troubling about low inflation is that it makes it difficult for monetary policy to do its job. Since central bankers tend to use interest rates as the primary tool to govern economic growth, low inflation implies higher real, or inflation-adjusted, interest rates and therefore a less stimulative effect on demand especially when close to the zero lower bound. As policymakers begin to lift rates off the floor, they hope that a corresponding pick-up in inflation will help keep real interest rates low, thereby supporting the economic recovery.

But, as recent experience suggests and our empirical work implies, the reinflation process will be a gradual one. As such, G5 central banks are likely to maintain a more gradual pace of tightening until signs of a persistent pick up in wage growth and inflation become more apparent.

Table 1 - Comparison of Inflation Forecasts

		2017	2018	2019
Canada	TD Economics	1.5	1.5	1.9
	Bank of Canada	1.5	1.7	2.1
Euro Area *	TD Economics	1.1	1.2	1.5
	European Central Bank	1.1	1.3	1.5
Japan *	TD Economics	0.5	0.8	1.3
	Bank of Japan	0.8	1.4	1.8
United Kingdom	TD Economics	2.7	2.5	2.0
	Bank of England	2.7	2.6	2.2
United States *	TD Economics	1.5	1.6	2.0
	Federal Reserve SEP	1.5	1.9	2.0

* Forecasts of core inflation. Forecast by TD Economics as of September 2017 QEF.

Endnotes

1. The output gap is defined as the percentage point gap between real GDP growth and potential output. Potential output is the measure of output that would result if the economy was utilizing labor and capital at full capacity.
2. See Chair Janet Yellen's speech "Inflation, Uncertainty, and Monetary Policy", September 26, 2017. https://www.federalreserve.gov/newsevents/speech/yellen20170926a.htm
3. The Phillips curve relates inflation with the degree of economic slack in an economy.
4. For a discussion on the historical variability of the inflation-capacity relationship in the U.S. see Nicolini & Fitzgerald (2013) "Is there a stable Phillips Curve after all". Federal Reserve Bank of Minneapolis. https://www.minneapolisfed.org/research/economic-policy-papers/is-there-a-stable-phillips-curve-after-all
5. See Cavallo, Alberto (2017). "Are online and offline prices similar? Evidence from large multi-channel retailers". American Economic Review, Forthcoming. Working Paper: http://www.hbs.edu/faculty/Publication%20Files/Cavallo_Online_Offline_87d5b930-c171-46fe-b854-416171fcbb47.pdf
6. See Introductory Statement to the Press Conference by ECB President Mario Draghi, September 7, 2017: https://www.ecb.europa.eu/press/pressconf/2017/html/ecb.is170907.en.html
7. For an in-depth discussion of the causes of the post-crisis global investment slump see Fay & Leboeuf (2016). "What is behind the weakness in global investment?" Bank of Canada staff discussion paper 2016-5. http://www.bankofcanada.ca/wp-content/uploads/2016/02/sdp2016-5.pdf

Box 1: Alternative underlying measures of inflation

Given the volatility in the prices of goods and services on a monthly basis, policymakers have developed alternative measures of underlying inflation in order to better distinguish the signal from the noise. The most common example of an alternative measure is core inflation, a measure that simply strips out the most volatile components of goods prices, such as food and energy.

While historically core inflation proved to be a useful measure of the underlying trend in headline inflation, it never really was the best measure to help forecast where inflation was heading a year or two into the future – the span of time over which changes to monetary policy feeds through to the economy. Other measures, such as the weighted-median, trimmed-mean, and common component, all have outperformed core inflation in forecasting headline inflation in advanced economies since 2010.

In this report we construct trimmed-mean, weighted median, and common component measures of inflation for the U.S., Japan, UK, and the Euro Area based on the methodology from the Bank of Canada.[1] Although some of these measures are published regularly by some central banks, others such as the common component are not made publicly available on a regular basis.[2] A simple out-of-sample forecasting exercise confirms that these measures, including an unweighted arithmetic average of the three measures, outperform core inflation in terms of forecasting inflation in a Phillip's curve framework since 2010.[3]

1. See the methodological article from Statistics Canada on how these measures were constructed. http://www23.statcan.gc.ca/imdb-bmdi/document/2301_D64_T9_V1-eng.htm.
2. For example the Federal Reserve Bank San Francisco publishes the weighted PCE median measure monthly, and a trimmed-mean PCE inflation measure is published monthly by the Federal Reserve Bank of Dallas. Similarly, both the U.S. Federal Reserve Bank of New York (FRBNY) and the European Central Bank have developed a measure of underlying inflation that utilizes a dynamic factor model, but only the FRBNY publishes the measure.
3. This was done utilizing a specification of the Phillips curve that includes Blue Chip forecasts of inflation as a proxy for inflation expectations, estimates of the output gap, and controlling for changes in the nominal trade-weighted currency, unit labor costs, and the domestic price of oil. Details available upon request.

Box 2: Data driven simulations suggest inflation to remain subdued for some time, and potentially weaker than central bank forecasts

Forecasting inflation has proven difficult of late, with even the most cutting edge, state-of-the-art models utilized by central banks failing to predict the persistent lack of inflation despite falling economic slack. In order to get a sense of what's going on, we've developed a forecasting framework based on economic theory but is entirely data driven. The advantage of this over using calibrated models is that the calibrated models may reflect historical relationships that no longer hold to the same degree as the calibrations imposed.

The details of our data-driven simulations are as follows:

- Estimate an IS curve (output gap as a function of real interest rates), Phillips curve (inflation as a function of expected inflation, target, output gap or unemployment gap, and control variables), and a monetary policy reaction function (inertial Taylor rule). Parameters are estimated using seemingly unrelated regression analysis (SUR) for each region.
- Test the forecast performance of alternative measures of inflation and compare with core and headline inflation.
- Use best performing measures of inflation to forecast inflation through 2018, holding the output gap exogenous.

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