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Advance Warning Indicators of Past Severe GDP per Capita Recessions in Turkey

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ADVANCE WARNING INDICATORS OF PAST SEVERE GDP PER CAPITA RECESSIONS IN TURKEY

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Abstract/Resumé

Advance Warning Indicators of Past Severe GDP per Capita Recessions in Turkey

The global financial crisis and its high economic and social costs have revived academic and policy interest in "early warning indicators" of crises. This paper aims to investigate the performance of vulnerability indicators as advance warning indicators of past severe GDP per capita recessions in Turkey. It draws on the recently established database of vulnerability indicators (Röhn et al., 2015) and employs the signalling approach as in Hermansen and Röhn (2015) complemented by visual inspections to detect vulnerability indicators that performed particularly well in the Turkish context. The evidence suggests that an index of the global stock market performs extremely well in the Turkish context. This index, which could be interpreted as a proxy for the risk appetite of global investors, exceeded its critical threshold before almost all past severe GDP per capita recessions in Turkey while sending only very few false alarms. Among domestic indicators, large positive deviations of household credit and the domestic stock market from trend also perform relatively well in signalling subsequent past severe GDP per capita recessions. The evidence is broadly robust to considering a more homogenous set of lower income OECD countries when defining the critical thresholds.

This Working Paper relates to the 2016 OECD Economic Survey of Turkey (http://www.oecd.org/eco/surveys/economic-survey-turkey.htm).

JEL classification codes: E32; E44; E51; F47; O5

Keywords: Resilience, early warning indicators, vulnerabilities, imbalances, severe recessions, crises, Turkey.

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Indicateurs d'alerte des récessions sévères passées en Turquie

La crise financière mondiale et ses coûts économiques et sociaux élevés ont ravivé l'intérêt académique et politique pour les « indicateurs d'alerte rapide » des crises. Ce document vise à étudier la performance des indicateurs de vulnérabilité comme indicateurs d'alerte des récessions sévères passées en Turquie. Il se fonde sur un nouvel ensemble d'indicateurs de vulnérabilité récemment établi (Röhn et al., 2015), et emploie la méthode de signalisation utilisée dans Hermansen et Röhn (2015), complétée par des inspections visuelles pour détecter des indicateurs de vulnérabilité ayant particulièrement bien fonctionné dans le contexte turc. Les résultats indiquent que l'indice du marché boursier mondial performe extrêmement bien dans le cas turc. Cet indice, qui pourrait être interprété comme un proxy de l'appétit pour le risque des investisseurs mondiaux, a dépassé son seuil critique avant presque toutes les récessions sévères passées en Turquie. Il a envoyé très peu de fausses alarmes. Parmi les indicateurs intérieurs, de grands écarts positifs des crédits aux ménages, et du marché boursier par rapport aux tendances fonctionnent aussi relativement bien. Les résultats sont dans l'ensemble robustes à la considération d'un ensemble plus homogène de pays à faible revenu de l'OCDE dans la définition des seuils critiques.

Ce Document de travail se rapporte à l'Etude économique de l'OCDE de la Turquie 2016 (http://www.oecd.org/fr/eco/etudes/etude-economique-turquie.htm).

Classification JEL: E32; E44; E51; F47; O5

Mots clefs: Résilience, indicateurs d'alerte rapide, vulnérabilités, déséquilibres, récessions sévères, crises, Turquie.

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ADVANCE WARNING INDICATORS OF PAST SEVERE GDP PER CAPITA RECESSIONS IN TURKEY

By Oliver Röhn[1]

Introduction

1. The global financial crisis and its high economic and social costs have revived academic and policy interest in "early warning indicators" of crises (e.g. Rose and Spiegel, 2011; Frankel and Saravelos, 2012, Alessi and Detken, 2011; Lo Duca and Peltonen, 2013 among many others). Despite recent methodological improvements of early warning models, predicting the timing of crises remains extremely difficult. Early warning models' most important value-added is to identify variables (or "early warning indicators") that should be monitored to detect risks. Vulnerability indicators can thus be a valuable input for monitoring country-specific economic risks, but should be complemented with other monitoring tools, including expert judgement.

2. This paper aims to investigate the performance of vulnerability indicators as advance warning indicators of past severe GDP per capita recessions in Turkey. In order to do so, the paper draws heavily on recent OECD work of the Resilience workstream of the Economics Department. Röhn et al. (2015) establish a database of more than 70 vulnerability indicators that are identified as particularly relevant for OECD countries based on a thorough review of the most recent evidence from the early warning literature and lessons learned from the global financial crisis. The indicators are grouped into five areas of domestic vulnerabilities: i) financial sector imbalances, ii) non-financial sector imbalances, iii) asset market imbalances, iv) public sector imbalances, v) external sector imbalances. An additional international "spillovers, contagion and global risks" category aims at capturing vulnerabilities that could transmit from one country to other countries. Hermansen and Röhn (2015) provide empirical evidence on the usefulness of these vulnerability indicators in predicting severe GDP per capita recessions and crises in OECD countries. In this paper we draw on the new database of Röhn et al. (2015) and apply the same methodology as in Hermansen and Röhn (2015). In particular, we employ the signalling approach, a commonly used methodology, to detect vulnerability indicators that could perform particularly well in the Turkish context. According to this approach a vulnerability indicator issues a warning signal of an upcoming severe GDP per capita recession if the indicator exceeds or falls below a threshold. We rely on the critical thresholds Hermansen and Röhn (2015) identified over the sample of OECD countries.

3. The evidence in this paper suggests that several indicators tend to provide early warning signals of past severe GDP per capita recessions in Turkey even as they issue only a limited number of false alarms. An index of the global stock market performs extremely well in the Turkish context. This index exceeded the critical threshold before almost all severe GDP per capita recessions in Turkey. This indicator could be viewed as a proxy for the risk appetite of global investors. Among domestic indicators, large positive deviations of household credit and the domestic stock market from trend also perform relatively well in signalling past severe GDP per capita recessions. The evidence is broadly robust to considering a more homogenous set of lower income OECD countries when defining the critical thresholds. In that case we find that external imbalance indicators perform somewhat better compared to the baseline.

1 . The author is a member of the Economics Department of the OECD. He would like to thank his colleagues: Aida Caldera Sanchez, Alain de Serres, Rauf Gönenç, Mikkel Hermansen, Vincent Koen, Catherine L. Mann, Jean-Luc Schneider and Cyrille Schwellnus for helpful comments and Caroline Abettan for technical and editorial assistance.

Data and empirical methodology

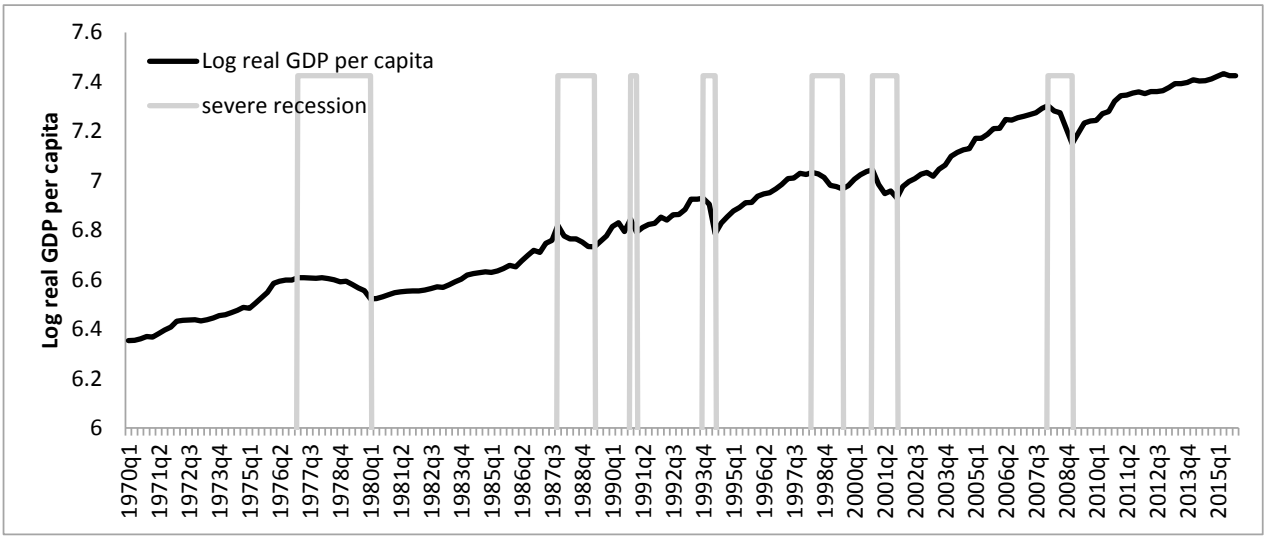
Severe GDP per capita recessions as costly economic events

4. In a first step it is necessary to define the economic events that the vulnerability indicators are meant to predict in the Turkish context to be able to assess their performance. Here we follow Hermansen and Röhn (2015) and use severe GDP per capita recessions as costly events to predict. The Bry and Boschan (1971) algorithm is applied to identify business cycle peaks and troughs in real GDP per capita in levels over the period 1970Q1-2015Q2. Next, severe GDP per capita recessions are defined as recessions with a fall in real GDP per capita from peak to trough above the median fall over the entire sample of 34 OECD countries and Latvia, which is close to 3.5 % of peak real GDP per capita. We use GDP per capita because it better captures true economic costs than measure of activity such as GDP growth and industrial production. For Turkey, seven severe GDP per capita recessions are identified in this way (see Table 1). Figure 1 shows that the algorithm picks up plausible GDP per capita recession dates. The GDP per capita recessions of the mid-1990s, the early 2000s and the last GDP per capita recession were particularly severe in Turkey with drops of real GDP per capita of more than 10% of peak real GDP per capita.

Table 1. Severe GDP per capita recessions in Turkey since the 1970s

1977q1 – 1980q1
1987q4 – 1989q2
1990q4 – 1991q1
1993q4 – 1994q2
1998q2 - 1999q3
2000q4 – 2001q4
2008q1 – 2009q1

Figure 1. Severe GDP per capita recessions in Turkey since the 1970s



5. The focus on severe GDP per capita recessions in contrast to particular types of acute economic crises, such as currency or banking crises, is motivated by two considerations. First, large drops in GDP per capita provide an efficient way to capture a range of costly economic events and represent an outcome that policymakers are presumably most concerned to avoid. Second, it is inherently difficult to define economic crises in an objective way. Crisis definitions often differ from one study to the next and studies often disagree whether a particular episode constitutes a crisis and differ on the exact timing of a particular crisis (e.g. Romer and Romer, 2015). Consequently, differences in definitions have led to differences in results. Moreover, most crisis indicators do not provide information on the relative severity of crises, but rather focus on timing.

Vulnerability indicators

6. The starting point is a set of indicators of potential macroeconomic and financial vulnerabilities that have been identified in recent OECD ECO work (Röhn et al., 2015), based on a review of the most recent early warning literature and lessons learned from the global financial crisis.[2] The indicators are classified into five types of domestic vulnerabilities (or "imbalances"): i) financial sector imbalances, ii) non-financial sector imbalances, iii) asset market imbalances, iv) public sector imbalances and v) external sector imbalances. Besides domestic imbalances, economies are also vulnerable to shocks and crises originating in other countries through international spillovers and contagion through financial, trade and confidence channels which is captured through an additional sixth international "spillovers, contagion and global risks" category.

7. Data availability across the indicators and across countries varies significantly. To investigate the usefulness of vulnerability indicators a sufficiently long time series that captures a number of severe GDP per capita recessions is necessary. For this reason, all financial imbalances indicators have to be excluded from the analysis as they are generally only available for a short time span of less than 10 years. Unfortunately, data limitations also preclude the use of indicators relating to real estate markets in Turkey (e.g. house prices, price-to-income or price-to-rent ratios). These indicators have been found to be good predictors of severe GDP per capita recessions in OECD countries plus Latvia in Hermansen and Röhn (2015). However, such indicators are only available in Turkey for a short time-span of less than 10 years.

8. In the early warning literature it is common to experiment with different transformations of the vulnerability indicators, such as deviations from a trend or growth rates. This increases the number of possible variables substantially. Here we employ the transformations of the indicators that have been found most useful in predicting severe GDP per capita recessions in Hermansen and Röhn (2015) for a sample of OECD countries plus Latvia. Details on the final set of vulnerability indicators investigated in this paper and their particular transformations can be found in Table A.1 in the Appendix.[3]

Empirical approach

9. To relate the vulnerability indicators to severe GDP per capita recessions and to assess their performance we use the signalling approach, one of the most commonly used early warning methodologies (e.g. Kaminsky et al., 1998; Borio and Lowe, 2002; Behn et al., 2013). The signalling approach is a non-parametric approach, which is based on the idea that a useful indicator behaves differently in pre-severe GDP per capita recession episodes compared to more tranquil periods. The advantage of the signalling approach is that it can accommodate differences in data availability across countries and allows for the inclusion of a potentially larger number of vulnerability indicators than alternatives based on multivariate regression methods such as probit/logit models (e.g. Demirgüc-Kunt and Detriagiache, 2000).

10. According to the signalling approach, the entire sample is split into three types of periods: i) severe GDP per capita recession periods, ii) pre-severe GDP per capita recession periods and iii) normal periods (the residual class). In a first step severe GDP per capita recession episodes are excluded from the evaluation sample. This step ensures that the approach identifies leading indicators rather than coincident

2. The vulnerability indicators database containing information for the 34 OECD countries, the BRIICS economies (Brazil, Russian Federation, India, Indonesia, China, and South Africa), Colombia, Latvia, Lithuania and Costa Rica can be downloaded at http://www.oecd.org/eco/economic-resilience.htm

3. The vulnerability indicators database contains quarterly and annual data. As the goal of this paper is to identify a set of vulnerability indicators that could be monitored regularly and that give an up-to-date picture of risks in Turkey, only indicators available quarterly are considered.

indicators.[4] [5] A period is considered as pre-severe- GDP per capita recession episode, if a severe GDP per capita recession occurs within a fixed number of quarters. Here we follow Hermansen and Röhn (2015) and consider the 8 quarters prior to the onset of a severe GDP per capita recession as pre-severe GDP per capita recession episodes, which is well within the range of 4-12 quarters commonly applied in the literature (e.g. Kaminsky et al., 1998; Borio and Drehmann, 2009; Alessi and Detken, 2011; Behn et al., 2013; Lo Duca and Peltonen, 2013).[6] The residual periods are labelled normal or tranquil episodes.

11. A vulnerability indicator issues a warning signal of an upcoming severe GDP per capita recession if the indicator exceeds or falls below a threshold, here defined by a percentile of an indicator's own distribution. Each indicator can then be evaluated according to the matrix below in which severe GDP per capita recession occurrence and warning issuance are compared (Table 2). A is the number of quarters in which an indicator provides a correct signal, which is a signal is issued during a pre-severe GDP per capita recession episode (a severe GDP per capita recession starts in one of the next 8 quarters). B is the number of quarters in which a wrong signal is issued, that is a signal was provided during a normal/tranquil period (no severe GDP per capita recession starts in one of the following 8 quarters). C is the number of quarters the indicator does not issue a signal despite a severe GDP per capita recession occurring within one of the next 8 quarters. Finally, D is the number of quarters in which the indicator does not provide any warning signal, and rightly so because there was no severe GDP per capita recession within one of the next 8 quarters.

Table 2. Evaluation matrix

	Severe GDP per capita recession (within the following 8 quarters)	**No severe GDP per capita recession (within the following 8 quarters)**
Signal issued	A	B
No signal issued	C	D

12. Ideally a threshold for each indicator should be chosen such that all observations fall into the A (a signal was issued and indeed there was a crisis) and D (a signal was not issued and indeed there was no crisis) cells. In reality, however, setting the threshold involves balancing two types of errors policy makers face. A high threshold would imply few crisis signals and a higher risk of missing a crisis (type I error). A low threshold would increase the number of signals, but would also raise the number of false crisis signals (type II error).

13. Here we rely on the thresholds identified in Hermansen and Röhn (2015) for each vulnerability indicator. They use a loss function to determine the optimal thresholds, which explicitly takes into account policymakers' preferences between type I (missing crises) and type II (false alarms) errors. Hermansen and Röhn (2015) investigate the sensitivity of the results to changes in the preference parameter $\theta \in [0,1]$. They find that, unsurprisingly, the stronger the preferences against missing a crisis, i.e. the higher θ, the lower

4. Bussière and Fratzscher (2006) provide another rationale for excluding crises episodes. They argue that the behaviour of a potential early warning indicator before a crisis should be compared to the behaviour during periods when these indicators are at sustainable levels (or growth rates), i.e. during normal or tranquil periods. During a crisis, indicators are often characterized by volatile corrections towards longer-term equilibria. These episodes therefore should not be included in an analysis of anticipating crises because one cannot extract meaningful information about the sustainability and vulnerability of a country's economic fundamentals by looking at crisis observations.

5 . In practice we only exclude the first four quarters following the start of a severe GDP per capita recession even if the GDP per capita recession lasts longer than four quarters. This is done to ensure that the indicators are able to pick up a potential subsequent GDP per capita recession that follows shortly after.

6. Hermansen and Röhn (2015) find that relative performance of the indicators is broadly robust considering to alternative pre-recession windows of 4 and 12 quarters.

the critical threshold of a given indicator, so that the indicator signals more often and crises are missed less often. Furthermore, the usefulness of the indicators generally increases in θ and reaches a peak at values of the preference parameter θ between around 0.8 and 0.9 after which the usefulness drops quite sharply. This highlights the fact that early warning indicators are more valuable to policymakers that are relatively averse to crisis. If the preference against missing crises is extremely strong, the usefulness of the indicators declines again, because it is difficult for an indicator to beat the benchmark of always signalling a crisis (and therefore never missing a crisis).Besides these general observations, Hermansen and Röhn (2015) also show that the ranking of best performing indicators (including the best transformation of an indicator in terms of relative usefulness) can vary with the value of θ. To keep the analysis tractable in the following, we use the results of Hermansen and Röhn (2015) for a preference parameter of θ=0.8, implying strong preferences against missing crises which appears to be a sensible baseline choice. Critical thresholds and optimal transformations of the indicators for other values of the preference parameter are available in Hermansen and Röhn (2015, Table 1).

14. Given the specification of the loss function, the threshold *percentile* is optimised over all OECD countries in Hermansen and Röhn (2015), *i.e*. a common percentile is chosen which minimises the aggregate loss over all OECD countries.[7] However. this optimal threshold percentile is applied to country-specific distributions of the indicators. Hence, the threshold *values* are allowed to differ across countries.

15. While it would in principle be possible to optimise the thresholds for Turkey alone, such a procedure may give rise to a problem similar to the well-known problem of overfitting in statistics given the low number of severe GDP per capita recessions in one country. In particular, overfitting implies that the optimal thresholds may lead to very strong in-sample performance of the indicators, but very poor out-of-sample performance. For example, optimising the thresholds only on the past 7 severe GDP per capita recessions in Turkey may result in a very good performance of some of the indicators for the past. However, these thresholds may be inappropriate to signal future crises because they may be different from past ones. By considering a larger sample size, the thresholds reflect a larger set of country experiences which could be useful information for predicting future crises. Of course, a larger sample size implies a more heterogeneous set of country experience and the problem of overfitting needs to be balanced with the problem of considering a too heterogeneous set of countries. This is why we also consider thresholds that have been optimised over the sample of the 17 lowest income OECD countries in the robustness section.

16. A number of statistics can be computed to summarise the performance of the indicators in signalling severe GDP per capita recessions in Turkey. For example the share of missed crises or type I errors (C/(A+C)) and the share of false alarms or type II (B/(B+D)) errors. Another commonly used statistic is the adjusted noise-to-signal ratio (aNtS) = [B/(B+D]/[A/(A+C)], which captures the ratio of the share of false alarms (noise) versus the share of correctly predicted crises (signal). A useful indicator has an aNtS of less than 1. A value of 1 would result if an indicator provides purely random signals. Finally, we also compute the average lead time, i.e. the average number of leading quarters by which an indicator has been signalling a severe GDP per capita recession for the first time.

17. Apart from these summary statistics, the indicators are also assessed based on a visual inspection of the time series and GDP per capita recession dates. In addition to the summary statistics, visual inspection can help identify whether the indicators performed better in earlier or more recent crises in Turkey and whether the indicators signal a severe GDP per capita recession at present.

7. In the following we also do not consider indicators for which Hermannsen and Röhn (2015) could not find a threshold that resulted in a lower loss than the simple benchmark of either always or never signalling a crisis. This includes for example the set of fiscal indicators.

Results

18. The results are summarised in Table 3. Of the non-financial sector imbalances, household credit (as a deviation from trend) performs best. It sends correct early warning signals in about 50% of the cases and issues false alarms in only 19% of the cases. The noise-to-signal ratio is also well below 1 and the indicator issues first warning signals on average more than a year before the onset of a severe GDP per capita recession. Figure 2 shows in addition that the indicator only missed the severe GDP per capita recessions in the mid-1980s and early 1990s while the indicator was well above the threshold before the latest three severe GDP per capita recessions in Turkey.[8] At its latest available date (2015Q2) the indicator is below the critical threshold that signals a severe GDP per capita recession. Among the other indicators of non-financial sector imbalances, private bank credit and corporate bank credit (Table 3) fare less well. Overall bank credit (growth rate) signalled the last crisis as well as the crisis in the late 1990s in Turkey (Figure 3). Corporate credit (deviation from trend) shows a very erratic behaviour and missed almost all severe GDP per capita recessions in Turkey (Figure 4).

Table 3. Performance of vulnerability indicators in Turkey

Indicator	Transformation	Signal issued above or below threshold?	Threshold percentile (value)	Type I error	Type II error	Adjusted noise-to-signal ratio	Average lead time in quarters
Non-financial sector imbalances							
Total private credit (% of GDP)	Level	above	80 (42.9%)	100%	40%	-	-
Private bank credit (% of GDP)	Cumulated growth rate over the preceding 6 quarters	above	75 (23.3%)	74%	30%	1.18	7
Household credit (% of GDP)	Deviations from a 20 quarter lagged moving average	above	70 (39.3%)	56%	19%	**0.43**	4.5
Corporate credit (% of GDP)	Difference from a recursive, faster-adjusting HP-filter with smoothing parameter λ=26000 for quarterly series	above	90 (1.5)	92%	7%	**0.85**	4.6
Asset market imbalances							
Real equity prices, index	Difference from a recursive, slowly-adjusting HP-filter with smoothing parameter λ=400000 for quarterly series	above	85 (16.8)	78%	14%	**0.62**	3
External imbalances							
Current account balance in % of GDP	Level	below	10 (-5.8%)	93%	13%	1.9	7
Foreign exchange reserves in % of GDP	Level	below	10 (1.3%)	93%	12%	1.74	6
Export performance, index	Deviations from a 20 quarter lagged moving average	below	10 (-7.8%)	93%	8%	1.19	1.5
Spillovers, contagion and global risk							
Trade openness	Level	above	80 (49.6%)	90%	18%	1.8	7
Global total private credit (% of GDP)	Year-on-year growth rate	above	55 (0.01%)	47%	26%	**0.48**	3.5
Global private bank credit (% of GDP)	Cumulated growth rate over the preceding 6 quarters	above	70 (1.1%)	56%	12%	**0.26**	5.3
Global real equity prices	Deviations from a 20 quarter lagged moving average	above	75 (15.4%)	50%	2%	**0.05**	5.2

Note: Figures in bold indicate that the indicator is useful as the adjusted noise-to-signal ratio is less than one. A value of one would result if an indicator provides purely random signals. The transformations and threshold percentiles are taken from Hermansen and Röhn (2015), Table 1. For a detailed definition of the variables see Table A.1.

8. The poor performance of this indicator in the early sample years should be viewed against the backdrop of a very low level of household credit of less than 1% of GDP until the early 1990s in Turkey.

19. The noise-to-signal ratio of the domestic stock price index also lies below 1. Figure 5 shows that the indicator correctly signalled the severe GDP per capita recessions of the mid-1980s and early 1990s as well as the GDP per capita recessions in the beginning of the 2000s. However, the indicator did not send early warning signals consistently in the eight quarters prior to these GDP per capita recessions and failed to issue any early warning signals for the remaining crises, which is reflected in the rather high share of type I errors of 78%.

20. The global risk indicators perform very well, with global credit measures, generally regarded as measures of global liquidity, and the global stock price index having noise-to-signal ratios well below one (Table 3). This is also in line with the finding of Hermansen and Röhn (2015) across the sample of all OECD countries plus Latvia. Figures 6 and 7 show that the good performance of the global credit measures mainly stems from their signalling of the early severe GDP per capita recessions as well as the global financial crisis. The performance of the global stock market indicator, which could be interpreted as a proxy for global risk taking, is even better. Except for the severe GDP per capita recession in the mid-1990s in Turkey, this indicator sends correct signals in almost all quarters preceding severe GDP per capita recessions (Figure 8). At the same time the indicator issued only very few false alarms. The indicator issues first warning signals on average 5 quarters before the onset of a severe GDP per capita recession. The noise-to signal ratio of less than 0.1 is also very low by standards of the literature.[9]

21. In contrast to the good performance of the global risk indicators, the external imbalances indicators all fare very poorly (see Table 3 and Figures A.2-A.4).[10] This finding is broadly in line with the results in Hermansen and Röhn (2015) for the sample of all OECD countries plus Latvia with the exception of foreign exchange reserves which they find to perform well in certain specifications. One reason why external imbalances are such noisy signals may be related to the fact that the risk they pose for the wider economy depends among other things on the exchange rate regime in place. Flexible exchange rates, which have been in place in Turkey for a long time, may mitigate the impact of current account reversals on GDP and reduce the need for precautionary foreign exchange reserve accumulation. This argument also highlights the broader point that vulnerability indicators should be assessed against (potentially time-varying) policy settings in place in a country.

22. A second possible reason for the poor performance of the external imbalance indicators is more technical and idiosyncratic to Turkey. Both the current account and the foreign exchange reserves in per cent of GDP appear to be non-stationary in Turkey over the time sample considered here (see Figures A.2 and A.3). For non-stationary variables the signalling approach will not yield reasonable results because it relies on time-invariant critical thresholds. We have considered the variables in levels here because levels have been found to perform best across the sample of all OECD countries and Latvia.

23. This second reason may also explain the seemingly inconsistent results between the global financial risks and external imbalances. The global risk indicators are well-performing early-warning indicators of severe GDP per capita recessions whereas external imbalances are not. This raises the question of the transmission of global shocks to the domestic economy. It would seem natural that a global equity or credit boom is transmitted through the financial account, thereby leading to current account imbalances. A different transformation of the current account that does not suffer from the non-stationary issue such as a deviation from a longer term trend may provide better forecasting performance and resolve

9. For example the best performing single indicators in Alessi and Detken (2011), Behn et al. (2013) and Lo Duca and Peltonen (2013) have adjusted noise-to-signal ratios of 0.3-0.4. However, these studies assess the performance over a sample of countries and hence a comparison with our single-country study is not straightforward.

10. Note that the external imbalances indicators issue an early warning signal if the indicators fall below the critical threshold.

the apparent disconnect between global shocks and the external imbalance. Another reason for the disconnect may be that the global risk indicators capture effects that are not directly accounted for in the current account such as confidence effects.

Robustness

24. In the baseline we used the transformations of the indicators and the critical thresholds that have been found most useful in predicting severe GDP per capita recession in Hermansen and Röhn (2015) for a sample of OECD countries plus Latvia. In this section we use instead the transformations and the critical thresholds that have been found most useful in predicting severe GDP per capita recession for a sample of the 17 OECD countries with the lowest GDP per capita (see Table 6 in Hermansen and Röhn, 2015).[11] While the optimisation procedure relies on fewer observations of severe GDP per capita recessions and may thus be more prone to the overfitting problem, the country sample might be more relevant for Turkey.

25. The results are summarised in Table 4. As in the baseline, we find the global equity price index to perform by far the best according to the aNtS criterion. The other global risk indicators also perform well as does the domestic real equity price index. However there are also some differences compared to the baseline. In particular the level of household credit in % of GDP is a poor early warning indicator. The reason is that this variable is highly non-stationary in Turkey exhibiting a strong upward trend since the early 2000s. As shown in the baseline, the deviation from trend is a better early warning indicator for household credit developments. In contrast, the particular transformation and critical threshold of the corporate credit indicator considered here performs better compared to the baseline.

26. Furthermore, we now also find some external imbalance indicators to perform better in predicting severe GDP per capita recessions in Turkey compared to the baseline. The cumulated growth rate of foreign exchange reserves and the deviation of the export performance index from trend have aNtS-ratios of less than one. However the type I error of the foreign exchange reserve indicator remains high. The performance of the current account balance stays weak despite the different critical threshold considered here compared to the baseline.

11. The optimal transformations and critical thresholds for the sample of the 17 OECD countries with the highest GDP per capita are also available in Hermansen and Röhn (2015, Table 6).

Table 4. Robustness: Performance of vulnerability indicators in Turkey

Indicator	Transformation	Signal issued above or below threshold ?	Threshold percentile (value)	Type I error	Type II error	Adjusted noise-to-signal ratio	Average lead time in quarters
Non-financial sector imbalances							
Total private credit (% of GDP)	Difference from a recursive, slowly-adjusting HP-filter with smoothing parameter λ=400000 for quarterly series	above	70 (1.4)	67%	21%	**0.64**	4.7
Private bank credit (% of GDP)	Cumulated growth rate over the preceding 6 quarters	above	65 (20.4%)	65%	42%	1.2	7.5
Household credit (% of GDP)	Level	above	55 (2.4%)	73%	63%	2.37	5.5
Corporate credit (% of GDP)	Difference from a recursive, slowly-adjusting HP-filter with smoothing parameter λ=400000 for quarterly series	above	65 (1.2)	61%	12%	**0.3**	5.8
Asset market imbalances							
Real equity prices, index	Deviations from a 20 quarter lagged moving average	above	50 (5.8%)	29%	44%	0.62	4.7
External imbalances							
Current account balance in % of GDP	Level	below	30 (-3.2%)	73%	30%	1.1	3.3
Foreign exchange reserves in % of GDP	Cumulated growth rate over the preceding 6 quarters	below	15 (-13%)	81%	9%	**0.49**	7.8
Export performance, index	Difference from a recursive, slowly-adjusting HP-filter with smoothing parameter λ=400000 for quarterly series	below	20 (-0.03)	64%	8%	**0.23**	7
Spillovers, contagion and global risk							
Trade openness	Level	above	65 (42.6%)	76%	37%	1.54	4.3
Global total private credit (% of GDP)	Year-on-year growth rate	above	55 (0.0%)	47%	26%	**0.48**	3.5
Global private bank credit (% of GDP)	Difference from a recursive, slowly-adjusting HP-filter with smoothing parameter λ=400000 for quarterly series	above	70 (0.4)	57%	9%	**0.22**	5
Global real equity prices	deviations from a 20 quarter lagged moving average	above	60 (8.9%)	35%	5%	**0.07**	6.2

Note: Figures in bold indicate that the indicator is useful as the adjusted noise-to-signal ratio is less than one. A value of one would result if an indicator provides purely random signals. The transformations and threshold percentiles are taken from Hermansen and Röhn (2015), Table 6. For a detailed definition of the variables see Table A.1.

Conclusion

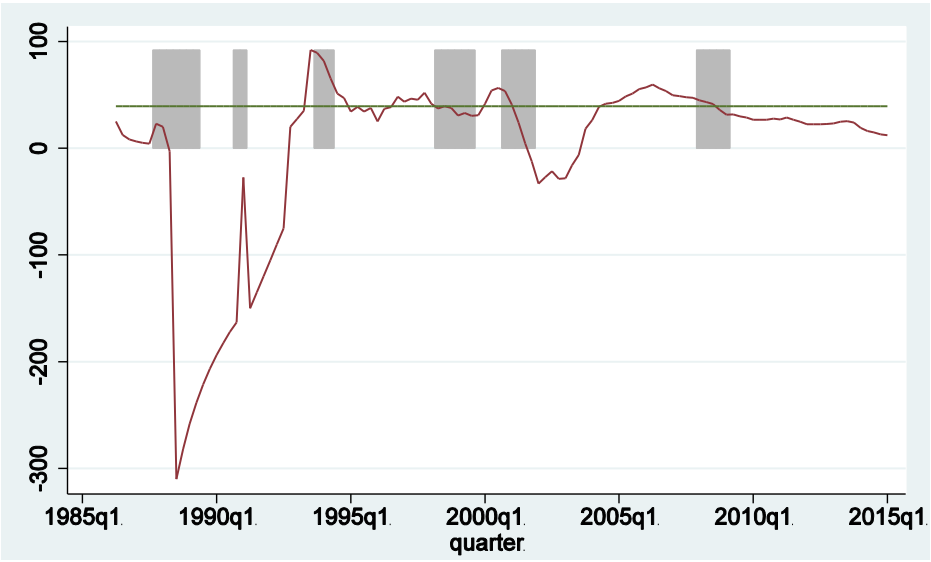
27. This paper investigated the performance of vulnerability indicators in predicting past severe GDP per capita recessions in Turkey, drawing on recent OECD work. To this end a simple signalling approach has been employed to identify vulnerability indicators that perform particularly well in the Turkish context. The results show that an index of the global stock market performs extremely well. This indicator could be viewed as a proxy for the risk appetite of global investors. Among domestic indicators, a measure of

household credit and an index of the domestic stock market also perform relatively well in signalling severe GDP per capita recessions. The evidence is broadly robust to considering a more homogenous set of lower income OECD countries when defining the critical thresholds. In that case we find that external imbalance indicators perform somewhat better compared to the baseline.

28. Due to data availability gaps potentially important areas of vulnerabilities relating for example to the financial and housing markets could not be assessed. Furthermore there may be Turkey-specific indicators or more broadly indicators that are more relevant for middle-income countries that would work well for Turkey but are not included in the cross-country dataset of Röhn et al. (2015) used here. In addition, in this paper we have looked at vulnerability indicators in isolation. There may be, however, complementarities among the indicators. For example, some studies suggest that asset busts have larger repercussions on the wider economy if the preceding asset boom was credit financed (e.g. Jorda et al. 2015). Taking these complementarities into account may improve forecasting accuracy. We view work in this area as an important avenue for future research.

29. Finally the analysis also highlighted the need to assess the vulnerability indicators against the (potentially time-varying) policy settings in place in a country. A case in point is the current account deficit which has attracted a lot of attention in Turkey in recent years (Röhn, 2012). The analysis in this paper suggests that the current account deficit has been a poor predictor of severe GDP per capita recessions in Turkey and has sent many false signals in the more recent past, even when it was largely financed by short-term capital inflows. It would be interesting to explore how policy settings influence the probability of a crisis for a given vulnerability. For example the flexible exchange rate and, more recently, macroprudential policies may have contributed to improving Turkey's resilience to external shocks.

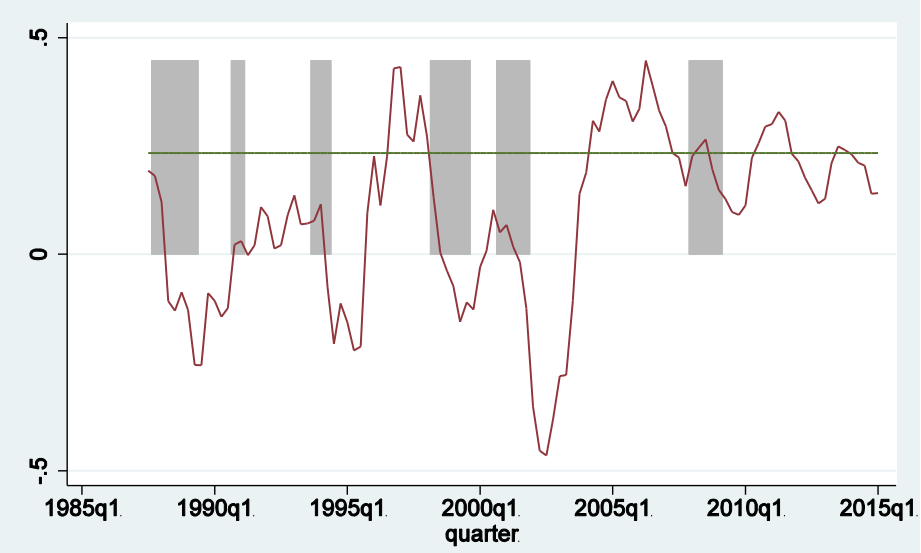
Figure 2. Household credit



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure 3. Private bank credit

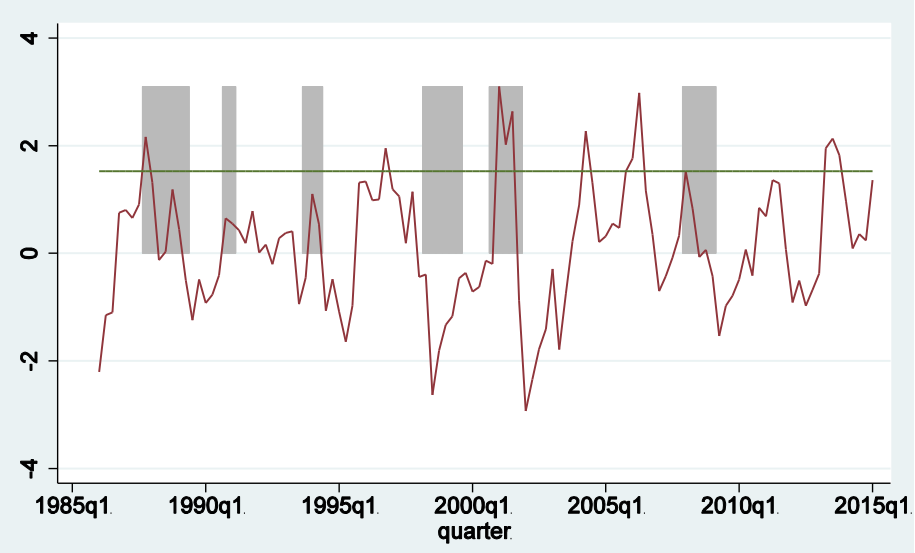
6-quarter cumulative growth rate



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure 4. Corporate credit

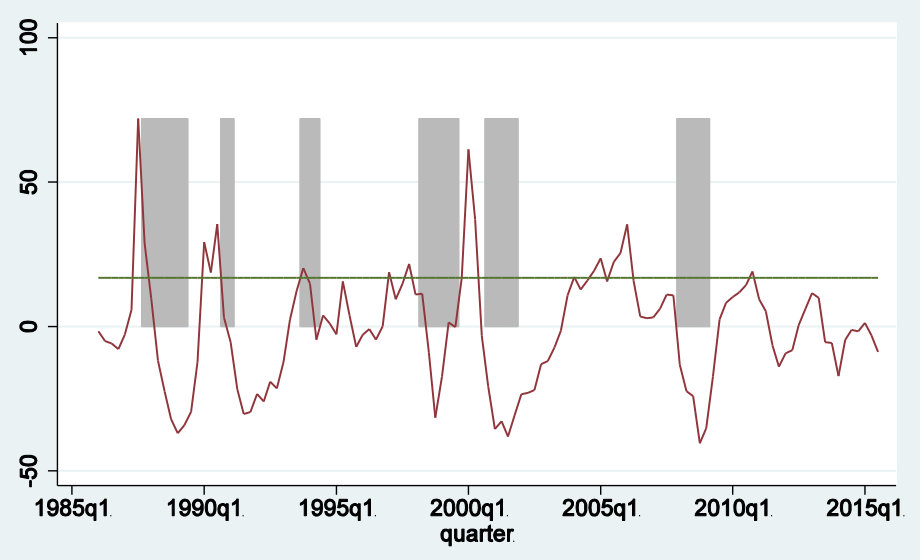
Difference from trend



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure 5. Real stock price index

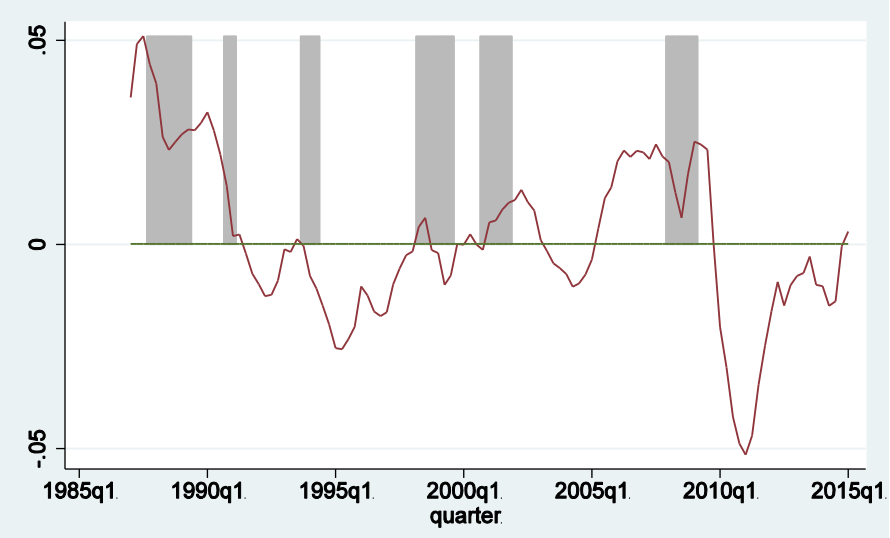
Difference from trend



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure 6. Global credit

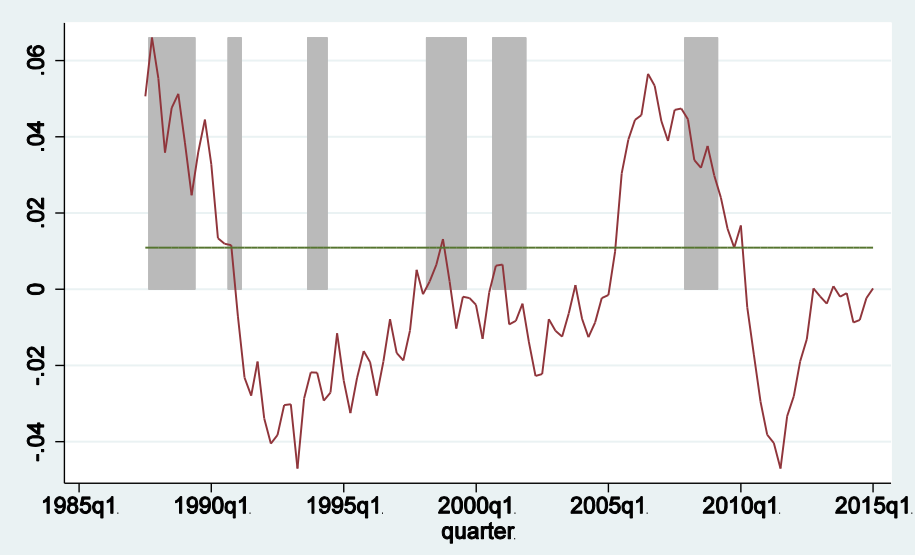
in % of GDP, y-on-y growth rate



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure 7. Global bank credit

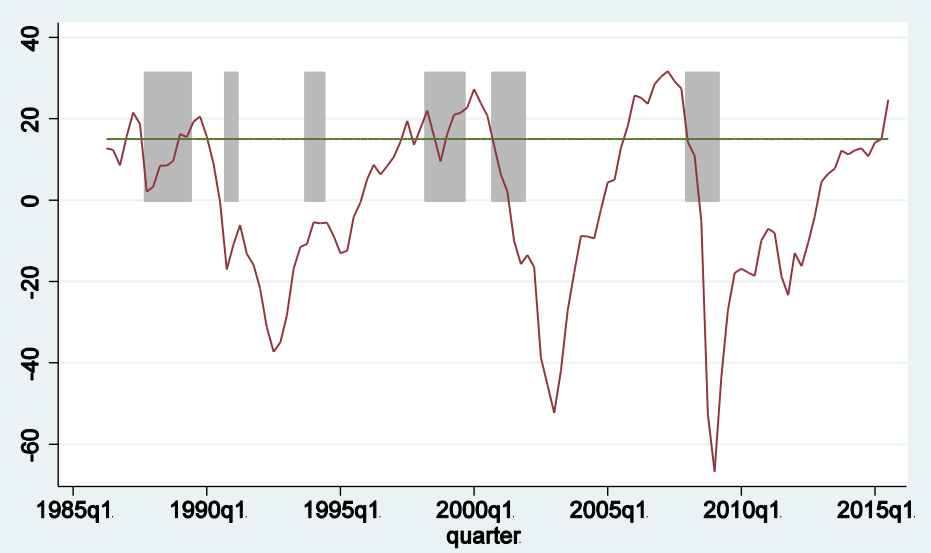
in % of GDP, 6-quarter cumulative growth rate



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure 8. Global real stock price index

deviation from trend



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

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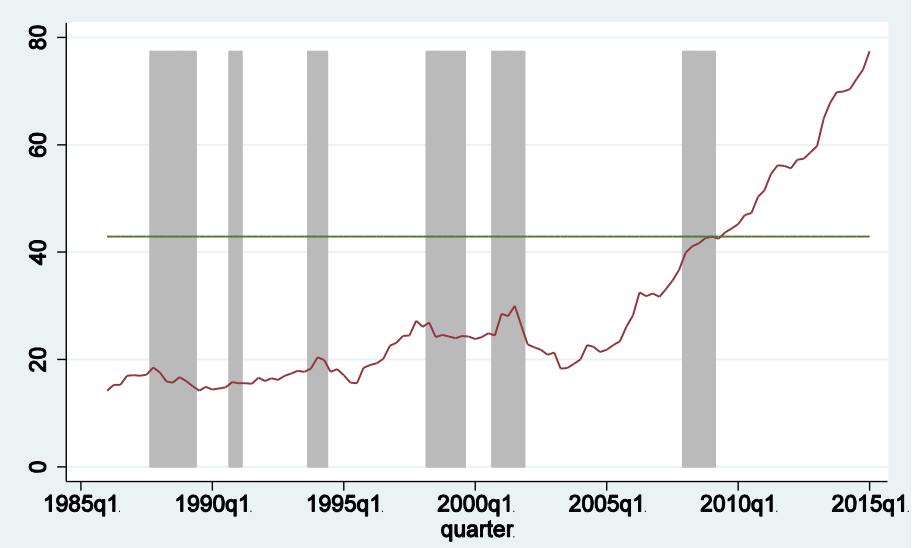
APPENDIX

Table A.1. Dataset

Indicator	Description	Data Source	Time coverage	Transformation
Non-financial sector imbalances				
Total private credit	Lending from all sectors (including foreign) to private non-financial sector in per cent of GDP.	BIS	1986Q1-2015Q1	Level
Private bank credit	Lending from domestic bank sector to private non-financial sector in per cent of GDP.	BIS	1986Q1-2015Q1	Cumulated growth rate over the preceding 6 quarters
Household credit	Lending from all sectors (including foreign) to households in per cent of GDP.	BIS	1986Q1-2015Q1	Deviations from a 20 quarter lagged moving average
Corporate credit	Lending from all sectors (including foreign) to non-financial corporations in per cent of GDP.	BIS	1986Q1-2015Q1	Deviation from a recursive, faster-adjusting HP-filter with smoothing parameter λ=26000 for quarterly series
Asset market imbalances				
Real equity prices	Share price index deflated by CPI.	OECD	1986Q1-2015Q3	Deviation from a recursive, slowly-adjusting HP-filter with smoothing parameter λ=400000 for quarterly series
External imbalances				
Current account balance	In per cent of GDP.	OECD	1970Q1-2015Q2	Level
Foreign exchange reserves	In per cent of GDP.	IMF	1970Q1-2015Q2	Level
Export performance	Exports of goods and services relative to export market for goods and services.	OECD	1975Q1-2015Q2	Deviations from a 20 quarter lagged moving average
Spillovers, contagion and global risk				
Trade openness	Sum of exports and imports in per cent of GDP.	OECD	1970Q1-2015Q2	Level
Global total private credit (% of GDP)	Weighted average of total private credit-to-GDP ratios across countries for each quarter. Weights defined by nominal GDP at Purchasing Power Parity (PPP).	BIS	1970Q1-2015Q1	Year-on-year growth rates
Global private bank credit (% of GDP)	Weighted average of private bank credit-to-GDP ratios across countries for each quarter. Weights defined by nominal GDP at PPP.	BIS	1970Q1-2015Q1	Cumulated growth rates over the preceding 6 quarters
Global real equity prices	Weighted average of country share price indexes for each quarter. Weights defined by nominal GDP at PPP.	OECD	1970Q1-2015Q3	Deviations from a 20 quarter lagged moving average

Figure A.1. Total private credit

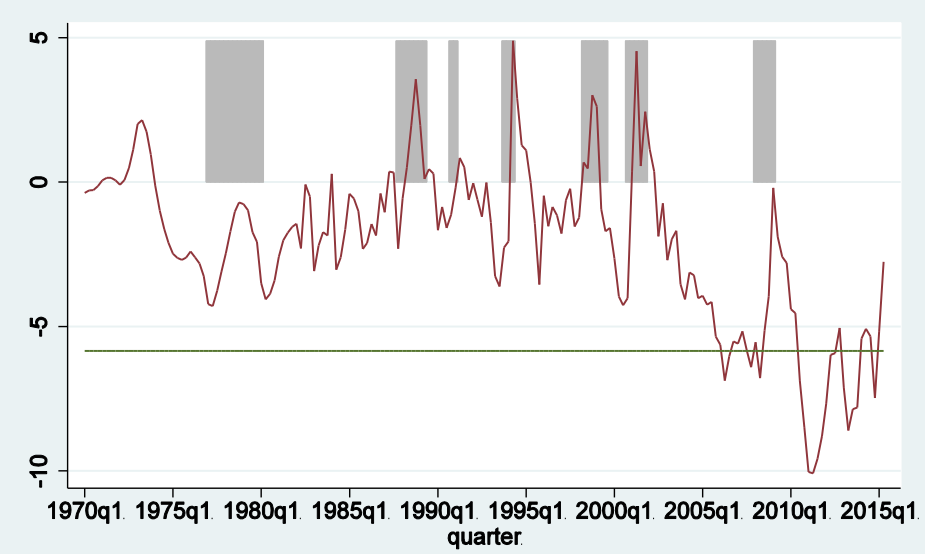
in % of GDP



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure A.2. Current account balance

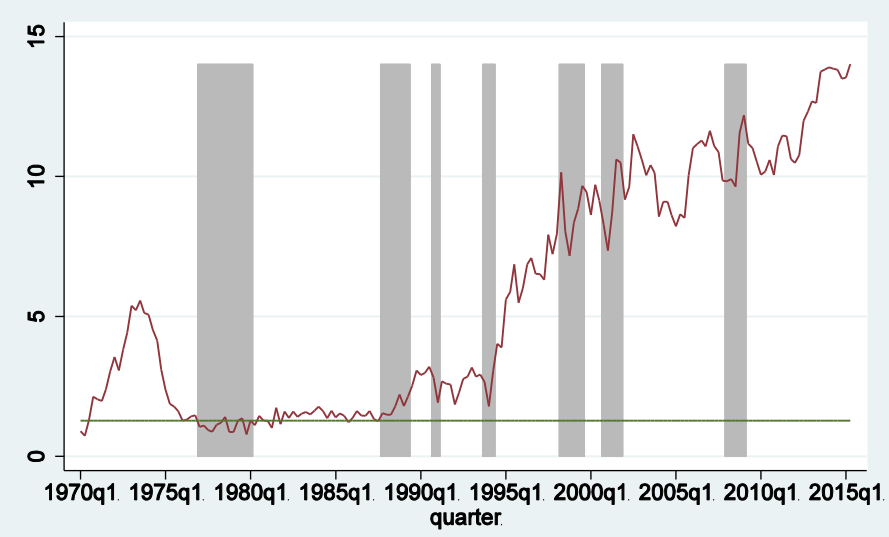
in % of GDP



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *falls below* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure A.3. Foreign reserves

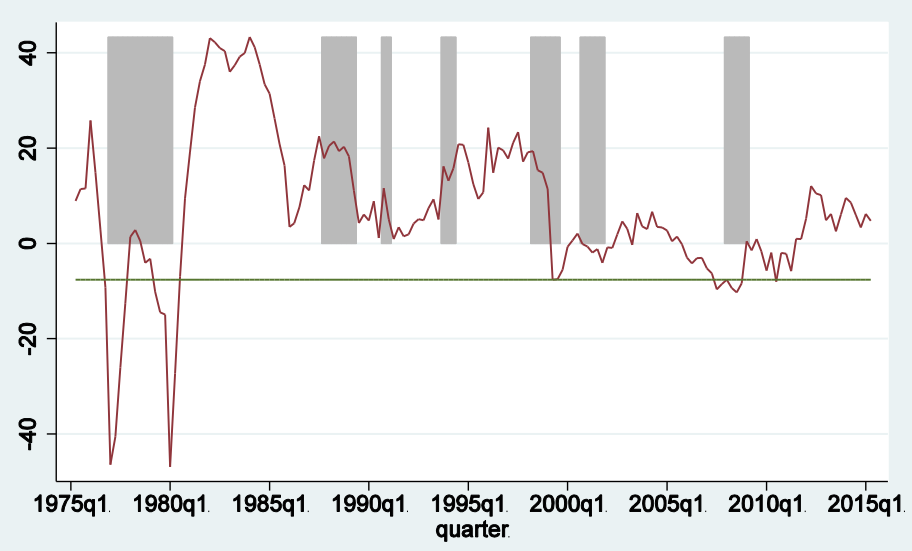
in % of GDP



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *falls below* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure A.4. Export performance

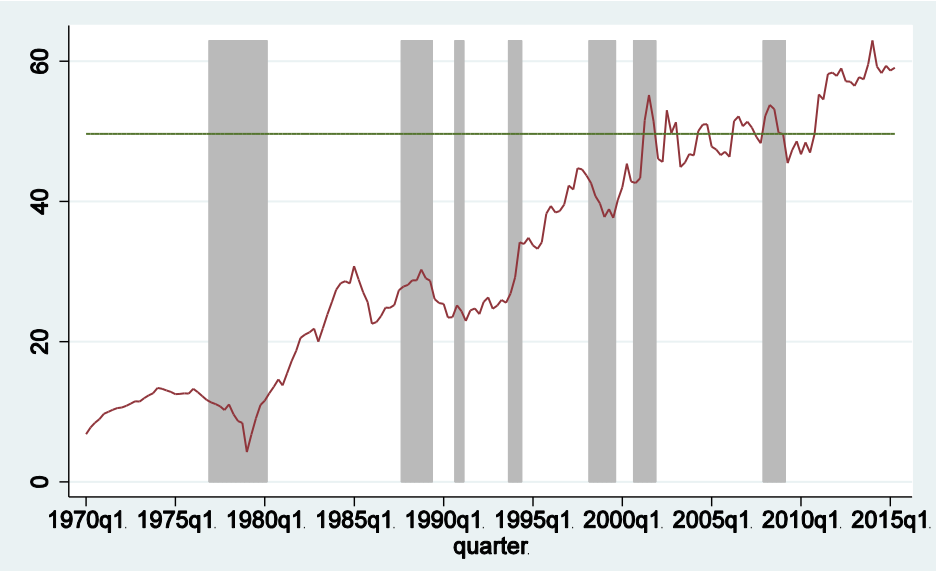
Index, deviation from trend



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *falls below* the critical threshold. Grey bars are severe GDP per capita recession dates.

Figure A.5. Trade Openness

in % of GDP



Note: The horizontal green line depicts the critical threshold. An early warning signal is sent if the indicator *exceeds* the critical threshold. Grey bars are severe GDP per capita recession dates.