Measuring the importance of global factors in determining inflation in Israel*

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Abstract

This paper presents evidence that inflation in Israel and many OECD member states was driven largely by global factors during 2009–17. In particular, inflation in Israel was strongly correlated with that in most OECD countries in the review period of January 2009–June 2017. Furthermore, the development of inflation in most OECD countries is captured well using a model that includes two unobserved common factors. The first two factors that explain most of the co-movement in inflation among OECD countries explain roughly 80% of the variance in Israel's headline as well as core (ie excluding food and energy) inflation rates during the review period. This finding emphasises the broad-based importance of global factors in determining inflation in Israel. We find that the first factor correlates with oil prices and the trade-weighted USD exchange rate index (the DXY), but this alone does not fully explain the strong cross-country correlation – due to the importance of the second factor. These findings emphasise the importance of analysing global inflation developments as a tool for understanding headline inflation in Israel as well as its subcomponents, and may contribute to a better understanding of monetary policy measures taken in the period reviewed.

Keywords: Global inflation, dynamic factors, cluster analysis, OECD, Israel.

JEL classification: C32, E31, F41.

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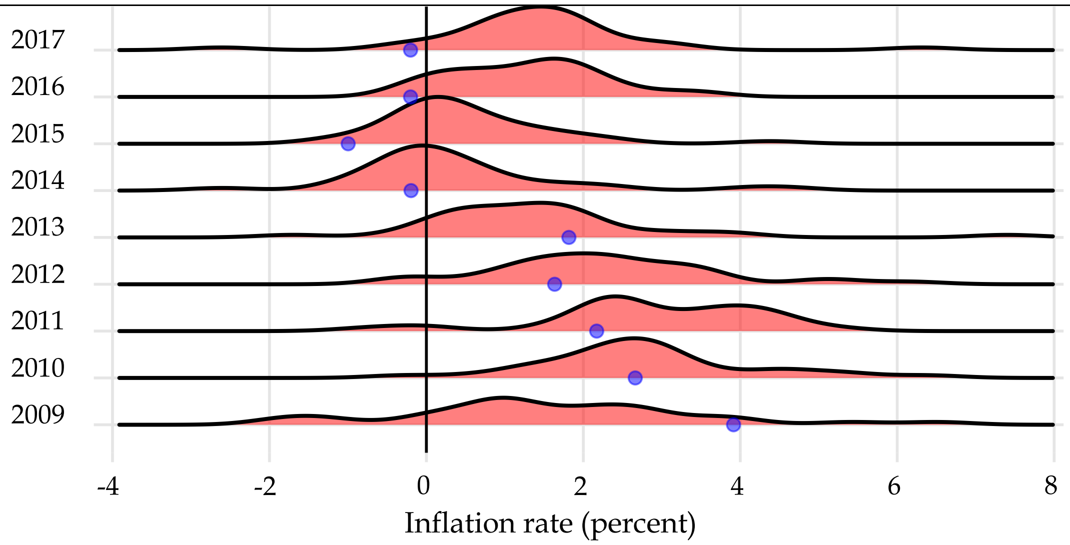
1. Introduction

The annual rate of increase in Israel's Consumer Price Index has varied considerably in the post-crisis period – peaking at 4.3% in the 12 months to March 2011 and plummeting to minus 1% in December 2015. Graph 1 presents the distribution of annual inflation in the OECD member states in 2009–17, our review period. As one may see, Israel's position in the distribution has varied considerably over the years – from the far right-hand tail in 2009 (higher inflation than in most countries) to the left-hand tail (lower inflation than in most) from 2015 onward. Israel is not, however, exceptional regarding the downward trend in inflation per se. Many OECD countries have experienced similar changes in recent years and quite a few of them, like Israel, have had to contend with a descent to negative inflation.[1] These facts are consistent with empirical studies that find a strong relationship between inflation rates in advanced economies.[2]

The empirical distribution of annual inflation rates in the OECD over time and Israel's relative position

Graph 1



Given the phenomenon described above, it is worth asking what portion of the changes in Israel's inflation rate during the review period reflects global effects. In this study, we will show that the annual inflation rates of most OECD countries displayed a significant positive correlation during the review period. We will show, using a dynamic factor model, that inflation among OECD members may be well described by two unobservable common factors that account for about two thirds of the variance in inflation among OECD countries. In addition, these two factors explain about 80% of the variance in the headline as well as core inflation rates in Israel, one

1 In 2014, for example, 15 of 35 OECD countries reported negative inflation rates.

2 See, for example, Ciccarelli and Mojon (2010), Mumtaz and Surico (2012), and Mumtaz and Surico (2012).

of the highest rates of explanation among all OECD members. The high explanatory level of the common factors persists when core measures of inflation (ie excluding energy and food) are used instead of headline inflation.

It is of the utmost importance to understand by these results the mechanisms that are responsible for the strong co-movement. This study, however, like much of the empirical literature, does not provide an unequivocal answer. Understanding the mechanisms is of vast importance in managing monetary policy; it even rests at the core of one of the leading controversies in monetary economics today (see, for example, Miles et al (2015). It is evident that developments in inflation abroad played a significant role in determining the domestic inflation rate and thus should be given much attention in the MPC's analysis.

2. Correlation among inflation rates in OECD countries[3]

Graph 2 presents the correlation coefficients among OECD countries during the review period. In the figure, red indicates a positive correlation, blue denotes a negative one, and the strength of the correlation (in absolute terms) is given by the brightness of the relevant colour and the size of the square within the cell.[4] The order of countries (on the vertical axis) is determined by the explanatory power of the first principal component (in descending order). The first principal component explains the largest share of the variance in the case of France and the smallest share in that of Norway. The deep red colour observed in most of the table in the figure means that, by and large, inflation among OECD countries is strongly and positively correlated. As for Israel, correlations are positive for 30 of the 34 states compared; the outliers are Turkey, Chile, Japan and Norway.[5]

What might have induced such a strong correlation in the development of inflation rates? The first possible explanation has to do with geographic proximity. In particular, the fact that 22 of the 35 OECD member states are European goes far in explaining the strong correlation. A second plausible explanation lies in shared structural trends and similar policies. For instance, it may be argued that the correlation among inflation rates around the world can be traced back to the global tendency towards greater competition, similar mechanisms that generate inflation expectations, similar inflation targets at the respective central banks, and similar methods used to attain them.[6] An additional explanation centres on the increasing globalisation of production and supply chains.[7] Shocks to commodity prices, particularly oil, are a salient example because they affect most developed markets simultaneously. Finally, at least some of the low inflation rates in developed markets owe their origin to the ascendancy of emerging markets. The threat of outsourcing

3 For a breakdown of the inflation data, see Appendix D.

4 The countries are ranked by the explanatory power (in descending order) of the first component regarding each country's variance, making this a principal component analysis (PCA).

5 Note that collapsing all EU states together (not shown) does not alter the picture very much: 12 of the 16 independent entities still show a positive correlation and the same four countries are outliers.

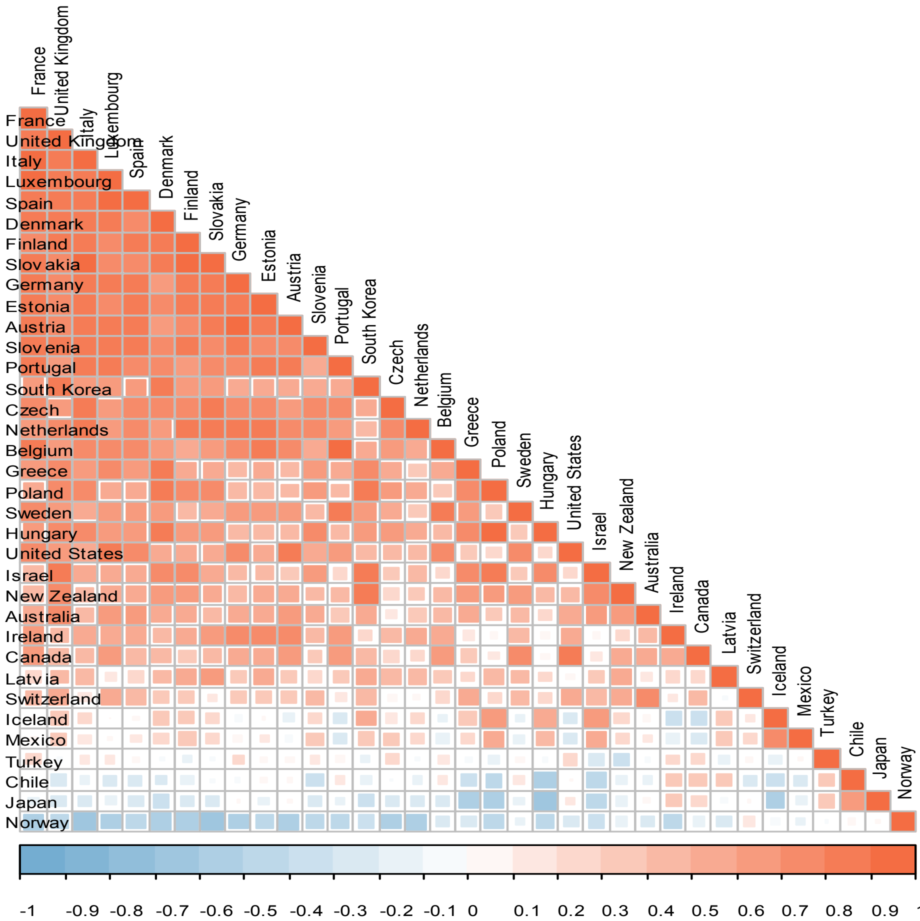
6 See, for example, Mumtaz and Surico (2009).

7 See, for example, Auer, Borio and Filardo (2017) and Auer, Levchenko and Sauré (2017).

places domestic wages under downward pressure while the free flow of cheap goods from abroad helps to keep prices of domestic goods low, both directly, due to low import prices, and indirectly, because of the threat of competition that domestic manufacturers face.[8]

Correlations among annual inflation rates of OECD member states

Graph 2



Note: This figure describes the intensity of the correlation between the annual inflation rates of the OECD countries (monthly figure, month vs. month of the previous year) in the period beginning in January 2009 and ending in June 2017. Red colour indicates a positive correlation and blue colour a negative correlation. The brightness of the colour and the size of the square in the cell indicate the strength of the relationship between each pair of countries. The order of countries is determined by the explanatory power of the first component in the PCA analysis (in descending order).

To gain some insights into the factors behind the strong correlations among most countries, one may apply contrarian reasoning, ie by focusing on the outliers, mainly the three at the bottom of the list – Japan, Norway and Chile. Japan is set apart from the other countries in one readily visible indicator: the very different nature of its inflation cycle and the monetary policy of the Bank of Japan operating in the background. Norway, in turn, is one of the world's biggest exporters of petroleum; as such, its economy is profoundly affected by volatility in global oil prices. Oil price volatility was typically acute in the review period, affecting oil importers (most of the OECD countries) and oil exporters, such as Norway, in opposite directions. Finally,

[8] This outlook has recently been termed "the internationalist view of inflation." [Link]

Chile produces about one third of the world's copper; for this reason, it is no surprise that both real activity and inflation there are strongly dependent on copper prices. Also, the presence of countries such as the United Kingdom, South Korea, Poland, the United States and Israel in the reddish part of the figure may indicate that the strong correlation does not originate exclusively in the European nature of many OECD countries.

3. Cluster analysis of national inflation rates

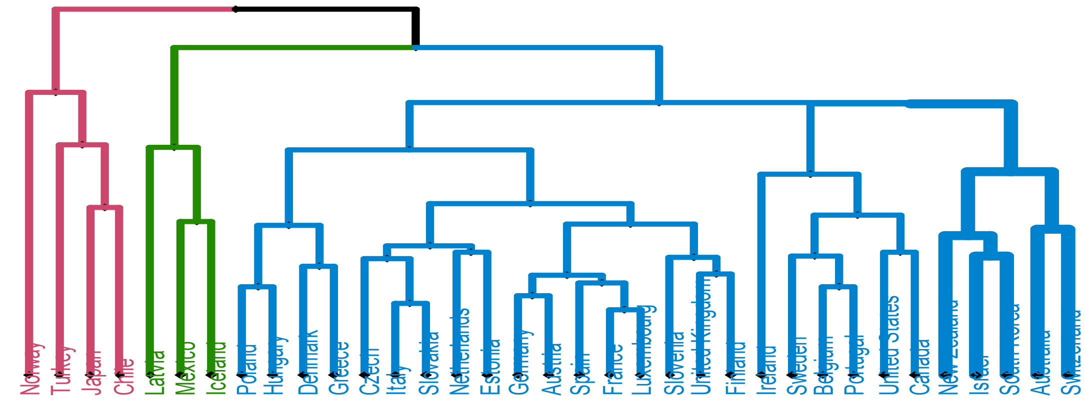
Although helpful in detecting conspicuous groups of similar countries, the eyeball test is limited in the extent to which it can capture correlation groups and assess the large number of possible combinations. A cluster analysis allows us to carry out this task with relative ease by using automatic and data-based algorithms. These algorithms accept, as a given, distance values that capture the "proximity" or "distance" between two observations in the sample and classify the countries into a predetermined number of clusters. The definition of distance that we use to cluster the annual inflation rates is based on the strength of the correlation between them. Thus, first, the correlation between the inflation rates of each pair of countries is calculated based on the entire sample. Second, this correlation is translated into distance terms.[9] Finally, the countries are sorted into a predetermined number of clusters on the basis of distance, "close" countries being aggregated and "distant" ones being separated.

The results of the cluster analysis appear in Graph 4, in which the colours signify division into three main clusters. According to this method, Norway, Turkey, Japan and Chile are separated out first (marked in blue and green). This separation is consistent with the description in Graph 2 – these four countries usually correlate negatively with the other countries – and with that in Figure 3, which shows that their inflation cycle is very different from that of the other countries. The second level of sorting separates Latvia, Mexico and Iceland (marked in green) from the other set (marked in blue). Although this separation is less visible in Graph 2 or Graph 3, it reflects, as stated, the distance of these countries from their peers in correlation terms. The largest cluster (marked in blue) contains most of the euro zone countries, the United States, as well as several small open economies with independent currencies. Israel (fourth from right) appears in the group of such small and open economies, alongside Switzerland, Australia, South Korea and New Zealand, with South Korea being the most similar to Israel.[10]

9 The distance between each pair of countries in terms of correlation between their (standardised) inflation rates, π_{it} and π_{jt}, is calculated as follows: $\text{distance}_{ij} = \sqrt{2(1-\rho_{ij})}$, where ρ_{ij} denotes a correlation coefficient lying between π_{it} and π_{jt}. For further details, see Golay et al (1998).

10 When we collapse the EU countries into one, the basic clustering groups remain similar, with Israel appearing in a cluster with South Korea, Poland and Hungary.

Classification of inflation rates in the OECD countries into clusters — Graph 3



Note: The position of each cluster and sub-cluster is based on distance in terms of correlation between inflation rates of the countries (see footnote 11). The colours of the tree branches and of the names of the countries illustrate the classification of inflation rates into three clusters. The sample period used for the estimation is January 2009 to June 2017.

Objective statistical criteria for determining the optimal number of clusters (see Charrad et al (2014)) point to the presence of, at most, two or three clusters. This, along with the fact that that majority of individual inflation rates belong to the same cluster, leads us to conclude that global rather than regional factors play an important role in explaining individual inflation rates. Accordingly, we now proceed to model OECD inflation rates using a dynamic factor model.

4. Common factor analysis

The evidence presented thus far for the strong correlation between Israel and most OECD countries is strong and raises an important question: to what extent is inflation in an individual country, specifically Israel, a global phenomenon? In other words, how much of the variance in a specific country's inflation rate can be attributed to global phenomena and, therefore, exogenous to the domestic economy, and how much to endogenous factors such as the conjunctural state of the domestic economy, the structure of economic competition, and monetary policy?

To address this issue, we use a dynamic factor model. This model assumes that the annual inflation rates of the OECD countries may be described using a finite and small number of unobserved time-varying common factors. In particular, we assume that the annual inflation rate of each OECD member state can be decomposed into two mutually orthogonal components: a shared component that includes factors common to all members of the organisation and a residual composed of factors that are relevant only to the individual country or a finite (and small) number of countries along with measurement noise.

Estimation of the global component poses a challenge because both the factors and their country-specific weights are unobserved. Nevertheless, if one assumes that the model was well designed and if one accepts several additional technical assumptions, one can estimate them using a principal component analysis (PCA).[11] Specifically, the first factor is estimated by the principal component (PC) that has the strongest ability to explain the covariance of inflation in the OECD countries. The second factor is estimated by the PC that has the second-strongest explanatory power, and so on. The contribution of each factor to explaining the inflation rate in each country in the sample is defined as the R^2 that is obtained by running its inflation rate on the estimated factor(s).

Table 1 presents the outcomes of the estimation. The covariance of inflation rates among all OECD countries that is accounted for by a single or by two factors is described on the top line. As may be seen, the first factor explains close to half of the covariance of OECD inflation rates, and the first two factors cumulatively explain 76%.[12] The explanatory power of the factors for Israel is presented on the second line of Table 1 alongside the R^2 values obtained from a regression of the inflation rate in Israel on the estimated common factors. As may be seen, the first factor explains 45% of the variance in Israel's inflation rate and the first two factors together cumulatively explain 85% (ie the marginal explanatory power of the second factor is 40%).[13, 14]

The variance in inflation rates explained by the common factors

Table 1

Dependent variable	Variance explained (R^2)	
	single factor	two factors
OECD inflation rates	0.45	0.76
	[0.39,0.51]	[0.68,0.81]
Israel's inflation rate	0.45	0.85
	[0.35,0.55]	[0.76,0.91]

Note: For inflation in the OECD countries (first row), the cumulative explanatory variance is obtained from a PCA analysis. For Israel (bottom two lines), the explained variance is defined by the R^2 value obtained from the regression of the Israeli inflation rate run on the cutoff and the factor or common factors obtained from the PCA analysis. The square brackets show a 90% confidence interval (for an explanation of the calculation method, see Appendix A). The sample period used for calculations is January 2009 to June 2017.

11 For a broad overview of a dynamic factor model and various ways of estimating it, see Stock and Watson (2016).

12 Notably, we also performed a PCA analysis on the monthly rate of change in the consumer price index (ie on monthly inflation). Here, too, we found factors that have considerable explanatory power: 36% for the first two factors at both the panel level and for Israel (see Appendix Table B4). This level of explanation, as stated, is weaker than that shown in the text. Importantly, however, the monthly rate of change is a much noisier estimate than the annual estimate, and for such a noisy estimate, it provides a non-negligible level of explanation.

13 Our results are robust to omitting Israel from the panel: we estimate an R^2 of 0.42 for a single factor and 0.80 for two factors.

14 We also ran Israel's inflation rate on a simple average of OECD inflation rates, a weighted average of OECD inflation (the weights based on size of the economy), the US inflation rate, and the euro zone inflation rate, and found that these variables have a lower explanatory power when compared with the common factors.

When comparing the explanatory power obtained for Israel with that obtained for the other OECD countries, we find that in most countries, much as in Israel, the cumulative explanatory power of two factors exceeds 50%. We also find that the first factor is very dominant in the leading euro zone countries, explaining almost all of the variance in countries such as Italy, Spain and France. The second factor, in contrast, is very silent in these countries but does stand out in countries that have independent currencies, such as Israel, Canada, Iceland and, to a lesser extent, the United Kingdom and the United States. Notably, the second factor is also dominant in countries that correlate weakly with most OECD member states, such as Japan and Chile. It is noteworthy that Israel stands out in the composition of the strength of explanatory power obtained for it. Finally, whereas in most countries, one of the first two components dominates, in Israel both components contribute in similar measure.[15] In particular, as shown in Graph A-2 in the appendix, the second factor is extremely important in explaining why Israeli inflation did not drop during the first couple of years following the Great Financial Crisis (GFC).

The estimated common factors lack predetermined labels and are estimated indirectly.[16] Nevertheless, economic theory provides us with some clues. For example, a relation between inflation, commodity prices (particularly, oil prices) and the exchange rate has attracted much attention in the literature.[17] We estimate to what extent the first and second common factors correlate with (Brent) oil prices and the USD exchange rate (using the DXY index, in which an increase denotes USD appreciation against a trade-weighted basket of currencies).[18] We find a relatively strong and positive correlation of 0.63 between the first factor, oil prices, and the DXY. Conversely, the correlation of the second factor with oil prices and the USD is essentially zero. We conclude that the first factor largely reflects changes in oil prices and the USD exchange rate. The second factor, which contributes much to explaining the variance among many countries including Israel, reflects other phenomena that are less straightforward to measure.

We now proceed to calculate the contribution of the common factors towards explaining Israel's inflation rate. Graph 4 shows Israel's annual inflation rate (black line) along with the contribution of the global component (as defined by equation 3), estimated using two factors (blue line) and a 90% confidence band (shaded gray area), where the uncertainty of the estimated contribution is with respect to the member states included in the panel. As the figure shows, Israel's inflation rate tracks the global component (the fitted value) well during the review period. Both the steep decline in inflation in 2011–16 and the turnaround that began in early 2016 correspond to the behaviour of the global component at the same time. In fact, one may cautiously say that the global component acts like a stochastic trend line around

15 In this respect, Israel to a large extent resembles Canada.

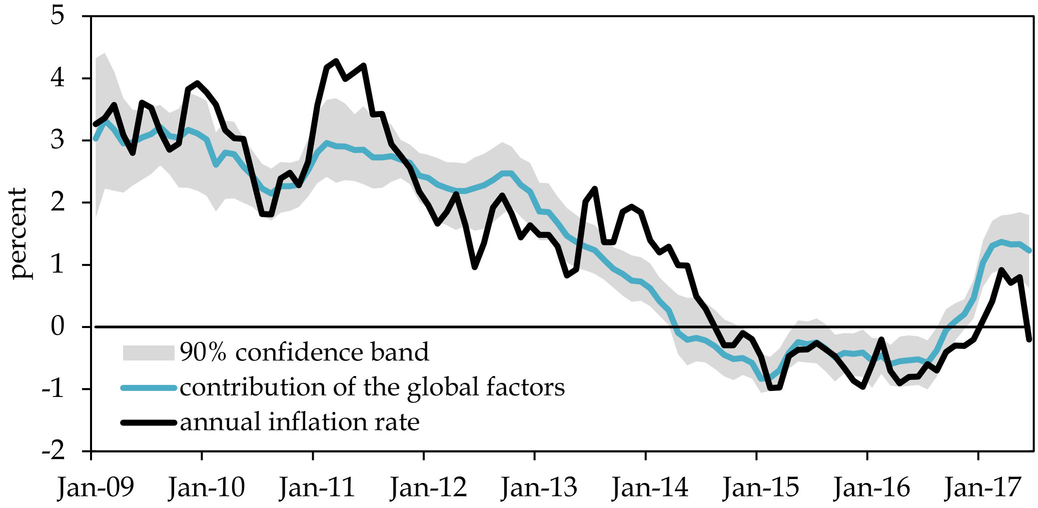
16 Unfortunately, it is much easier to determine what the common factors do not represent than what they do represent.

17 Boz et al (2017) show, for example, that the USD exchange rate is an important predictor of the volume of global trade and inflation and that countries with a relatively large share of USD-denominated import contracts feature stronger USD exchange rate transmission to consumer and producer price inflation.

18 Oil prices and the DXY were taken in terms of the annual rate of change (year-on-year).

which Israel's inflation follows. In other words, the non-global component behaves like an error-correction component.[19]

Israel's annual inflation and the contribution of the global component Graph 4



Note: This figure shows the year-on-year inflation rate in Israel and the global component (i.e.,ie the contribution of the two common factors). The shaded area around the global component indicates a 90% confidence interval (for an explanation of the calculation method, see Appendix A). The sample period used for the estimation is January 2009 to June 2017.

We also perform an analysis where we replace the panel of headline inflation rates with a panel of core inflation rates, ie inflation excluding energy and food. Although the explanatory power of the factors declines considerably for core measures of inflation, it remains high. The cumulative explanatory power of the first two factors, for example, stands at 47% as against 76% for headline OECD inflation. Surprisingly, the explanatory power for Israel remains unchanged for two factors. The first factor explains 76% of the variance in Israel's core index as against 45% for the general index. We conclude that much of the decrease in the explanatory power of the factors does trace to factors associated with energy and food. This, however, is not the whole story – the strong explanatory factor of the global component is a broader phenomenon that also characterises the "core" components of Israel's inflation.

5. Monetary policy implications

Understanding inflation dynamics is essential to designing the appropriate monetary policy response, be it the magnitude of the response or the specific tools chosen. In this study, we noted a highly correlated inflation dynamic within OECD countries since the GFC that suggests that global factors have played a major part in determining inflation developments. We do not offer a "structural" interpretation of the mechanism generating the strong correlation that we found, and, in fact, we choose

[19] This finding is consistent with the findings of Ciccarelli and Mojon (2010).

to remain relatively agnostic about the structural interpretation of the factors that has been offered.

Nevertheless, our results do allow us to discuss possible explanations and interpretations of policy measures during the review period consistent with our findings, and to discuss the implications of these explanations for future policy. One possible interpretation of our findings is that policymakers were less responsive to external and possibly transitory shocks because they construed them in real time as temporary supply side shocks. Conversely, inflation may have been largely of foreign origin, and hence hard to control for domestic policymakers.[20]

Given the current inflation targeting regime, if the first interpretation of events (reluctance to respond) is correct, and if at least some of the supply-side shocks prove, in practice, to have been more persistent and associated with phenomena of a more structural nature such as a global upward trend in competitiveness or greater globalisation of supply chains, this should be taken into account and the risk of low inflation expectations becoming entrenched should be borne in mind. Conversely, if the second explanation (inability to respond) is correct, additional steps or more vigorous steps may be necessary to return inflation to the desired target within a reasonable time frame. These measures, however, might come with a few risks, foremost among them the financial stability risk that is sometimes associated with monetary expansion.

It is important to emphasise, however, that there is no evidence that the public lost confidence, during the review period, in the ability of policymakers (domestic and foreign) to meet the targets. Indeed, medium- to long-run inflation expectations remained firmly anchored within the target range throughout the review period.

6. Conclusions

In this study, we presented empirical support for the claim that global factors effectively explain inflation in Israel and in most OECD countries. We found that roughly 80% of variance in inflation in Israel during the review period – in headline inflation and inflation excluding energy and food – may be explained with the help of two common factors, one of which is correlated with oil prices and the DXY index. Admittedly, the analysis is not based on a structural model; therefore, it provides little information about the mechanism through which the strong correlation that we found came about. It does, however, allow us to offer two alternative interpretations of the monetary policy measures that were taken during the review period. Irrespective of these interpretations, we conclude that these findings emphasise the importance of analysing global consumer price index developments as a tool for understanding the underlying trend of headline inflation in Israel as well as its subcomponents.

[20] See Woodford (2017) for a theoretical discussion on the conditions under which national central banks are able to control inflation within their borders.

References

Auer, R, C Borio and A Filardo (2017): "The globalisation of inflation: the growing importance of global value chains", *CEPR Discussion Papers*, no 11905.

Auer, R, A Levchenko, and P Sauré (2017): "International inflation spillovers through input linkages", *CEPR Discussion Papers*, no 11906.

Boz, E, G Gopinath and M Plagborg-Møller (2017): "Global trade and the dollar", *NBER Working Papers*, no 23988.

Charrad, M, N Ghazzali, V Boiteau and A Niknafs (2014): "NbClust: An R package for determining the relevant number of clusters in a data set", *Journal of Statistical Software*, vol 61, no 6, pp 1–36.

Ciccarelli, M and B Mojon (2010): "Global inflation", *The Review of Economics and Statistics*, vol 92, no 3, pp 524–35.

Golay, X, S Kollias, G Stoll, D Meier, A Valavanis and P Boesiger (1998): "A new correlation-based fuzzy logic clustering algorithm for fMRI", *Magnetic Resonance in Medicine*, vol 40, no 2, pp 249–60.

Miles, D, Panizza, U, Reis, R and À Ubide (2015): "And yet it moves: inflation and the great recession", *Geneva Report on the World Economy*, vol 19, CEPR.

Moench, E, S N and S Potter (2013): "Dynamic hierarchical factor models", *Review of Economics and Statistics*, vol 95, no 5, pp 1811–17.

Montero, P and J Vilar (2014): "TSclust: An R Package for time series clustering", *Journal of Statistical Software*, vol 62, no 1, pp 1–43.

Mumtaz, H and P Surico (2012): "Evolving International Inflation Dynamics: World and Country-specific Factors", *Journal of the European Economic Association*, vol 10, no 4, pp 716–34.

——— (2009): "The transmission of international shocks: A factor-and augmented VAR approach", *Journal of Money, Credit and Banking*, vol 41, no 1, pp 71–100.

Neely, C and D Rapach (2011): "International comovements in inflation rates and country characteristics", *Journal of International Money and Finance*, vol 30, no 7, pp 1471–90.

Politis, D and J Romano (1994): "Large sample confidence regions based on subsamples under minimal assumptions", *Annals of Statistics*, vol 22, no 4, pp 2031–50.

Stock, J and M Watson (2016): "Factor models and structural vector autoregressions in macroeconomics", in J Taylor and H Uhlig (eds), *Handbook of Macroeconomics*, vol 2, Elsevier, pp 415–525.

Sussman, N and O Zohar (2016): "Has inflation targeting become less credible? oil prices, global aggregate demand and inflation expectations during the global financial crisis", *CEPR Discussion Papers*, no 11535.

Woodford, M (2007): "Globalization and monetary control", *NBER Working Papers*, no 13329.

Appendix A: Evaluating uncertainty in estimating explained variance and the global component

The estimates that we used to evaluate (1) the variance in a panel of inflation rates, (2) the global factor in inflation in Israel, and (3) the explained variance obtained from the PCA analysis are ultimately statistical. The estimates are subject to uncertainty that derives, among other things, from the use of a finite sample of countries that is not particularly large in the cross-sectional sense (35).[21] In particular, these estimates may be sensitive to the deletion of one or more countries from the sample. Here we attempt to quantify this uncertainty by means of a subsampling simulation (Politis and Romano (1994)), using the existing data set.

The following algorithm is used in the simulation:

1. Randomly delete K countries from the thirty-five countries in the sample[22] (so that $K<35$).
2. Perform a PCA to extract the P factors that explain most of the variance.[23]
3. Preserve the cumulative explanation of the variance in the first P factors.
4. Estimate a regression of domestic inflation on the factors and retain the predicted value (the "global factor") and R^2.
5. Repeat steps (1)–(4) B times.

Once the algorithm is run, we will have B simulated cumulative explanation of the factors (ie R^2 values), and B simulated time-series of the global component. By using the values obtained from the simulation, we can evaluate the existing uncertainty in the estimate of the explained variance and the global variable by tracing it to the selection of countries in the sample. For example, we define a 90% confidence band of the estimate of explained variance as the distance between the fifth percentile and the 95th percentile of the series of R^2's obtained from the simulation.

Graph A-1 presents the results of the simulation for a selection of K = 25 countries, P = 1,2,3 factors, and B = 1,999 replications.[24] The figure shows the scatter of the estimate of explained variance—the R^2 values—that were obtained by running the regression on the simulated data when the global factor was estimated by means of one factor (upper left-hand panel in the figure), two factors (upper right-hand panel), and three factors (lower panel).[25] As one may see, the median values in the three versions of the estimation (0.47, 0.83, and 0.88) closely resemble those obtained

[21] The justification for using PCA estimates is based, among other things, on the assumption that both the number of series and the number of observations in each series and in the panel tend to infinity.

[22] Israel need not be in the group of countries selected out. If we were to restrict the inclusion of Israel, the confidence band that we would obtain would probably be narrower than that actually found.

[23] The number of commonalities, P, is constant in each replication.

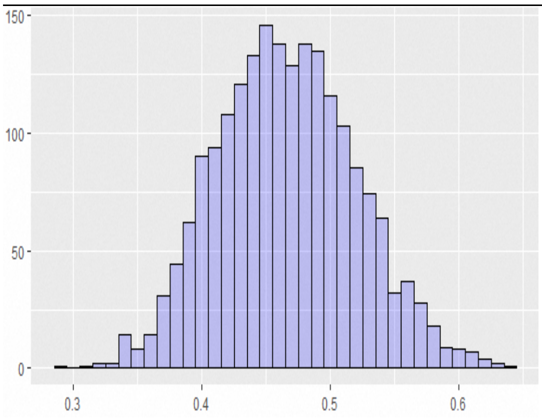
[24] The number of unrepeated combinations that may be extracted from a selection of 25 out of the 35 countries is 183,579,396. The simulation is used to simplify the computational complications that would arise if each of these possibilities were run.

[25] The distribution of R^2 is not necessarily symmetrical. Therefore, to evaluate the uncertainty surrounding the estimate, it is best to use median values and not standard deviations.

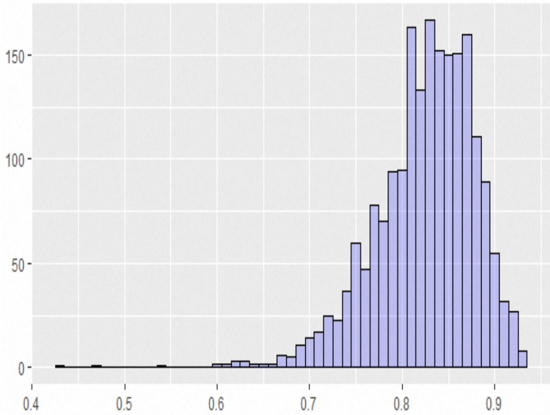
from the actual estimation (Table 1 in the study proper). Similarly, 90% of the estimates that were based on one factor fall into the 0.38–0.57 range, 90% of those based on two factors fall into the 0.74–0.89 range, and 90% of those based on three factors fall into the 0.79–0.93 range. The interval between the fifth and ninety-fifth percentiles yields an estimate of a 90% confidence band for the actual estimates obtained in Table 1 of the study proper.

Uncertainty in estimating the extent of variance of fluctuation in Israel that is explained by the global factor

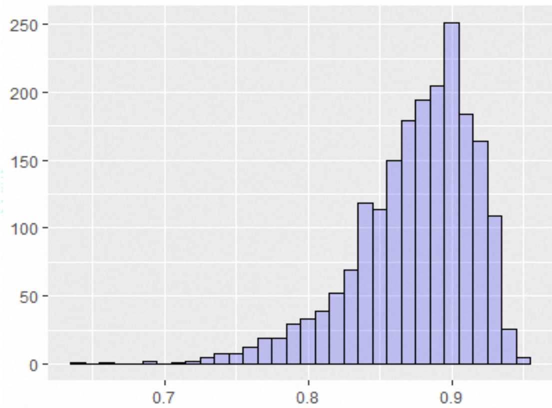
Graph A-1



One factor



Two factors

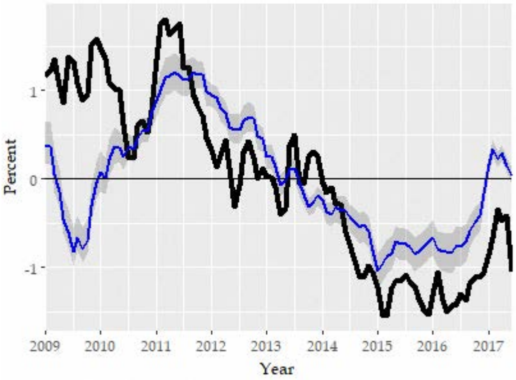


Three factors

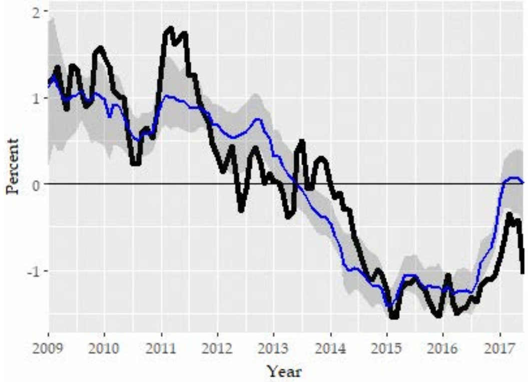
Graph A-2 estimates the global component that the simulation yielded—this time for a selection of K = 25 countries, P = 1,2,3 factors, and B = 1,999 replications. Specifically, the blue line in each subfigure shows the median value of the estimates and the shaded area captures the values between the fifth and 95th percentiles. As may be seen, the estimates of the global component are relatively accurate, although the larger the number of factors used for the estimation, the more uncertainty there is surrounding the estimator of the global component (as one would expect). These results demonstrate the low sensitivity of our estimates to the set of countries in the sample, at least in respect of the trend.

Uncertainty in estimating the global component of inflation in Israel

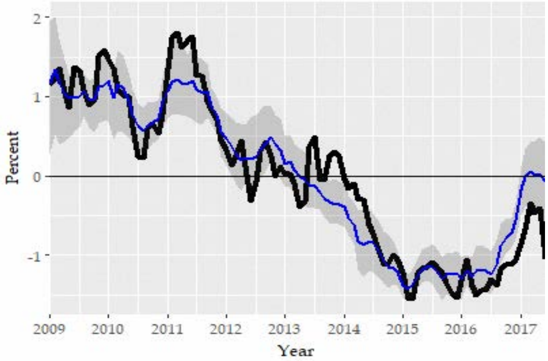
Graph A-2



One factor



Two factors



Three factors

Appendix B: Additional Sensitivity Tests

B.1 Sensitivity to exclusion of Israel from the panel

Variance in inflation rates explained by factors measured, not including Israel

Table B-1

Explained variable	Variance explained (R^2) by		
	1 factor	2 factors	3 factors
Inflation, total	0.44	0.80	0.87
	[0.36, 0.51]	[0.69, 0.84]	[0.79, 0.93]
Inflation, tradable prices	0.56	0.61	0.70
	[0.51, 0.61]	[0.54, 0.66]	[0.59, 0.81]
Inflation, non-tradable prices	0.19	0.71	0.74
	[0.13, 0.26]	[0.56, 0.82]	[0.59, 0.87]

Notes: The table presents the variance in annual inflation—total, tradable, and non-tradable—that is explained by the global factor. The explained variance is defined by an R^2 value obtained by running a regression of the relevant inflation rate on an intercept and on the factor/factors. The factors were estimated by means of a panel that does not include Israel's inflation rate. A 90 percent% confidence band appears in the brackets. (The method of calculation is explained in Appendix A.) The sample used for the calculations is January 2009–March 2017.

Sources: CBS and OECDstat.

B.2 Sensitivity to estimation period

Variance in inflation rates explained by factors in sample beginning in January 2010

Table B-2

Explained variable	Variance explained (R^2) by		
	1 factor	2 factors	3 factors
Inflation, total	0.76	0.85	0.89
	[0.71, 0.80]	[0.77, 0.93]	[0.81, 0.93]
Inflation, tradable prices	0.67	0.84	0.84
	[0.62, 0.72]	[0.72, 0.91]	[0.75, 0.89]
Inflation, non-tradable prices	0.71	0.74	0.83
	[0.66, 0.75]	[0.73, 0.83]	[0.74, 0.87]

Notes: The table presents the variance in annual inflation—total, tradable, and non-tradable—that is explained by the global factor. The explained variance is defined by an R^2 value obtained by running a regression of the relevant inflation rate on an intercept and on the factor/factors. The factors were estimated by means of a panel that does not include Israel's inflation rate. A 90 percent% confidence band appears in the brackets. (The method of calculation is explained in Appendix A.) The sample used for the calculations is January 2010–March 2017.

Sources: CBS and OECDstat.

Variance in inflation rates explained by factors in sample beginning in January 2008

Table B-3

Explained variable	Variance explained (R^2) by		
	1 factor	2 factors	3 factors
Inflation, total	0.61	0.86	0.90
	[0.53, 0.67]	[0.61, 0.69]	[0.84, 0.93]
Inflation, tradable prices	0.64	0.69	0.70
	[0.59, 0.67]	[0.64, 0.72]	[0.66, 0.74]
Inflation, non-tradable prices	0.37	0.72	0.87
	[0.31, 0.44]	[0.46, 0.88]	[0.75, 0.88]

Notes: The table presents the variance in annual inflation—total, tradable, and non-tradable—that is explained by the global factor. The explained variance is defined by an R^2 value obtained by running a regression of the relevant inflation rate on an intercept and on the factor/factors. The factors were estimated by means of a panel that does not include Israel's inflation rate. A 90 percent% confidence band appears in the brackets. (The method of calculation is explained in Appendix A.) The sample used for the calculations is January 2008–March 2017.

Source: CBS and OECDstat.

B.3 Sensitivity to the type of inflation used

Variance in different definitions of inflation rates explained by factors measured

Table B-4

Explained variable	Variance explained (R^2) by		
	1 factor	2 factors	3 factors
a. Annual inflation			
35 OECD countries	0.45	0.76	0.84
	[0.39, 0.51)	[0.68, 0.81]	[0.78, 0.87]
Israel	0.45	0.85	0.90
	[0.35, 0.55]	[0.76, 0.91]	[0.82, 0.95]
b. Annual inflation, HP filtered			
35 OECD countries	0.40	0.54	0.65
	[0.34,0.46]	[0.49,0.60]	[0.60,0.69]
Israel	0.16	0.24	0.27
	[0.10,0.24]	[0.14,0.43]	[0.08,0.66]
c. Annual inflation, linearly detrended			
35 OECD countries	0.56	0.66	0.74
	[0.50,0.64]	[0.60,0.73]	[0.69,0.80]
Israel	0.35	0.35	0.54
	[0.29,0.41]	[0.30,0.58]	[0.33,0.73]
d. Monthly inflation			
35 OECD countries	0.30	0.37	0.43
	[0.27, 0.35]	[0.34, 0.43]	[0.37, 0.53]
Israel	0.21	0.36	0.44
	[0.10, 0.35]	[0.23, 0.51]	[0.36, 0.55]

Notes: The explained covariance of inflation in the OECD countries is obtained through a PCA analysis for Israel. Explained variance is defined by an R^2 value obtained by running a regression of Israel's inflation rate (month on year-earlier month or month on previous month) on an intercept and on the factor/factors obtained through the PCA analysis. A 90 percent% confidence band appears in the brackets. (The method of calculation is explained in Appendix A.) The sample used for the calculations is January 2009–June 2017.

Source: OECDstat.

B.4 Correlations of the common factors

Correlation among factors and oil prices and USD exchange rate — Table B-5

	F1	F2	Oil	DXY
F_1	—			
F_2	0	—		
Oil	0.63	0.01	—	
DXY	-0.57	0.07	-0.87	—

Notes: The table presents correlation coefficients for the first two common factors (marked by F_1, F_2), Oil, and DXY. All variables are expressed in terms of annual rates of change (month on year-earlier month). The underlying sample period is January 2009–June 2017.

Source: OECDstat.

B.5 Factor analysis for core, tradable, and non-tradable inflation

Explanatory power of factors for variance in inflation rates, excluding food and energy — Table B-6

Explained variable	Variance explained (R^2) by		
	1 factor	2 factors	3 factors
Inflation in OECD countries	0.31	0.47	0.61
	[0.27, 0.35]	[0.44, 0.53]	[0.57, 0.63]
Inflation in Israel	0.76	0.81	0.90
	[0.60, 0.85]	[0.63, 0.91]	[0.76, 0.95]

Notes: The explained covariance of inflation in the OECD countries is obtained through a PCA analysis for Israel. Explained variance is defined by an R^2 value obtained by running a regression of Israel's inflation rate on an intercept and on the factor/factors obtained through the PCA analysis. A 90 percent% confidence band appears in the brackets. (The method of calculation is explained in Appendix A.) The sample used for the calculations is January 2009–June 2017.

Source: OECDstat.

Explanatory power of factors for variance in tradable and non-tradable inflation

Table B-7

Explained variable	Variance explained (R^2) by		
	1 factor	2 factors	3 factors
Inflation, total	0.45	0.85	0.90
	[0.35, 0.55]	[0.76, 0.91]	[0.82, 0.95]
Inflation, tradable G&S	0.56	0.62	0.70
	[0.50, 0.62]	[0.56, 0.68]	[0.62, 0.82]
Inflation, non-tradable G&S	0.20	0.75	0.77
	[0.14, 0.29]	[0.32, 0.87]	[0.64, 0.89]

Notes: The table presents the variance in annual inflation—total, tradable, and non-tradable—that is explained by the global component. The explained variance is defined by an R^2 value obtained by running a regression of the relevant inflation rate on an intercept and on the factor/factors. A 90 percent% confidence band appears in the brackets. (The method of calculation is explained in Appendix A.) The sample used for the calculations is January 2009–June 2017.

Source: CBS and OECDstat.

Appendix C: Common factor or dominant country?

One possible critique of the use of the factor model and, particularly, the use of PCA for estimation purposes is that the strong correlation observed may have been produced by means of one country or a small number of countries that effectively dictated the pace of all the others. In the extreme case, one bloc of countries (e.g., the United States and Germany) is ostensibly the factor that dictates the inflation rates of all the rest.

To test this hypothesis, we ran for each country separately a regression of the country's inflation rate on the inflation rates of the other OECD member states and used a statistical method to select relevant variables for the regression, so that "important" variables would be non-zero and "unimportant" ones zeroed. Formally, we estimated the following model for each country:

$$\pi_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j \pi_{jt} + \varepsilon_{it}, \qquad k \neq i,$$

where in our case k = 34 is the number of countries (apart from country i) in the sample. To select the relevant variables, we used the LASSO estimator, which sustains the following condition:

$$\hat{\beta}_{\lambda}^{LASSO} = \arg \max_{\beta_0, \beta_1, \ldots, \beta_k} \sum_{t=1}^{T} \left(\pi_{it} - \beta_0 + \sum_{j=1}^{k} \beta_j \pi_{jt} \right)^2 + \lambda \sum_{j=1}^{k} |\beta_j|$$

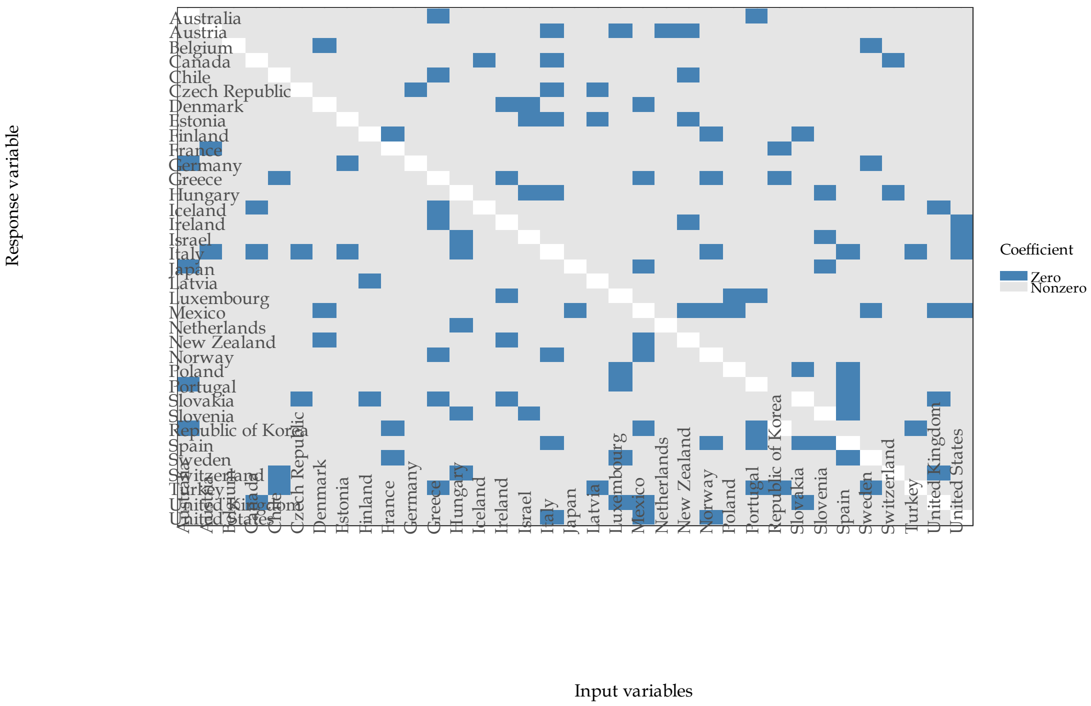
The limitation that appears in this formulation, $\lambda \sum_{j=1}^{k} |\beta_j|$, "forces" the model to zero some of the coefficients.[26] When $\lambda = 0$, ie when the "penalty" for breaching the limit is zero, the LASSO estimates for β_j are identical to ordinary OLS estimates.

The only remaining task in estimating the model is to choose a value for λ. To do this, we ran the model for values of λ between zero and 1 and chose the λ that led to the lowest average AIC value (for the full set of countries).[27] The value chosen for λ stood at 0.0008, at which an average AIC value of 157.9 was obtained. The choice of a value very close to zero as the optimal one (in accordance with the AIC criterion) already indicates that our LASSO estimates will be very close to the OLS estimates; ie one should expect not to obtain too many zeroed estimates.

Figure C-1 presents the results of the estimation. The explained variables (inflation rates parsed by individual countries) appear on the y-axis and the explanatory variables (inflation rates in all countries apart from the explained country) are arrayed on the x-axis. A gray cell in the matrix indicates that the coefficient for that country is non-zero; a blue cell represents a zeroed coefficient. As the figure demonstrates clearly, most coefficients of the countries in all regressions are non-zero, giving evidence that the sparsity assumption is probably a poor fit in our case. Namely, it does not stand to reason that one country or a small number of countries dictates the pace.

LASSO coefficient matrix

Graph C-1



26 This contrasts with ridge estimators, for example, which merely compress the coefficients toward zero without forcing the issue.

27 The AIC value decreases as the sum of the squares of the deviations of the model increases and increases as the number of explanatory values in the regression rises. The optimal AIC value is the lowest.

Appendix D: Data

D.1 Inflation in OECD countries

In this study, we used monthly data to determine the annual inflation rate (month on year-earlier month) and monthly data for the period between January 2009 and June 2007. Our source of data was OECD.Stat.[28] Data for all countries are monthly except for Australia and New Zealand, for which they are quarterly. To convert the quarterly data into monthly data, linear interpolation was used. Table D-1 presents comparative statistics of the data on the basis of the sample and Figure D-1 graphs the (standardised) data for each country.

[28] For the list of OECD member states, see http://www.oecd.org/about/membersandpartners/

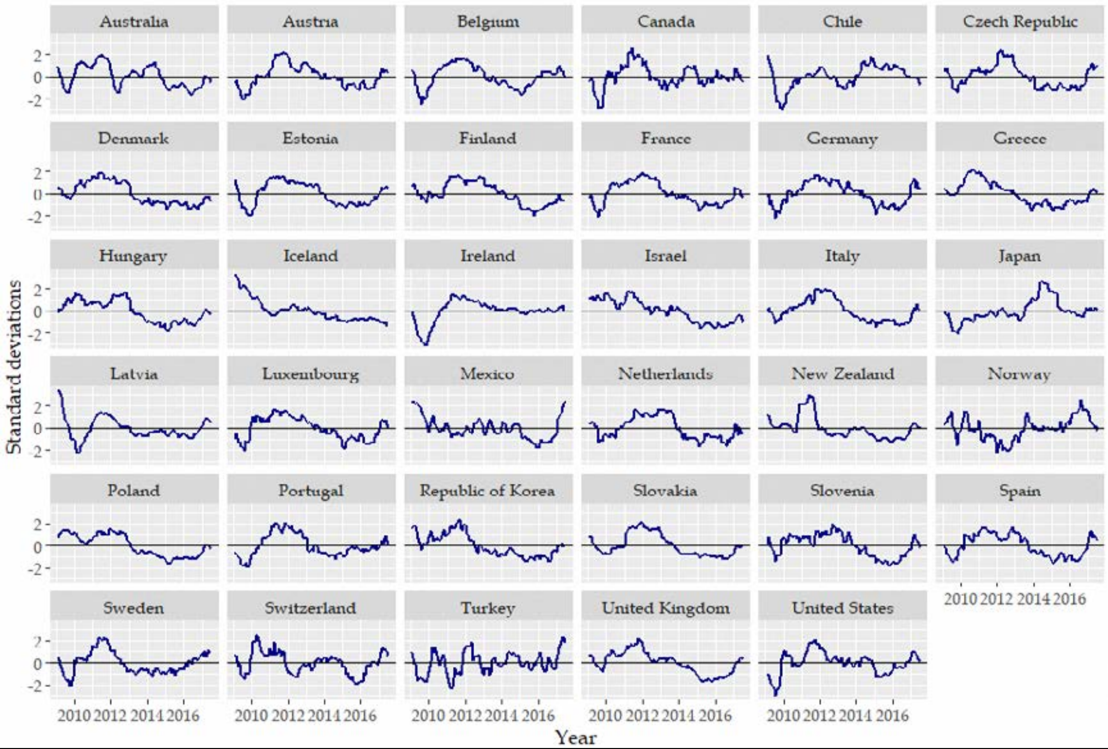
Comparative statistics: Annual inflation rates in OECD countries, January 2009–June 2016

Table D-1

Countries	Mean	Median	Max	Min.	Std. Dev.
Australia	2.2	2.1	3.5	1	0.7
Austria	1.7	1.7	3.6	-0.3	0.9
Belgium	1.6	1.7	3.8	-1.7	1.3
Canada	1.5	1.4	3.7	-0.9	0.8
Chile	3	3	6.3	-2.3	1.7
Czech Republic	1.4	1.3	3.7	-0.1	1
Denmark	1.3	1	3.1	-0.1	0.9
Estonia	1.9	2	5.7	-2.1	2.3
Finland	1.2	1	4	-1.6	1.3
France	0.9	0.8	2.5	-0.7	0.8
Germany	1.1	1.2	2.4	-0.5	0.8
Greece	0.8	0.6	5.6	-2.9	2.3
Hungary	2.6	2.7	6.6	-1.5	2.3
Iceland	4.3	3.3	18.6	0.8	3.5
Ireland	-0.1	0.2	3.1	-6.5	2.1
Israel	**1.4**	**1.5**	**4.3**	**-1**	**1.6**
Italy	1.2	1.2	3.4	-0.6	1.2
Japan	0.2	0	3.7	-2.5	1.3
Latvia	1.4	0.7	9.8	-4.2	2.4
Luxembourg	1.5	1.5	3.7	-0.7	1.2
Mexico	3.9	3.7	6.3	2.1	1
Netherlands	1.5	1.4	3.1	-0.2	0.9
New Zealand	1.6	1.5	5.3	0.1	1.2
Norway	2.1	2	4.4	0.1	0.9
Poland	1.7	1.8	4.8	-1.3	2
Portugal	1	0.7	4.2	-1.7	1.5
Slovakia	1.3	1	4.6	-0.9	1.6
Slovenia	1.1	1.3	3.3	-0.9	1.1
South Korea	2	1.6	4.7	0.4	1.1
Spain	1	0.8	3.8	-1.4	1.5
Sweden	0.7	0.5	3.4	-1.9	1.2
Switzerland	-0.2	-0.2	1.4	-1.4	0.6
Turkey	7.9	7.9	11.9	4	1.7
United Kingdom	2.2	2.4	5.2	-0.1	1.4
United States	1.4	1.5	3.9	-2.1	1.2
All	1.7	1.5	18.6	-6.5	2.1

Source: OECDstat.

Annual inflation rates, OECD countries Graph D-1

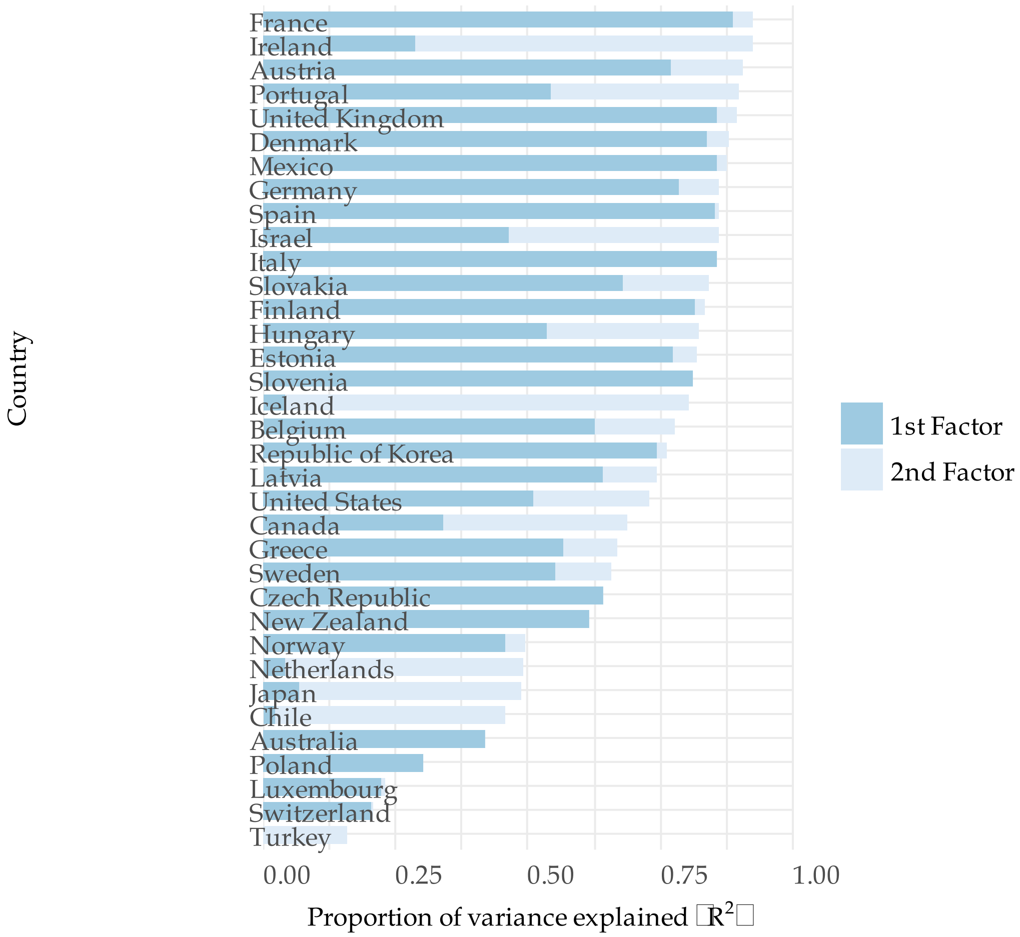


Source: OECDstat.

Appendix E: Additional factor analysis results

Marginal and cumulative contribution of factors to the explanation of inflation in OECD countries

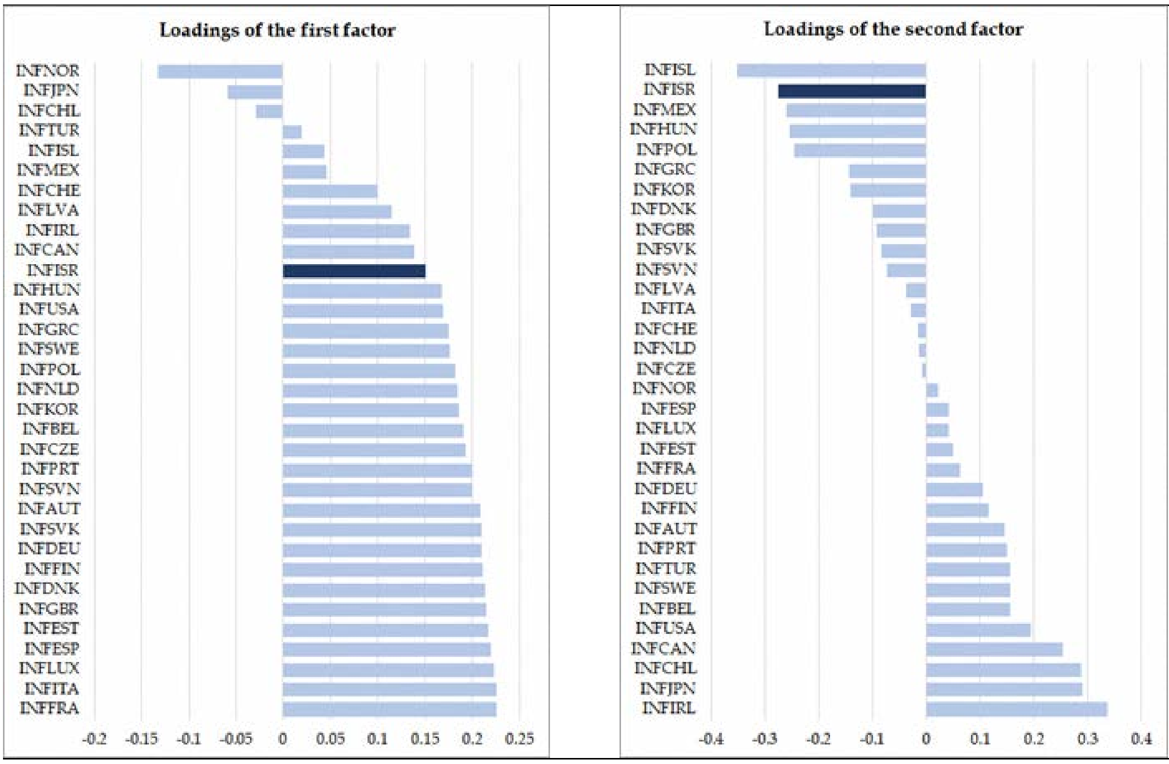
Graph E-1



Notes: The figure presents the marginal R^2 values from a regression of the annual inflation rate in each country on a constant and the first two common factors. The length of each bar indicates the total variance explained by the two factors. The sample period used for the estimation is January 2009–June 2017.

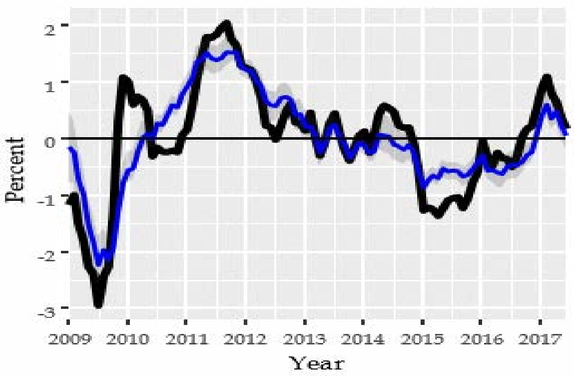
Sensitivity of individual inflation rates to the common factors

Graph E-2

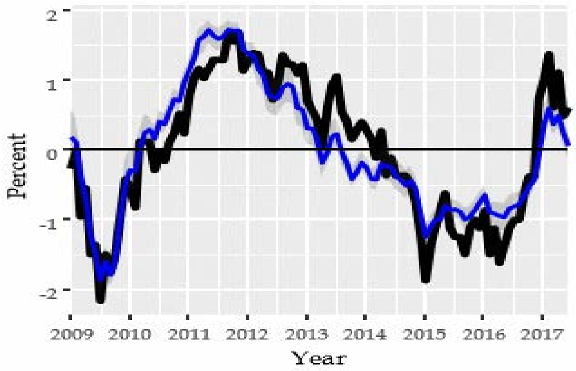


Annual inflation in selected countries and the contribution of the global component, obtained by a latitudinal approach

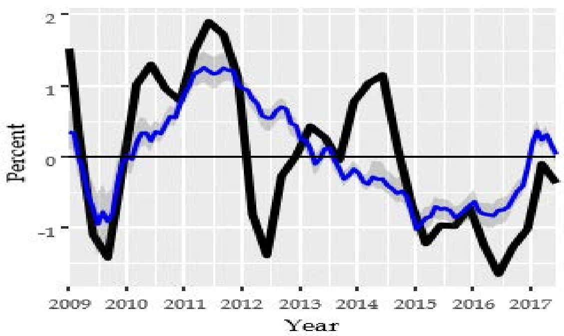
Graph E-3



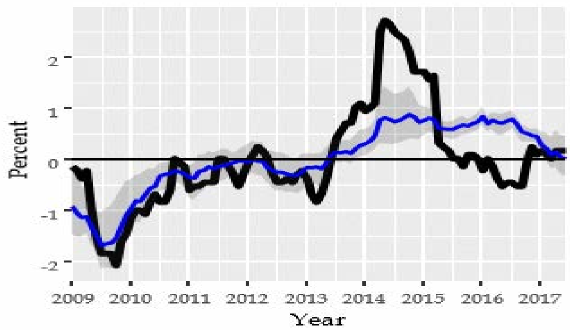
(a) United States



(b) Germany



(c) Australia



(d) Japan