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COST-BENEFIT ANALYSIS OF LEANING AGAINST THE WIND: ARE COSTS LARGER ALSO WITH LESS EFFECTIVE MACROPRUDENTIAL POLICY?

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ABSTRACT

"Leaning against the wind" (of asset prices and credit booms) (LAW), that is, a somewhat tighter monetary policy and a higher policy interest rate, has costs in terms of a weaker economy with higher unemployment and lower inflation. It has been justified by possible benefits in terms of a lower probability or magnitude of a future financial crisis. A worse macro outcome in the near future is then considered to be an acceptable cost to be traded off against a better expected macro outcome further into the future. But a crisis can come any time, and the cost of a crisis is higher if initially the economy is weaker due to previous LAW. LAW thus has an additional cost in the form of a higher cost of a crisis when a crisis occurs. With this additional cost, for existing empirical estimates, the costs of LAW exceed by a substantial margin the possible benefits from a lower probability of a crisis. Furthermore, empirically a lower probability of a crisis is associated with lower real debt growth. But if monetary policy is neutral in the long run, it cannot affect real debt in the long run. Then, if a higher policy rate would result in lower debt growth and a lower probability of a crisis for a few years, this is followed by higher debt growth and a higher probability of a crisis in the future. This implies that the cumulated benefits over time of LAW are close to zero. But even if monetary policy is assumed to be non-neutral and permanently affect real debt, empirically the benefits are still less than the costs. Finally, somewhat surprisingly, less effective macroprudential policy, and generally a credit boom, with resulting higher probability, magnitude, or duration of a crisis, increase costs of LAW more than benefits, thus making costs exceed benefits by an even larger margin.

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1 Introduction

By "leaning against the wind" (of asset prices and credit booms) (LAW for short) I here mean a monetary policy with a somewhat higher policy interest rate than what is consistent with with just stabilizing inflation around an inflation target and unemployment around its estimated long-run sustainable rate without taking any effects on financial stability into account. LAW has obvious costs in terms of a weaker economy with higher unemployment and lower inflation. It has been justified as a way of reducing the probability and magnitude of a future financial crisis (Bank for International Settlements (2014, 2016a), Olsen (2015), Sveriges Riksbank (2013)). A somewhat worse macro outcome in the near future is then considered to be an acceptable cost to be traded off against a better expected macro outcome further into the future. But a crisis can come any time, and the cost of a crisis is higher if initially the economy is weaker. If the unemployment rate is higher when a crisis occurs, the unemployment rate during the crisis will be higher, which increases the cost of a crisis. LAW thus not only has cost in terms of a weaker economy if no crisis occurs; it has an additional cost in terms of a higher cost of a crisis *if* a crisis occurs. The present paper shows that, with this additional cost of LAW, for existing empirical estimates, the cost of LAW can be shown to exceed, by a substantial margin, the benefit from a lower probability or magnitude of a crisis.

Furthermore, empirically one of the channels through which a higher policy rate might reduce the probability of a crisis is through lower real debt growth. According to existing empirical estimates, the probability of a crisis is positively correlated with the growth rate of real debt during the previous few years (Schularick and Taylor (2012)). If a higher policy rate reduces real debt growth, it might therefore reduce the probability of a crisis. However, there are three important limitations of this channel.

First, if monetary policy is neutral in the long run, it cannot affect real debt in the long run. Therefore, even if a higher policy rate would reduce real debt growth and thereby the probability of a crisis for a few years, if there is no permanent effect on the real debt level, a lower real debt growth and probability of a crisis will be followed by a higher debt growth and probability, and the average and cumulated debt growth and probability would not be affected over a longer period. The probability of a crisis would just be postponed and thus shifted between different periods.

Second, as discussed in Svensson (2013a), the effect on real debt of a higher policy rate is likely to be small and could be of either sign. The stock of nominal debt, in particular the stock of mortgages, has considerable inertia. A higher interest rate may reduce the growth rate of housing prices and, at given loan-to-value ratios, reduce the growth rate of new mortgages. But only a fraction of the stock of mortgages is turned over each year. Furthermore, even if a higher policy rate slows down the rate of growth of nominal mortgages, it is also slows down the rate of growth of the price level. Thus, both the numerator and the denominator of real debt are affected in the same direction by the policy rate, making the effect on the ratio smaller. And if the price level is affected more or quicker than the stock of debt, real debt will rise rather than fall. Indeed, the "stock" effect may dominate over the "flow" effect for several years or longer. The effect on the debt-to-GDP ratio of a higher policy rate is even more likely to be small or of the opposite sign, because then not only the price level but also real GDP enter in the denominator, and the growth of both are slowed down by a higher policy rate. Several recent papers have indeed found empirical evidence supporting the notion that a higher policy-rate increases rather than decreases the debt-to-GDP ratio (Alpanda and Zubairy (2014), Bauer and Granziera (2016), Gelain, Lansing, and Natvik (2015), and Robstad (2014)).

Third, the empirical relation between previous real debt growth and the probability of a crisis is of course a reduced-form and correlation result. The underlying determinants of the probability of a financial crisis are the nature and magnitude of the shocks to the financial system and the resilience of the system. The former depend on, among other things, possible overvaluation and riskiness of assets. The latter depends on such things as the strength of balance sheets and thereby the resilience of borrowers and lenders, the quality of assets, the amount of loss-absorbing capital, the degree of liquidity and of maturity transformation, the quality of lending standards, the debt-servicing capacity of borrowers, the amount of risk-taking and speculation, and so on. The extent to which higher real debt growth increases the probability of a crisis depends on to what extent it is "bad" credit growth that is related to things such as an increase in credit supply due to lower lending standards and excessive loan-to-value ratios, or to speculation, overvaluation of assets, and so on, rather than "good" credit growth related to financial deepening and developments that does not weaken but rather strengthens the financial system. With better data on the underlying determinants of the nature and magnitude of shocks and the resilience of the system, it should be possible to assess the probability of a crisis without relying on aggregate real debt growth. Given the list of underlying determinants of the probability of a crisis, it is also rather clear that the policy rate is unlikely to have any systematic impact on most or any of them, and that micro- and macroprudential policy is much more likely to have such an impact.[1]

In this paper, I will take into account the first limitation, the implication of long-run neutrality of monetary policy, but I will also consider the result of non-neutrality and possible permanent effects on real debt of monetary policy. As for the second and third limitations, I will simply take existing empirical estimates as given, in particular those of the Riksbank in Ekholm (2013) and Sveriges Riksbank (2014a) and of Schularick and Taylor (2012), to see what follows from them. Thus, I arguably stack the cards somewhat in favor of LAW.

Another possible benefit of a higher policy rate might be a smaller increase in the unemployment rate in a crisis. According to the empirical results of Flodén (2014), for OECD countries, a higher household debt-to-income ratio before the recent financial crisis is associated with a somewhat lower increase in unemployment during the crisis. If a higher policy rate reduces the debt-to-income or debt-to-GDP ratios, a higher policy rate might this way reduce the cost of the crisis. However, according to Flodén (2014), the impact of the initial debt-to-income rate on the crisis increase in the unemployment rate is small. Furthermore, as noted above, the effect of the policy rate on the debt-to-income ratio is apparently quite small, often not statistically significant from zero, and, according to both theoretical and empirical analysis, a higher policy rate probably *increases* rather than decreases the debt-to-GDP ratio. This means that there is hardly theoretical or empirical support for the idea that this channel would provide any economically significant benefit from LAW. This is confirmed when the channels empirical importance is examined in some detail in appendix D. The channel is therefore disregarded in the benchmark case in the main text.[2]

The existing pre-2016 small literature that has tried to quantify the costs and benefits of LAW has mainly considered a two-period setup where a higher policy rate has a cost in terms of higher unemployment in the first period and a benefit in terms of a lower probability of a crisis in the second period (Kocherlakota (2014), Svensson (2014, 2015), Ajello, Laubach, Lopez-Salido, and Nakata (2015) (ALLN for short), and International Monetary Fund (2015)).[3] By assumption there

[1] International Monetary Fund (2015) discusses the transmission channels from the policy rate to the probability of a crisis and documents its complexity, uncertainty of direction, and variation over time. Dagher, Dell'Ariccia, Laeven, Ratnovski, and Tong (2016) shows that more but still relatively moderate bank capital relative to risk-weighted assets would likely have had a dramatic effect in reducing the frequency of banking crises in the advanced countries since 1970. Korinek and Simsek (2016) show that macroprudential policies can be quite effective in dealing with excess household debt and that interest-rate policies are likely to be inferior to macroprudential policies in dealing with excess household debt.

[2] In appendix D, it is also shown that the estimate that follows from Jordà, Schularick, and Taylor (2013, tables 3 and 8) is, with an Okun coefficient of 2, also very small and about twice that of Flodén's. Also, as noted there, the estimate of Krishnamurthy and Muir (2016, table 4) of the effect of previous credit growth on the decline of GDP from peak to trough is also very small and, with an Okun coefficient of 2, similar to Flodén's estimate.

Clouse (2013) provides a theoretical analysis of optimal policy in a two-period model where the policy rate affects the magnitude of a possible crisis.

[3] LAW has been discussed in more general terms by, for instance, Bernanke (2015), Evans (2014), International

is no possibility of a crisis in the first period, and by assumption a crisis in the second period would start from an initial situation in which unemployment equals its long-run sustainable rate and the unemployment gap thus is zero.

This two-period framework is an over-simplification. By disregarding the possibility of a crisis in the first period and by assuming that a crisis in the second period occurs when the unemployment gap initially is zero, it disregards that a crisis could come any time and that LAW increases the cost of a crisis by causing it to start from a higher unemployment rate. The two-period framework in effect assumes that the loss level in a crisis is fixed and independent of any LAW. Thus it *understates the cost* of LAW. Furthermore, by assuming that there is only one period for which the probability of a crisis can be affected, it disregards the consequences of the long-run neutrality of monetary policy and the resulting property that then the probability of a crisis is shifted between periods but the sum of the probabilities remains the same. Thus it *overstates the benefit* of LAW.

Given these simplifications of the two-period model, Svensson (2014, 2015) and International Monetary Fund (2015) nevertheless show that, given existing empirical estimates and reasonable assumptions, the cost of a higher unemployment rate the next few years because of a higher policy rate is many times larger than the benefit of LAW in terms of an expected lower future unemployment rate due to a lower probability of a crisis. ALLN furthermore shows that a tiny amount of LAW may be justified, corresponding to a few basis points increase in the policy rate, but that extreme assumptions are needed to justify more significant LAW. In particular, the net benefit of such a tiny amount of LAW is completely insignificant.[4]

An exception to this two-period framework is the dynamic approach and analysis of Diaz Kalan, Laséen, Vestin, and Zdzienicka (2015) in a quarterly model, where the probability of a crisis varies over quarters and the cost and benefit of LAW are cumulated over time. The present paper follows that approach and uses a multi-period quarterly model.

The preliminary results of Diaz Kalan, Laséen, Vestin, and Zdzienicka (2015), summarized in International Monetary Fund (2015, box 7, p. 41), indicate that the cost dominates over the benefit during the first few years but that the cost is about equal to the benefit over a longer period. However, the loss level in a crisis is still assumed to be fixed and independent of the initial state of the economy. It is as if a crisis is assumed to result in a 5 percent unemployment gap regardless of whether the initial unemployment gap is zero or 3 percent. Furthermore, it is assumed that

Monetary Fund (2015), Laséen, Pescatori, and Turunen (2015), Smets (2013), Stein (2013, 2014), Svensson (2013b), Williams (2015), Woodford (2012), and Yellen (2014).

[4] The early and innovative contribution of Kocherlakota (2014), expressing the value of reducing the probability of a crisis to zero in terms of an unemployment-gap equivalent, is discussed in appendix E.

monetary policy has a permanent effect on real debt and thus is non-neutral in the long run. If the cost of a crisis depends on the initial state of the economy or if monetary policy is neutral in the long run, the cost would exceed the benefit.

The new elements in the present paper are (i) to take into account that the cost of a crisis (the loss *increase* in a crisis) depends in the initial state of the economy, which in turn depends on the amount of LAW that has preceded the crisis, (ii) to derive the effect of the policy rate on the probability of a crisis, taking into account that this probability depends both on the probability of a crisis start and the duration of a crisis, (iii) to examine the possible effect of the policy rate on the magnitude of a crisis (in an appendix), (iv) to derive the expected marginal cost and marginal benefit of LAW, (v) to take into account and assess the role of monetary neutrality, (vi) to assess whether more or less effective macroprudential policy affects the relative cost and benefit of LAW. The last element thus challenges the common argument that LAW is justified as a last resort, if macroprudential policy is ineffective.[5]

The main result of this paper is then that, for existing empirical estimates, the cost of LAW exceeds the benefit by a substantial margin. If anything, a positive probability of a crisis implies an optimal policy that involves a small leaning *with* the wind rather than against. This result is quite robust and holds for a variety of alternative assumptions, including if monetary policy is non-neutral and has a long-run effect on real debt. Furthermore, somewhat surprisingly, a less effective macroprudential policy is likely to increase the cost of LAW more than the benefit, thus making the cost exceed the benefit by an even larger margin.

Why is the cost of LAW normally so much larger than the benefit? We can understand this by representing a crisis by a fixed *increase* in the unemployment rate from its non-crisis level and, in particular, by preliminarily assuming that the probability of a future crisis is given and not affected by the policy rate. With a given positive probability of a crisis, the expected unemployment gap (taking into account the probability of a crisis increase in the unemployment rate) is larger than the non-crisis unemployment gap. If the future non-crisis unemployment gap is zero, the expected future unemployment gap is positive. The optimal policy, the policy that minimizes the expected future squared unemployment gap, is to set the expected future unemployment gap equal to zero. This requires the future non-crisis unemployment gap to be somewhat negative, more precisely such that the probability-weighted future negative non-crisis unemployment gap in absolute value equals the probability-weighted future positive crisis unemployment gap.

[5] This common argument is challenged by Williams (2015): "[M]onetary policy is poorly suited for dealing with financial stability concerns, even as a last resort."

Thus, if the probability of a crisis is given, the optimal policy is actually to *lower* the policy rate and lean *with* the wind. There is thus an initial incentive to lean with the wind. If the probability of crisis is not given but depends on and decreases with a higher policy rate, there is an incentive to increase the policy rate from its lower level and thereby reduce the probability of a crisis. For the incentive to increase the policy rate to dominate over the initial incentive to lower the policy rate, so the net incentive is to lean against the wind, the effect of the policy rate on the probability or magnitude of a crisis must be sufficiently large. However, for existing empirical estimates, the effect is much too small, so the net incentive is a small leaning with the wind.

Why would a less effective macroprudential policy increase the cost of LAW more than the benefit? The incentive to lean *with* the wind is stronger if the probability of a crisis is higher. With a higher probability of a crisis, everything else equal the expected future unemployment gap is larger. In order to make it zero, the non-crisis unemployment gap must become more negative and the policy rate has to be lowered more. This is also the case if the magnitude of a crisis is larger and involves a larger increase in the unemployment rate.

Therefore, if a less effective macroprudential policy, for instance by resulting in a credit boom, leads to a higher probability or larger magnitude of a crisis, the less effective macroprudential policy actually increases the cost of LAW. Even if a credit boom and higher probability of a crisis might increase the effect of credit growth and the policy rate on the probability or magnitude of a crisis, empirically the increase in the effect is too small to significantly increase the benefit of LAW. Thus, less effective macroprudential policy increases the cost of LAW more than the benefit, making the cost exceed the benefit by an even larger margin.

1.1 Some recent criticism

After the first version of this paper was distributed in January 2016, it has been subject to some criticism. In the BIS Annual Report (Bank for International Settlements (2016a, Box IV.B, pp. 76–77)), the main criticism seems to be that the paper would (1) rely on credit growth rather than a "financial cycle" as a predictor of crises, (2) assume that the magnitude of a crisis is exogenous and independent of the policy rate, (3) just discuss a one-off policy-rate increase instead of a systematic and optimal policy of LAW. Furthermore, as also suggested in Juselius, Borio, Disyatat, and Drehmann (2016, p. 3), such a policy-rate increase would (4) involve "[r]esponding to financial stability risks only when they become evident would inevitably lead to doing too little too late, as it would ignore the cumulative impact of policy over the whole financial cycle."

Regarding criticism (1), I use real credit growth only because the results of Schularick and Taylor (2012) and those from a dataset used in International Monetary Fund (2015) provide empirical support for real credit growth predicting a crisis. But there is no principle difference between using credit growth and a "financial cycle." The crucial issue is (a) what the best predictor of future crises is and (b) what the impact of the policy rate on that predictor is. This is an empirical issue. Given any empirical estimates of the impact of a financial cycle on the probability of a crisis and the impact of the policy rate on the financial cycle, my analysis can easily be redone using those.

In this context, one may note that the impact of the policy rate on a financial cycle is likely to be small and of uncertain sign. The credit-to-GDP ratio is an important component of a financial cycle (Drehmann, Borio, and Tsatsoranis (2012)). As noted above, the policy-rate effect on the credit-to-GDP ratio may be to *increase* rather than decrease the ratio, because a policy-rate increase may slow down the growth of nominal GDP more and quicker than it slows down credit growth.

Regarding criticism (2), a possibly endogenous magnitude of the crisis is not at all disregarded in the paper but is actually, as mentioned above, examined in some detail in appendix D. Empirically, the impact of the policy rate on the magnitude is too small to affect the results.

Regarding criticism (3), the paper actually also examines optimal policy, not only a one-off policy tightening. For the empirical estimates used, the optimal policy involves a small amount of leaning *with* the wind, not against. Quantitatively, the optimal amount of leaning with the wind and the corresponding reduction in loss is so small that it is hardly worth bothering about.[6]

Regarding criticism (4), that the policy-rate increase that I consider would imply responding too late and would ignore the cumulative impact of the policy, the fact is that the cumulative effect of the policy rate on the probability and magnitude of a of crisis *is* taken into account, over a horizon as long as 10 years, beyond which the impact is so small that it can safely be disregarded.

In summary, the criticism presented in Bank for International Settlements (2016a) is, as far as I can see, off the mark.

After the first version of this paper was distributed, also Filardo and Rungcharoenkitkul (2016) (FR for short) and Gourio, Kashyap, and Sim (2016) (GKS for short) have argued that LAW would be optimal and maintained that this contradicts my result that, given existing empirical estimates, the cost of LAW exceeds the cost. However, as far as I can see, their results can be

[6] In particular, Bank for International Settlements (2016a, Box IV.B, pp. 76–77) refers to Filardo and Rungcharoenkitkul (2016) providing a quantitative case for LAW. However, as discussed in Svensson (2016a) and below, that paper seems to get other results than mine not because it relies on an assumption of a financial cycle but because it assumes a different loss function, namely that the cost of a crisis (the loss *increase* when a crisis occurs) is constant and independent of the state of the economy, in contrast to my arguably more realistic assumption that the cost of a crisis is higher if initially the economy is weaker.

explained by their assumption about the loss function. They assume that the cost of a crisis, the loss *increase* in a crisis, instead of being higher in a weak economy, is fixed and independent of the initial unemployment (or output) gap. As discussed in Svensson (2016a), this assumption is similar to the assumption of the previous literature, used by, for instance, ALLN and discussed in detail in the first version of this paper, that the loss *level* in a crisis is fixed and independent of the state of the economy. It is then not surprising that they get the same result as ALLN, that a very small amount of positive LAW is optimal, with an economically insignificant gain.

More precisely, GKS make the rather unrealistic assumption that a crisis consists of a negative supply shock in the form of a 10 percent fall in productivity, capital, output, consumption, and real wages together with a preference shock that increases households' disutility of labor (utility of leisure) by 11 percent, which then keeps employment, unemployment, and, therefore, inflation unaffected by the crisis. A crisis is in their model simply a scaling down of the whole economy by 10 percent, except of employment. Under these circumstances, for a zero initial unemployment gap, the marginal cost of LAW is zero whereas the marginal benefit is positive, implying that some positive LAW is optimal. But because the marginal cost increases rather steeply, the optimal LAW is small, and the net gain is economically insignificant. For GKS, the gain is equivalent to an increase in average consumption of 6 to 8 basis points. The annual probability of a crisis falls by 6 basis points from 2.08 percent to 2.02 percent, implying on average one crisis in 49.5 years instead of one in 48.1 years, which is hardly economically significant. As we shall see below, in my framework, under the assumption of a fixed loss increase in a crisis, the small optimal LAW implies that the annual probability of a crisis start falls by 5 basis points, very similar to the result of GKS, and obviously a fall in the probability that is economically insignificant.

Thus, neither the qualitative nor quantitative result of GKS are surprising, given their assumption about the loss function, the results of a ALLN, the discussion in the first version of this paper and in Svensson (2016a), and further discussion below.

But, more generally, the results, in particular the numerical results, of a relatively complex calibrated DSGE model are very model- and parameter-dependent and depend on a long list of assumptions, model characteristics, distortions introduced, shocks and their persistence, numerous other parameters, and so on. Many results from DSGE models are therefore both unreliable and difficult to interpret.[7] In the present context, the purpose of the analysis is to assess the relative size

[7] In addition, GKS assess whether LAW is beneficial by examining whether the total loss is reduced if an additional variable is added as an argument to a Taylor-type rule, namely "inefficient credit," which variable is assumed to affect the probability of a crisis. But Taylor-type rules are suboptimal; they have too few arguments (Svensson (2003b)). Optimal policy normally requires responding to all state variables, including shocks. Adding an argument to a

of the estimated numerical costs and benefits of LAW. For this purpose, a simple and transparent method, where the analysis uses few and transparent assumptions based on existing empirical estimates and empirically supported relations and where the analysis can easily be redone with different assumptions and estimates, seems to me have a comparative advantage in delivering more robust and reliable results.

Finallly, Adrian and Liang (2016) have challenged the robustness of my result that the cost of LAW exceeds the benefit and argued that alternative reasonable assumptions about the effect of the policy rate on the probability or magnitude of a crisis would overturn it. However, as is shown in Svensson (2016b), Adrian and Liang's alternative assumptions required to overturn my result imply an effect of debt on the magnitude of a crisis that is more than 40 standard errors larger than the estimate of Flodén (2014) and more than 11 standard errors larger than an estimate that follows from Jordà, Schularick, and Taylor (2013), or an effect of credit on the probability of a crisis that is more than 13 standard errors larger than the estimate of Schularick and Taylor (2012). Given this, and the extensive sensitivity analysis already done in the paper, my result so far seems to be quite robust and not very sensitive to reasonable alternative assumptions.

1.2 Outline

The paper is outlined as follows: Section 2 examines the effect of LAW on the expected future unemployment rate, taking the possibility of a crisis into account. This is a generalization of the previous two-period analysis in Svensson (2014, 2015). Section 3 examines the effect of LAW on expected future quadratic losses, demonstrates the importance of the assumption that the cost of a crisis is larger when the economy is weaker, and contrasts with the cases when the loss level or the loss increase in a crisis is fixed and independent of the state of the economy. In particular, section 3.6 discusses in some detail the results of FR and GKS and their relation to the result of ALLN. Section 4 derives the corresponding marginal cost and benefit of LAW, to assess whether the optimal policy is to lean against or with the wind. The sensitivity of the results to the initial state of the economy, to the magnitude of the policy-rate effect on the expected non-crisis unemployment rate, and to the probability of a crisis is also reported. Section 5 examines the common argument that LAW is justified if there is a less effective macroprudential policy. Section 6 provides additional sensitivity analysis by examining whether monetary non-neutrality with a permanent effect on real

suboptimal policy rule, as is common in many papers on monetary policy, means that the set of arguments better span the space of state variables and shocks. It is therefore not surprising if adding an argument, often any argument, reduces total loss.

debt changes the results. Sections 2–6 use estimates from Schularick and Taylor (2012) of the effect of real debt growth on the probability of crisis with data for 14 countries for 1870–2008. Section 7 shows that recent IMF staff estimates in International Monetary Fund (2015) with the Laeven and Valencia (2012) data for 35 advanced countries for 1970-2012 give similar results. Section 8 summarizes the conclusions. Appendices A-J provide further details, sensitivity analysis, and extensions. In particular, appendix D examines the policy-rate effect on the magnitude of a crisis and appendix J examines and rejects the Bank for International Settlements (2016a) criticism in some detail.

2 The effect on expected future unemployment of leaning against the wind

This section examines the effect of LAW, that is, a somewhat higher policy rate, on the expected future unemployment rate in an economy, taking the possibility of a crisis into account. This is in line with the approach in Svensson (2014, 2015), but extends it from a two-period framework to a multi-period quarterly framework.

Let u_t denote the unemployment rate in quarter t. Assume that, in each quarter t, there are two possible states in the economy, non-crisis and crisis. In a crisis, the unemployment rate is higher by a fixed magnitude, the *crisis increase in the unemployment rate*, $\Delta u > 0$.[8] This crisis increase in the unemployment rate should more generally be interpreted as the unemployment increase after possible policy actions, including policy-rate cuts after the crisis has occurred, to moderate the cost of the crisis.[9] Let u_t^{n} and u_t^{c} denote the quarter-t *non-crisis and crisis unemployment rates*, respectively. They then satisfy

$$u_t^{\mathrm{c}} = u_t^{\mathrm{n}} + \Delta u > u_t^{\mathrm{n}}. \tag{2.1}$$

Let q_t denote the probability of a crisis *starting* in (the beginning of) quarter t, meaning that the unemployment rate increases by Δu and equals the crisis unemployment rate, u_t^{c}, during quarter t. Assume that a crisis has a fixed duration of n quarters, so if a crisis starts in (the beginning of) quarter t it ends in (the beginning of) quarter $t+n$. Thus, if a crisis starts in quarter t, the unemployment rate equals the crisis unemployment rate for the n quarters t, $t+1$, ..., $t+n-1$.

[8] For simplicity, the crisis increase in the unemployment rate is taken to be deterministic. As shown in appendix G, the analysis can easily be generalized to include the case where the crisis increase is random with a fixed mean, Δu, and a fixed variance, $\sigma^2_{\Delta u}$, but this would not affect the results.

[9] If a crisis occurs in quarter t, the increase Δu in the unemployment rate will in reality not occur within the quarter but over the next few quarters. For simplicity, the increase is nevertheless assumed to occur within the quarter.

Let p_t denote the probability of the economy *being* in a crisis in quarter t. If a crisis lasts n quarters, the probability of being in a crisis (approximately) equals the probability that a crisis started in any of the last n quarters, including the current quarter t, that is, in any of the quarters $t-n+1$, $t-n+2$, ..., t. Then the probability of a being in a crisis in quarter t satisfies

$$p_t = \sum_{\tau=0}^{n-1} q_{t-\tau}. \tag{2.2}$$

In the rest of the paper, I will refer to p_t as the *probability of a crisis* in quarter t and to q_t as the *probability of a crisis start* in quarter t.[10]

It follows that the quarter-t unemployment rate, u_t, will equal the non-crisis unemployment rate, u_t^{n}, with probability $1-p_t$ and the crisis unemployment rate with probability p_t. The unemployment rate in quarter $t \geq 1$ that is expected in quarter 1, the *expected unemployment rate*, is then given by

$$\mathrm{E}_1 u_t = (1-p_t)\mathrm{E}_1 u_t^{\mathrm{n}} + p_t \mathrm{E}_1 u_t^{\mathrm{c}} = (1-p_t)\mathrm{E}_1 u_t^{\mathrm{n}} + p_t(\mathrm{E}_1 u_t^{\mathrm{n}} + \Delta u) = \mathrm{E}_1 u_t^{\mathrm{n}} + p_t \Delta u, \tag{2.3}$$

where E_1 denotes the expectations held in quarter 1. The expected future unemployment rate equals the *expected non-crisis unemployment rate*, $\mathrm{E}_1 u_t^{\mathrm{n}}$, plus the increase in the *expected* unemployment rate due to the possibility of a crisis, $p_t \Delta u$, the probability of a crisis times the crisis increase in the unemployment rate.

What is then the effect of a higher policy rate on the expected future unemployment rates? Let $\bar{i}_1$ denote a constant policy rate during quarters 1–4, so the policy rate in quarter t, i_t, satisfies $i_t = \bar{i}_1$ for $1 \leq t \leq 4$. Consider the effect on the expected future unemployment rate of increasing the policy rate during quarters 1–4, $d\bar{i}_1 > 0$. By (2.3), it is given by the derivative

$$\frac{d\mathrm{E}_1 u_t}{d\bar{i}_1} = \frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} + \Delta u \frac{dp_t}{d\bar{i}_1}. \tag{2.4}$$

It consists of the effect on the expected non-crisis unemployment rate, $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$, and the effect on the crisis increase in the expected unemployment rate, $\Delta u\, dp_t/d\bar{i}_1$.[11] Let us examine these in turn.

[10] I am grateful to Stefan Laséen and David Vestin for alerting me to the fact that equation (2.2) is a linear approximation to the probability of a crisis. A more thorough treatment is to model the dynamics of the probability of a crisis as a Markov process, as discussed in appendix A. For the parameter range used here, the linear approximation slightly exaggerates the probability of a crisis but simplifies the derivation of the effect of the policy rate on the probability of a crisis.

[11] Here I am abstracting from the possible effect of the policy rate on the crisis increase in the unemployment rate, $d\Delta u_t/di_t$. It is examined separately in appendix D, where it is shown that the effect can be of either sign but is empirically so small that it can be disregarded.

2.1 The effect of the policy rate on the expected non-crisis unemployment rate

The effect on the policy rate on the expected non-crisis unemployment rate is just the standard impulse response of the unemployment rate to an increase in the policy rate. As an example and benchmark, I use the impulse response in the Riksbank's main model, the DSGE model Ramses, shown in Figure 2.1.[12] The gray line shows an increase in the policy rate of 1 percentage point during quarters 1–4 ($\Delta\bar{i}_1 = 1$ percentage point) and then a return to the baseline level. The red line shows the corresponding deviation of the unemployment rate from the baseline level ($\Delta \mathrm{E}_1 u_t^{\mathrm{n}}$). The unemployment rate increases above the baseline level to about 0.5 percentage point in quarter 6 and then slowly falls back towards the baseline level. Under the assumption of approximate linearity, I can take this effect on the expected future non-crisis unemployment rates as the derivative with respect to the policy rate $\bar{i}_1$ of the expected future non-crisis unemployment rate,

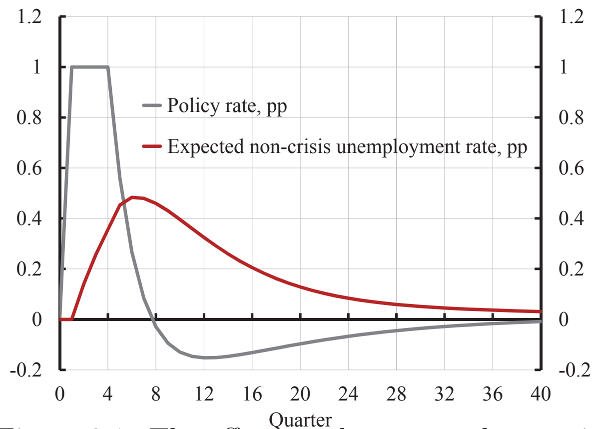

Figure 2.1: The effect on the expected non-crisis unemployment rate of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: Sveriges Riksbank.)

$$\frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} = \frac{\Delta \mathrm{E}_1 u_t^{\mathrm{n}}}{\Delta \bar{i}_1} = \Delta \mathrm{E}_1 u_t^{\mathrm{n}} \quad \text{for } t \geq 1, \tag{2.5}$$

where $\Delta \mathrm{E}_1 u_t^{\mathrm{n}}$ is given by figure 2.1.

Thus, we have determined the first term in (2.4). It remains to determine the second term, that is, the product of the crisis increase in the unemployment rate and the effect on the probability of a crisis of the policy rate. As a benchmark crisis increase in the unemployment rate, I will use the same assumption as in a crisis scenario discussed in Sveriges Riksbank (2013), that the crisis increase in the unemployment rate is 5 percentage points ($\Delta u = 5$ percentage points).[13] It remains to determine $dp_t/d\bar{i}_1$, the effect of the policy rate on the probability of a crisis in quarter $t \geq 1$.

[12] The figure shows the impulse response in Ramses of the unemployment rate that was reported by Riksbank deputy governor Karolina Ekholm in Ekholm (2013). It is the same response as the one reported to alternative policy-rate paths for quarters 1–12 in Sveriges Riksbank (2014b).

[13] Schularick and Taylor (2012, table 2) report that, in the aftermath of postwar financial crises, output dropped a cumulative 7.9 percent five years after the crisis start relative to trend growth in non-crisis years.

2.2 The effect of the policy rate on the probability of a crisis

In order to determine the effect of the policy rate on the probability of a crisis, p_t, I will use that the probability of a crisis depends on the probability of a crisis start, q_t, in the n quarters before and including quarter t according to (2.2), that the probability of a crisis start may depend on real debt growth, and that real debt growth may depend on the policy rate.

2.2.1 The effect of real debt growth on the probability of a crisis start

According to Schularick and Taylor (2012), the probability of a crisis start depends on the growth rate of real debt during the previous few years. Schularick and Taylor use annual data for 14 developed countries for 1870–2008 and estimate the annual probability of a crisis as a function of annual debt growth lagged 1–5 years. I use their estimates of the coefficients in their main logit regression, Schularick and Taylor (2012, table 3, specification 5) , in a quarterly variant of their equation,

$$q_t = \frac{1}{4}\frac{\exp(X_t)}{1+\exp(X_t)},$$

where

$$X_t = -3.89 - \underset{(2.110)}{0.398}\, g_{t-4} + \underset{(2.631)}{7.138^{***}}\, g_{t-8} + \underset{(2.948)}{0.888}\, g_{t-12} + \underset{(1.378)}{0.203}\, g_{t-16} + \underset{(1.640)}{1.867}\, g_{t-20}, \tag{2.6}$$

numbers within parenthesis are robust standard errors,[14]

$$g_t \equiv (\sum\nolimits_{\tau=0}^{3} d_{t-\tau}/4)/(\sum\nolimits_{\tau=0}^{3} d_{t-4-\tau}/4) - 1, \tag{2.7}$$

and d_t is the level of real debt in quarter t.[15] That is, g_t is the annual growth rate of the average annual real debt level. Schularick and Taylor (2012, p. 1046) report a marginal effect on the annual probability of a crisis start over all lags equal to 0.30, implying the summary result that 5 percent lower real debt in 5 years reduces the probability of a crisis by about 0.3 percentage point per year. That is, it reduces the quarterly probability q_t by 7.5 basis points.[16] [17]

[14] One, two, and three stars denote significance at the 10, 5, and 1 percent level, respectively. The five lags are jointly significant at the 1 percent level.

[15] More precisely, what I call real debt is in Schularick and Taylor (2012) total bank loans, defined as the end-of-year amount of outstanding domestic currency lending by domestic banks to domestic households and nonfinancial corporations (excluding lending within the financial system).

[16] The linear regression in Schularick and Taylor (2012, table 3, specification 1) implies a corresponding somewhat higher marginal effect of 0.4. This explains the summary result that I have used in Svensson (2014, 2015): 5 percent lower real debt in 5 years reduces the annual probability of a crisis start by about 0.4 percentage point. In figure 2.2, a 1 percentage point increase in the policy rate reduces real debt by 0.25 percent in 5 years. Then the summary result is that a 1 percentage point increase in the policy rate decreases the annual probability of a crisis by about $0.25 \cdot 0.4/5 = 0.02$ percentage point, which is the summary result that I have used in Svensson (2014, 2015).

[17] A full 1 percentage point reduction of the annual real debt growth for 5 years actually reduces the annual probability of a crisis start by 0.288 percentage points rather than 0.30 percentage point, because of the slight

However, we notice that the coefficients in (2.6) are not uniform, so the summary result strictly only applies for *uniform* annual real debt growth during 5 years. If real debt growth fluctuates, the dynamics of the probability of a crisis start is more complicated, as in the dynamic approach of Diaz Kalan, Laséen, Vestin, and Zdzienicka (2015). In particular, we see that annual real debt growth lagged 2 years, g_{t-8}, has by far the largest coefficient in (2.6). Thus, annual real growth lagged two years is the major determinant of the probability of a crisis start.[18]

2.2.2 The effect of the policy rate on real debt, real debt growth, the probability of a crisis start, and the probability of a crisis

Given the effect on the probability of crisis start of real debt growth in (2.6), it remains to determine the effect of the policy rate on real debt growth. As an example and benchmark, I use the Sveriges Riksbank (2014a) estimate of the effect on the *level* of real household debt, d_t, of a 1 percentage point higher policy rate during 4 quarters, shown as the red line in figure 2.2.[19] Real debt falls relative to the baseline level by 1 percentage in two years and then rises back and reaches the baseline level again in about 8 years.[20] Because monetary policy is neutral, there is no long-run effect on real debt.

We can interpret the red line as showing the derivative of real debt d_t with respect to the policy rate $\bar{i}_1$, $d(d_t)/d\bar{i}_1$ for $t \geq 1$, where furthermore $d(d_t)/d\bar{i}_1 \approx 0$ for $t \geq 32$.

The yellow line in figure 2.2, shows the resulting effect on real debt growth g_t, the annual growth rate of the average annual real debt level defined by (2.7). Because the real debt *level* first falls and then rises back to the baseline level, real debt *growth* will first fall below the baseline growth rate and then rise above the baseline growth rate. Thus, lower real debt growth rates are followed by higher real debt growth rates. Importantly, because there is no effect of the policy rate on real debt in the longer run, there is no effect on the average growth rate over a longer period.

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curvature of the logistic function. A smaller reduction of the real debt growth of 0.1 percentage point per year reduces the probability of crisis start by 0.03 percentage point per year, corresponding to the marginal effect equal to 0.30.

Given the sum of the coefficients in (2.6), 9.698, the marginal effect of 0.30 is consistent with a probability of a crisis start equal to 3.2 percent per year, that is, 0.8 percent per quarter.

The constant in (2.6), -3.89, is chosen so as to be consistent with this probability and a steady real debt growth rate of 5 percent per year. See appendix B for details.

[18] Schularick and Taylor (2012, table 7, specification 22) reports the result of a model specification that adds debt to GDP as an explanatory variable. The coefficient is significantly different from zero, but as discussed in detail in appendix H, it is so small that it has a very small impact on the probability of a crisis start and the probability of a crisis. I therefore disregard that effect here.

[19] The Schularick and Taylor (2012) estimates refer loans to both households and nonfinancial corporations, whereas the estimates in Sveriges Riksbank (2014a) refer to loans to households only. I assume that this difference does not affect the conclusions.

[20] As discussed in Svensson (2014, 2015), there is a wide 90 percent probability band around the red line, and the effect is not significantly different from zero and could be of either sign.

We can interpret the yellow line as showing the derivative of the annual real debt growth g_t with respect to the policy rate $\bar{i}_1$, $dg_t/d\bar{i}_1$ for $t \geq 1$, where furthermore

$$\sum\nolimits_{t=1}^{40} \frac{dg_t}{d\bar{i}_1} \approx 0.$$

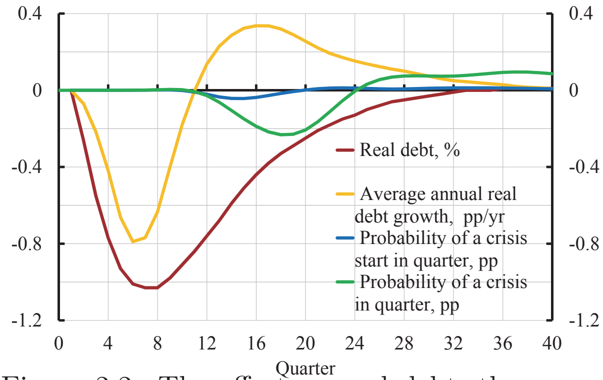

Figure 2.2: The effect on real debt, the average annual real debt growth, the probability of a crisis start in quarter, and the probability of being in a crisis in quarter of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

The blue line in figure 2.2 shows the resulting dynamics of the probability of a crisis start for each quarter, q_t, that follows from (2.6). Because annual real debt growth lagged two years is the main determinant of the probability of a crisis start and the annual real debt growth falls below the baseline and has a negative peak (of about -0.8 percentage point per year) in quarter 6, the probability of a crisis will fall below the baseline and have a negative peak (at -0.04 percentage point) about two years later, in quarters 14 and 15. Furthermore, annual real debt growth rises above the baseline in quarter 12, which causes the probability of a crisis start to rise above the baseline and have a *positive* peak (of 0.013 percentage point, barely visible) about 2 years later. Thus, these results imply that an increase in the policy rate actually, after about five years, *increases* the probability of a crisis start above the baseline. The increase in the policy rate shifts the probability of a crisis start between quarters, first reducing it and then increasing it. But importantly, because the average effect over time on real debt growth is zero, the average effect over time on the probability of a crisis start is also zero.

We can hence interpret the blue line as showing the derivative $dq_t/d\bar{i}_1$ for $t \geq 1$, with

$$\sum\nolimits_{t=1}^{40} \frac{dq_t}{d\bar{i}_1} \approx 0.$$

The green line in figure 2.2 shows the dynamics of the probability of a crisis, p_t. According to (2.2), that probability depends on the sum of all the probabilities of a crisis start, q_t, during the last n quarters, the duration of a crisis. I assume that the benchmark duration of a crisis is $n = 8$ quarters, so that a crisis implies that the unemployment rate is 5 percentage points higher during the 8 quarters, corresponding to 10 point-years of higher unemployment. Thus, the green line shows an 8-quarter moving sum of the blue line. It has a negative peak of about -0.23 percentage point in quarter 18 and then rises back to zero and turns positive from quarter 25. It is still positive in quarter 40 but will eventually fall to zero.[21]

The green line can be interpreted as showing the derivative of the probability of a crisis with respect to the policy rate, $dp_t/d\bar{i}_1$ for $t \geq 1$. Furthermore,

$$\sum\nolimits_{t=1}^{40} \frac{dp_t}{d\bar{i}_1} \approx 0. \tag{2.8}$$

Thus, the higher policy rate reduces the probability somewhat after 3 years and increases it after 6 years, but without any cumulated and average effect over the 40 quarters.

2.3 The effect of the policy rate on the expected future unemployment rate

Given the effect of the policy rate on the probability of a crisis, $dp_t/d\bar{i}_1$, from figure 2.2, the assumption that the crisis increase in the unemployment rate Δu is 5 percentage points from Sveriges Riksbank (2013), and the effect of the policy rate on the non-crisis expected unemployment rate $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$ from figure 2.1, we can compute the effect of the policy rate on the expected unemployment rate $d\mathrm{E}_1 u_t/d\bar{i}_1$ according to (2.4). It is shown in figure 2.3.

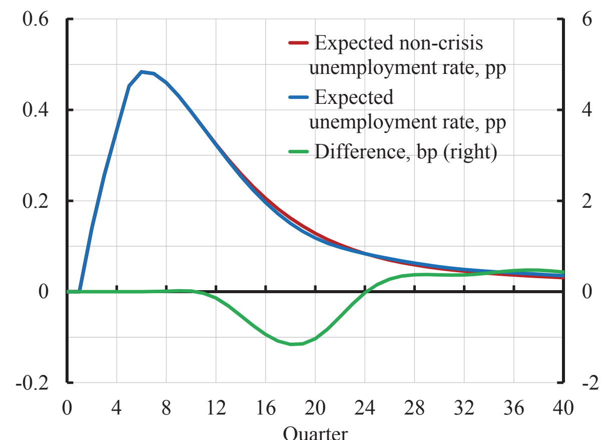

Figure 2.3: The effect on the expected unemployment rate and the expected non-crisis unemployment rate of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

The red line shows the effect on the expected non-crisis unemployment rate, the same line as in figure 2.1. The blue line shows the effect on the expected unemployment rate. It hardly differs from the red line, the effect on the non-crisis unemployment rate. The reason is that the effect on the crisis increase in the expected unemployment rate, $\Delta u \, dp_t/d\bar{i}_1$, is very small compared to the effect on the expected non-crisis unemployment rate. It is shown as the green line, in *basis* points, measured along the right vertical axis. As we have noticed in figure 2.2, the largest effect on the probability occurs in quarter 18, when $dp_{18}/d\bar{i}_1$ is -0.23 percentage points. This means that the term $\Delta u \, dp_t/d\bar{i}_1 = 5 \cdot (-0.0023) = -0.0116$ percentage point $= -1.16$ basis points, is quite small compared to the effect on the expected non-crisis unemployment rate in quarter 18, $d\mathrm{E}_1 u_{18}^{\mathrm{n}}/d\bar{i}_1 = 0.16$ percentage point $= 16$

[21] Note that the Schularick and Taylor estimates in (2.6) have a relatively large coefficient (although not significant) on the annual real growth rate lagged 5 years, meaning that the probability of a crisis start and the probability of a crisis are still affected by the higher real debt growth 5-6 years earlier.

basis points. And from quarter 25 the effect of the policy rate on the probability of a crisis continues to be very small, but positive.

Furthermore, because the cumulated and average effect on the probability of a crisis over the 40 quarters is approximately zero, the cumulated effect on the expected unemployment rate is approximately equal to the effect on the expected non-crisis unemployment rate,

$$\sum\nolimits_{t=1}^{40} \frac{d\mathrm{E}_1 u_t}{d\bar{i}_1} = \sum\nolimits_{t=1}^{40} \frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} + \Delta u \sum\nolimits_{t=1}^{40} \frac{dp_t}{d\bar{i}_1} \approx \sum\nolimits_{t=1}^{40} \frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1}.$$

In figure 2.3, the cumulated effect on the expected non-crisis unemployment rate is 6.9 point-quarters, whereas the cumulated effect on the expected crisis increase in the unemployment rate is only -0.03 point-quarters. The area under the red and the blue curves are approximately equal for a horizon of 40 quarters.

In summary, the effect of the policy rate on the expected future unemployment rate is the sum of the effect on the expected non-crisis unemployment rate and the effect on the crisis increase in the expected unemployment rate, the product of the probability of a crisis and the crisis increase in the unemployment rate. The latter effect is very small, because a higher policy rate has only a small decreasing effect on the probability of a crisis for a few years. Furthermore, after a few years the effect is a small increase. Because, by the long-run neutrality of monetary policy, the cumulated effect on the probability of a crisis is approximately zero, there is no cumulated effect of the policy rate on expected crisis increase in the unemployment rate.[22]

According to these results, it is simply not true that a higher unemployment rate in the near future can be traded for a lower expected unemployment rate further into the future. Instead, LAW increases the expected unemployment rate both in the near future and further into the future.

3 The effect on expected future quadratic losses of leaning against the wind

In order to assess the cost and benefit of LAW, it is not sufficient to only look at the expected future unemployment rate. The marginal welfare loss from a higher unemployment rate is larger the more the initial unemployment rate exceeds its desirable level, something that is captured by

[22] This zero long-run effect is strictly true only under the assumption of the probability being a linear function of debt growth. But the effects of nonlinearities, for instance from a logistic model of the probability of a crisis, will be of second order under these small changes and will hardly change the conclusions. Furthermore, the logistic function (2.6) is slightly convex in the range of the relevant real debt growth rates (see figure 5.1 below), meaning that any increased variability in real debt growth rates caused by the higher policy rate will *increase* the average probability of a crisis, but very slightly so.

a quadratic loss function. In this section I therefore examine the cost and benefit when gains and losses are measured by a quadratic loss function. For simplicity, the quadratic loss function has only unemployment as an argument, instead of both inflation and unemployment. However, such a simple loss function can be seen as an indirect loss function resulting from the minimization of a loss function of both inflation and unemployment.

More precisely, let u_t^* denote the *benchmark unemployment rate*. This benchmark unemployment rate should be interpreted as the unemployment rate resulting from the minimization of a quadratic loss function of inflation and unemployment subject to a Phillips curve, as shown in some detail in appendix C. Furthermore, this minimization is undertaken under the assumption that the possibility of a crisis is disregarded and thus that the probability of a crisis is set to zero, $p_t \equiv 0$ for $t \geq 1$. Thus, the benchmark unemployment rate can be seen as the optimal unemployment rate under flexible inflation targeting, when the possibility of a financial crisis is disregarded. It is assumed to depend on exogenous shocks (see appendix C for details).

Let $\tilde{u}_t$ denote the *unemployment gap*, here defined as the gap between the unemployment rate and the benchmark unemployment rate,

$$\tilde{u}_t \equiv u_t - u_t^*, \tag{3.1}$$

and let $\tilde{u}_t^{\mathrm{n}} \equiv u_t^{\mathrm{n}} - u_t^*$ and $\tilde{u}_t^{\mathrm{c}} \equiv u_t^{\mathrm{c}} - u_t^*$ denote the non-crisis and crisis unemployment gaps, respectively. Introduce the expected intertemporal loss,

$$\mathrm{E}_1 \sum_{t=1}^{\infty} \delta^{t-1} L_t = \sum_{t=1}^{\infty} \delta^{t-1} \mathrm{E}_1 L_t, \tag{3.2}$$

where δ denotes a discount factor and satisfies $0 < \delta < 1$ and the quarter-t loss function, L_t, is a simple quadratic loss function of the unemployment gap,

$$L_t = (\tilde{u}_t)^2. \tag{3.3}$$

Thus, (3.3) can be seen as an indirect loss function resulting from the minimization of a quadratic loss function of inflation and unemployment in quarter t, when the possibility of a financial crisis is disregarded.[23]

Let me next examine the expected quarter-t loss, $\mathrm{E}_1 L_t$, when the possibility of a financial crisis is taken into account. It can be expressed as

$$\mathrm{E}_1 L_t = \mathrm{E}_1(\tilde{u}_t)^2 = (1-p_t)\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t \mathrm{E}_1(\tilde{u}_t^{\mathrm{c}})^2 = (1-p_t)\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}} + \Delta u)^2, \tag{3.4}$$

[23] Stein (2013) also uses a loss function in terms of unemployment only.

where I have used that

$$\tilde{u}_t^{\mathrm{c}} = \tilde{u}_t^{\mathrm{n}} + \Delta u. \tag{3.5}$$

Thus, the expected quarter-t loss can be seen as the probability-weighted expected loss in a non-crisis, $(1-p_t)\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2$, plus the probability-weighted expected loss in a crisis, $p_t\mathrm{E}_1(\tilde{u}_t^{\mathrm{c}})^2$. [24]

Furthermore, because the expected square of a random variable equals the square of the expected random variables plus its variance,[25] we have

$$\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 = (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}},$$
$$\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 = (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}},$$

where $\mathrm{Var}_1\tilde{u}_t^{\mathrm{n}}$ denotes the variance of $\tilde{u}_t^{\mathrm{n}}$ conditional on information available in quarter 1. Then I can write the quarter-t expected loss (3.4) as [26]

$$\mathrm{E}_1 L_t = (1-p_t)(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + p_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}}. \tag{3.6}$$

Consider the initial situation in which there is no crisis in quarter 1 and the expected future non-crisis unemployment gaps are zero,

$$\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = 0 \quad \text{for } t \geq 1. \tag{3.7}$$

That is, the expected future unemployment rates are equal to the expected benchmark unemployment rates, and the situation is optimal if the probability of a crisis in future quarters is assumed to equal zero. Under that assumption, the quarter-t expected loss is just $(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}}$, which is minimized if $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = 0$.

However, the actual probability of a future crisis is not zero. Let $\bar{p}_t$ for $t \geq 1$ denote the actual probability of a crisis in quarter t, conditional on the initial situation (3.7) and the corresponding current and expected future policy rates. I will call it the *benchmark probability of a crisis* in quarter t. By adding and subtracting $(1-\bar{p}_t)(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2$ from (3.6), the expected quarter-t loss when the probability of a crisis is taken into account can be rewritten as

$$\begin{aligned}\mathrm{E}_1 L_t - \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}} &= [(1-\bar{p}_t)(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2] - (\bar{p}_t - p_t)[(\Delta u)^2 + 2\Delta u \mathrm{E}_1\tilde{u}_t^{\mathrm{n}}] \\ &\equiv C_t - B_t,\end{aligned} \tag{3.8}$$

[24] Here, the fixed crisis increase in the unemployment rate, Δu, in the expected crisis loss, $\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}} + \Delta u)^2$, should be interpreted as the crisis increase in the unemployment rate after possible policy actions during the crisis to moderate the crisis cost, as in section 2. More generally, since a crisis has many different costs, Δu represents the unemployment-increase *equivalent* of these crisis costs.

[25] For a random variable X, we have $\mathrm{E}(X)^2 = \mathrm{E}[\mathrm{E}X + (X - \mathrm{E}X)]^2 = (\mathrm{E}X)^2 + \mathrm{E}(X-\mathrm{E}X)^2 = (\mathrm{E}X)^2 + \mathrm{Var}\,X$.

[26] As noted in footnote 8, the crisis increase in the unemployment rate could be random instead of deterministic. As shown in appendix G, this can easily be incorporated but would not affect the results.

where I have used that the crisis loss increase satisfies

$$(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 - (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 = (\Delta u)^2 + 2\Delta u \mathrm{E}_1\tilde{u}_t^{\mathrm{n}}. \tag{3.9}$$

Also, under the assumption of a linear relation between the policy rate and the expected non-crisis unemployment gap together with additive shocks, the conditional variance $\mathrm{Var}_1\tilde{u}_t^{\mathrm{n}}$ is independent of policy. Therefore I have moved it to the left side of (3.8), and it is sufficient for our purpose to examine the terms on the right side of (3.8).

The expression (3.8) allows us to assess the effect of a higher policy rate on the expected future losses. A higher policy rate will increase the expected future unemployment gap, $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}$, above zero and possibly reduce the probability of a crisis in future quarters, p_t, below the benchmark probability of a crisis, $\bar{p}_t$. In particular, I will refer to the first term in (3.8),

$$C_t \equiv (1-\bar{p}_t)(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 \equiv C_t^{\mathrm{n}} + C_t^{\mathrm{c}}, \tag{3.10}$$

as the *cost* of deviating from a zero unemployment gap. It consists of the sum of the probability-weighted expected loss in a non-crisis, C_t^{n}, and the probability-weighted loss in a crisis, C_t^{c}, when the benchmark probability of a non-crisis and crisis is used. Furthermore, I will refer to the second term in (3.8),

$$B_t \equiv (\bar{p}_t - p_t)[(\Delta u)^2 + 2\Delta u \mathrm{E}_1\tilde{u}_t^{\mathrm{n}}], \tag{3.11}$$

as the *benefit* of deviating from a zero unemployment gap. It consists of the reduction in the probability of a crisis from the benchmark probability, $\bar{p}_t - p_t$, multiplied by the loss increase in a crisis, (3.9).

3.1 The benchmark probability of a crisis

Before looking more closely at this expression for the cost and benefit, let me specify the estimate of the benchmark probability of a crisis. The sum of the coefficients in (2.6) and the reported marginal effect of 0.30 by Schularick and Taylor (2012) is consistent with a constant annual probability of a crisis start equal to 3.2 percent.[27] This corresponds to a crisis start on average every 31 years. A constant annual probability of a crisis start of 3.2 percent implies a corresponding constant probability of a crisis start in a given quarter, denoted q, equal to $3.2/4 = 0.8$ percent. I will use this as my benchmark probability of a crisis start. Furthermore, as mentioned, I have assumed that a crisis lasts 8 quarters ($n = 8$).

[27] See appendix B for details.

Conditional on no crisis in quarter 1, for a given q and n, the benchmark probability of a crisis in quarter t is then, according to (2.2),

$$\bar{p}_t = \begin{cases} 0 & \text{for } t = 1, \\ (t-1)q > 0 & \text{for } 2 \leq t \leq n, \\ nq > 0 & \text{for } t \geq n+1. \end{cases} \quad (3.12)$$

Thus, $\bar{p}_t$ rises linearly from 0 in quarter 1 to its steady-state value $p \equiv nq$ in quarter $n+1$. With $n = 8$ quarters and $q = 0.8$ percent, $\bar{p}_t$ rises linearly from 0 in quarter 1 to $p = 6.4$ percent in quarter 9 and then stays at 6.4 percent, as shown by the solid green line in figure 3.1.[28]

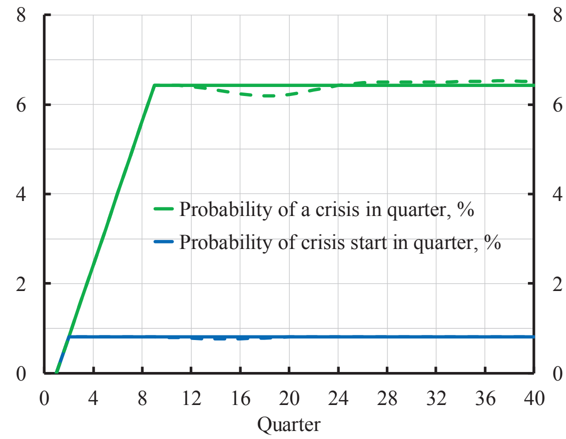

Figure 3.1: The probability of a crisis start and of a crisis for the benchmark (solid lines) and for a 1 percentage point higher policy rate during quarters 1–4 (dashed), conditional on no crisis in quarter 1.

The dashed green line lines show the probability of a crisis for a 1 percentage point higher policy rate during quarters 1–4. Thus, the difference between the dashed and solid green line equals the policy-rate effect on the probability of a crisis, the green line in figure 2.2. The small wiggle in the probability of a crisis illustrates the small and temporary effect of LAW on the probability and indicates that the benefit of LAW will be small.

To get a sense of proportion, results of Dagher, Dell'Ariccia, Laeven, Ratnovski, and Tong (2016, figures 3 and 7) indicate that around 20 percent bank capital relative to risk-weighted assets would have been enough to avoid about 80 percent of the historical banking crises in the OECD countries since 1970. In figure 3.1, an 80 percent reduction in the frequency and probability of financial crises would mean that the green curve would shift down from 6.4 percent to 1.3 percent. This is a permanent fall in the probability of a crisis that is 22 times larger than the maximum temporary fall in the probability from a 1 percentage point higher policy rate during quarters 1–4. Thus, macroprudential policy in the form of sufficiently high capital requirements capital may lead to a large reduction in the probability of a crisis, much larger than the small fluctuations in the probability that monetary policy apparently can achieve.

[28] As mentioned in footnote 10, (3.12) is a linear approximation to a Markov process for the probability of a crisis. As shown in appendix A and figure A.1, for the relevant Markov process, the benchmark probability of a crisis can be shown to rise from zero in quarter 1 to 6.2 percent in quarter 9 and then converges to 6.0 percent in quarter 16.

3.2 The cost of deviating from a zero expected non-crisis unemployment gap

Let me next examine in some detail the quarter-t cost and benefit (3.8) of deviating from a zero expected non-crisis unemployment gap. To best understand what determines the cost and benefit for a particular quarter, it is practical to examine how they depend on the expected non-crisis unemployment gap.

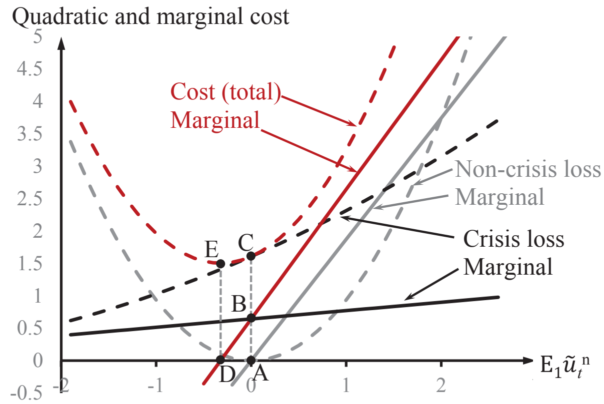

Figure 3.2: The probability-weighted quadratic (dashed line) and marginal (solid) expected non-crisis loss (gray), expected crisis loss (black), and (total) cost (red), as a function of the expected non-crisis unemployment gap (under the assumption that the benchmark probability of a crisis is 6.4 percent and the crisis increase in the unemployment rate is 5 percent).

Let me do this for quarters $t \geq 9$, when the benchmark probability of a crisis is constant and equal to the steady-state level, $\bar{p}_t = p = 6.4$ percent. Let me start with the cost, C_t, given by (3.10) for $\bar{p}_t = p$, the sum of the probability-weighted expected loss in a non-crisis (C_t^{n}) and a crisis (C_t^{c}).

In figure 3.2, the gray dashed line shows the probability-weighted non-crisis expected loss,

$$C_t^{\mathrm{n}} = (1 - \bar{p}_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 = 0.936(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2,$$

as a function of the expected non-crisis unemployment gap, $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}$. It has a minimum for $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = 0$, corresponding to point A. The gray solid line shows the corresponding probability-weighted *marginal* non-crisis loss (with respect to an increase in the expected non-crisis unemployment gap),

$$\frac{dC_t^{\mathrm{n}}}{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}} = \frac{d[(1 - \bar{p}_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2]}{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}} = 0.936 \cdot 2\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}.$$

It is zero where the probability-weighted non-crisis loss has a minimum, for $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = 0$, and has a positive slope of 1.872.

Under the assumption that the probability of a crisis is zero, the non-crisis loss is the only loss that matters, and the optimal policy is to set the expected non-crisis unemployment gap equal to zero. But if the probability of a crisis is positive, the probability-weighted crisis loss has to be taken into account.

The black dashed line shows the probability-weighted crisis loss,

$$C_t^{\mathrm{c}} = \bar{p}_t(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} + \Delta u)^2 = 0.064(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} + 5)^2,$$

where I have used that the crisis increase in the unemployment rate is assumed to be 5 percent. The probability-weighted crisis loss has a minimum for $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = -5$ percentage points, and is upward-sloping for the range of expected non-crisis unemployment gaps shown in the figure. For $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = 0$, the probability-weighted crisis loss is $0.064 \cdot 5^2 = 1.61$, corresponding to point C in the figure. The black solid line shows the corresponding probability-weighted marginal crisis loss,

$$\frac{dC_t^{\mathrm{c}}}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} = \frac{d[\bar{p}_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2]}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} = 0.064 \cdot 2(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + 5) = 0.128\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + 0.64.$$

The probability-weighted marginal crisis loss is zero for $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = -5$ and positive and equal to $0.064 \cdot 2(5) = 0.64$ for $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = 0$, and it has a positive slope of 0.128.

That the marginal crisis loss is positive for $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = 0$ reflects the realistic and crucial assumption that the cost of crisis is larger if the economy is weaker.

The red dashed line shows the cost of deviating from a zero expected non-crisis unemployment gap, the sum of the probability-weighted expected non-crisis and crisis losses,

$$C_t = (1 - \bar{p}_t)(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 = 0.936(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + 0.064(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + 5)^2,$$

that is, the vertical sum of the gray and black dashed lines. The red solid line shows the corresponding marginal cost (with respect to increasing the expected non-crisis unemployment gap),

$$\frac{dC_t}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} = \frac{d[(1 - \bar{p}_t)(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2]}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} = 2(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \bar{p}_t\Delta u) = 2(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + 0.32). \qquad (3.13)$$

For $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = 0$, the total loss is $0.064 \cdot 5^2 = 1.61$, corresponding to point C, and the marginal loss is 0.64, corresponding to point B. It is obvious from the figure that this is not a minimum for the cost.

The minimum for the cost occurs where the marginal cost is zero, for which $\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = -0.32$ percentage point, corresponding to point D. Then the cost is 1.50, corresponding to point E. The gain, the reduction in total loss from point C to point E is $0.11 = 0.32^2$, thus equivalent to the negative of the loss of increasing the unemployment rate by 0.32 percentage point from its optimal level.

Thus, if the probability of a crisis is zero, it is optimal to set the expected non-crisis unemployment gap equal to zero. If the probability of a crisis is positive, it is optimal to *reduce* the expected non-crisis unemployment gap below zero. That is, it is optimal to *lower* the policy rate and thus lean *with* the wind. More precisely, as long as the probability of a crisis is taken as given, without taking into account the possible benefit from a reduced probability of a crisis, it is optimal to lean with the wind.

We can see this in a alternative way. We can rewrite the expected quarter-t loss as the sum of the squared expected unemployment gap and the conditional variance of the unemployment gap, the first equality in (3.14),[29]

$$\mathrm{E}_1 L_t = \mathrm{E}_1(\tilde{u}_t)^2 = (\mathrm{E}_1\tilde{u}_t)^2 + \mathrm{Var}_1\tilde{u}_t = (\mathrm{E}_1\tilde{u}_t)^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}} + p_t(1-p_t)(\Delta u)^2. \tag{3.14}$$

The second equality in (3.14) uses that the conditional variance of the unemployment gap ($\mathrm{Var}_1\tilde{u}_t$) is the sum of the conditional variance the non-crisis unemployment gap ($\mathrm{Var}_1\tilde{u}_t^{\mathrm{n}}$) and the variance of a binomial distribution $[p_t(1-p_t)(\Delta u)^2]$ because the unemployment gap is the sum of the non-crisis unemployment gap and a binomial random variable that takes the value Δu with probability p_t and the value 0 with probability $1-p_t$.[30]

Under the assumption that the probability of a crisis is given by the benchmark probability of a crisis, $p_t = \bar{p}_t$, the variance terms in (3.14) are exogenous and independent of policy.[31] Then the marginal loss with respect to an increase in the expected unemployment gap satisfies,

$$\frac{d\mathrm{E}_1 L_t}{d\mathrm{E}_1\tilde{u}_t} = \frac{d(\mathrm{E}_1\tilde{u}_t)^2}{d\mathrm{E}_1\tilde{u}_t} = 2\mathrm{E}_1\tilde{u}_t,$$

and the optimal policy is to set the marginal loss and thereby the expected unemployment gap equal to zero,

$$\mathrm{E}_1\tilde{u}_t = \mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \bar{p}_t\Delta u = 0.$$

This implies setting the expected non-crisis unemployment gap equal to the minus the probability-weighted crisis increase in the unemployment rate,

$$\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = -\,\bar{p}_t\Delta u < 0.$$

Once seen, this is completely obvious. If there is a given positive probability of a crisis, the expected unemployment gap is greater than the expected non-crisis unemployment gap. It is optimal to set the expected unemployment gap equal to zero; hence it is optimal to set the expected non-crisis unemployment gap below zero. Leaning *with* the wind is the obvious optimal policy in this case. The optimal amount of leaning with the wind is a non-crisis unemployment gap equal to $-\,\bar{p}_t\Delta u = -\,0.064 \cdot 5 = -\,0.32$ percentage point instead of zero, a rather small amount of leaning with the wind.[32]

[29] Kocherlakota (2014) and Stein (2014) use such a decomposition of the loss function.

[30] The conditional covariance between the non-crisis unemployment gap and a crisis start is assumed to be zero.

[31] If the conditional variance terms are independent of policy, Certainty Equivalence holds, and it is sufficient to focus on the conditional means of the relevant variables. When the conditional variance terms depend on policy, as when the probability of a crisis depends on the policy rate, Certainty Equivalence no longer holds and optimal policy also has to take into account the effect on the conditional variance terms.

[32] This is in line with the discussion of optimal policy with low-probability extreme events in Svensson (2003a).

3.3 The possible benefit of leaning against the wind

The discussion in section 3.2 above shows that for a given probability of a crisis, the optimal policy is to lean somewhat *with* the wind. However, an increase in the policy rate may reduce the probability of a crisis and this way reduce the expected loss increase in a crisis, as the benefit B_t given by (3.11) shows. Thus, the increase in the expected non-crisis unemployment gap from the increase in the policy rate is here accompanied by a change in the probability of a crisis.

The probability of a crisis can then be seen as an implicit function of the expected non-crisis unemployment gap, $p_t = p_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})$, with the linear approximation

$$p_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}) - \bar{p}_t = \frac{dp_t}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}}\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}, \text{ for } t \geq 1, \tag{3.15}$$

where $p_t(0) = \bar{p}_t$ and the implicit derivative $dp_t/d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}$ is given by[33]

$$\frac{dp_t}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} \equiv \frac{dp_t/d\bar{i}_1}{d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1}. \tag{3.16}$$

This makes it possible to specify the benefit from deviating from a zero unemployment gap as a function of the expected non-crisis unemployment gap and rewrite it as

$$\begin{aligned} B_t \equiv [\bar{p}_t - p_t(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})][(\Delta u)^2 + 2\Delta u\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}] \; &= \; (-\frac{dp_t}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}})\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}[(\Delta u)^2 + 2\Delta u\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}] \\ = 0.0086\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}(25 + 10\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}). \end{aligned} \tag{3.17}$$

Here the number -0.0086 is the average of the derivative (3.16) over quarters 12-24, where the derivatives $dp_t/d\bar{i}_1$ and $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$ are given by the green line in figure 2.2 and the red line in figure 2.1, respectively. This is clearly an overestimate of the magnitude of the average reduction of the probability of a crisis per unemployment rate increase, something which exaggerates the benefit and stacks the cards in favor of LAW.[34]

In figure 3.3, the green dashed line shows the benefit B_t of deviating from a zero expected non-crisis unemployment gap. It is by (3.17) equal to zero for a zero expected non-crisis unemployment gap. Furthermore, it is quadratic and, for a negative derivative $dp_t/d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}$, convex and increasing in the expected non-crisis unemployment gap. It is convex because the crisis loss increase (3.9) is increasing in the expected non-crisis unemployment gap, making the benefit increase more than linearly.

[33] Because the derivative $d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}/d\bar{i}_1$ by figure 2.1 is positive for $1 < t \leq 40$, the implicit derivative $dp_t/d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}$ in (3.16) is well-defined for $1 < t \leq 40$.

[34] Figure F.1 in appendix F shows the negative of the derivative (3.16) for each quarter.

The red dashed line in figure 3.3 is the cost C_t of deviating from a zero expected non-crisis unemployment gap, the same line as in figure 3.2. The blue dashed line is the net cost, $C_t - B_t$, the difference between the red and the green dashed lines.

The green solid line is the marginal benefit of increasing the expected non-crisis loss, given by

$$\frac{dB_t}{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}} = (-\frac{dp_t}{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}})[(\Delta u)^2 + 4\Delta u \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}] = 0.0086\,(25 + 20\,\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}) \tag{3.18}$$

It is linear and increasing in the expected non-crisis unemployment gap when the derivative of the probability of a crisis with respect to the expected non-crisis unemployment gap is negative. The blue solid line is the net marginal cost, the difference between the red and green solid lines.

We see that the net cost has a minimum at point G, between the points E and C, where the marginal cost and marginal benefit are equal (point F) and where the net marginal cost thus equals zero, at point H between points D (corresponding to an expected non-crisis unemployment gap equal to − 0.32 percentage point) and A (corresponding to an expected non-crisis unemployment gap equal to zero). We see that in this case, the optimal policy is rather close to point D and still involves some small leaning with the wind, not against. It corresponds to an expected non-crisis unemployment gap of − 0.23 percentage point.

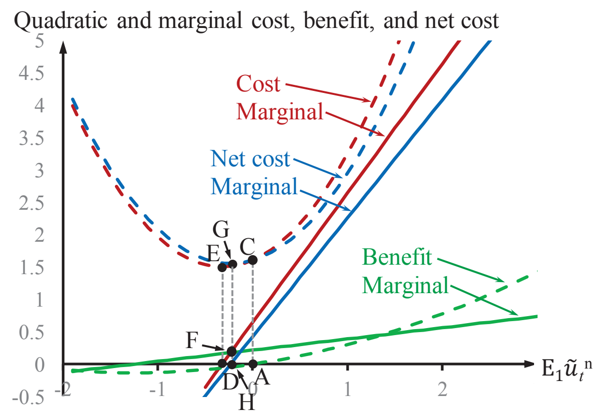

Figure 3.3: The probability-weighted quadratic (dashed line) and marginal (solid) cost (red), benefit (green), and net cost (blue), as a function of the expected non-crisis unemployment gap (under the assumption that the benchmark probability of a crisis is 6.4 percent and the crisis increase in the unemployment rate is 5 percent).

Consistent with this, we see that the net marginal cost for a zero expected non-crisis unemployment gap is positive. This means that in the initial situation, in which the expected future non-crisis unemployment gaps are zero, the marginal cost of LAW exceeds the marginal benefits, meaning that the optimal policy is a small leaning *with* the wind, not against. This happens in spite of the exaggerated estimate that I have used of the reduction of the probability of a crisis per expected non-crisis unemployment gap increase

In summary, we see that there is a strong tendency towards some leaning *with* the wind rather than against. Only if the policy rate has a sufficiently strong negative effect on the probability will there be a tendency to lean *against* the wind.

3.4 The alternative assumption of a fixed loss *level* in a crisis

As mentioned, an important assumption in this paper is the realistic assumption that a crisis is more costly if the economy is weak. This is represented by the assumption that a crisis implies an *increase* in the unemployment gap by Δu,

$$\tilde{u}_t^{\mathrm{c}} = \tilde{u}_t^{\mathrm{n}} + \Delta u, \qquad \text{(3.5 revisited)}$$

so the expected crisis unemployment gap is higher if the non-crisis unemployment gap is higher,

$$\mathrm{E}_1 \tilde{u}_t^{\mathrm{c}} = \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} + \Delta u.$$

In this subsection, let me briefly examine the consequences of the unrealistic assumption that that a crisis means that the expected unemployment gap does not *increase* by Δu but *reaches* Δu, regardless of what the expected non-crisis unemployment gap is. That is, the expected crisis unemployment gap simply satisfies

$$\mathrm{E}_1 \tilde{u}_t^{\mathrm{c}} = \Delta u,$$

regardless of $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}$. This means that the loss level in a crisis is fixed and independent of the non-crisis unemployment gap, in line with the assumption made in Svensson (2014, 2015), ALLN, and Diaz Kalan, Laséen, Vestin, and Zdzienicka (2015).[35]

We first note that it is practical in this case to make the innocuous assumption that the crisis unemployment gap is random with mean Δu and conditional variance equal to that of the non-crisis unemployment gap. Then the expected loss in a crisis satisfies

$$\mathrm{E}_1 (\tilde{u}_t^{\mathrm{c}})^2 = (\Delta u)^2 + \mathrm{Var}_1 \tilde{u}_t^{\mathrm{c}} = (\Delta u)^2 + \mathrm{Var}_1 \tilde{u}_t^{\mathrm{n}},$$

and is independent of the expected non-crisis unemployment gap, $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}$.

The expected quarter-t loss then satisfies

$$\begin{aligned} \mathrm{E}_1 L_t &= (1 - p_t)\mathrm{E}_1 (\tilde{u}_t^{\mathrm{n}})^2 + p_t[(\Delta u)^2 + \mathrm{Var}_1 \tilde{u}_t^{\mathrm{n}}] \\ &= (1 - p_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + p_t(\Delta u)^2 + \mathrm{Var}_1 \tilde{u}_t^{\mathrm{n}}, \end{aligned} \qquad (3.19)$$

where I have used that $\mathrm{E}_1 (\tilde{u}_t^{\mathrm{n}})^2 = (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + \mathrm{Var}_1 \tilde{u}_t^{\mathrm{n}}$. Furthermore, by adding and subtracting $(1 - \bar{p}_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\Delta u)^2$, the expected quarter-$t$ loss can be rewritten

$$\begin{aligned} \mathrm{E}_1 L_t - \mathrm{Var}_1 \tilde{u}_t^{\mathrm{n}} &= [(1 - \bar{p}_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\Delta u)^2] - (\bar{p}_t - p_t)[(\Delta u)^2 - (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2] \\ &\equiv C_t - B_t, \end{aligned}$$

[35] It is also the assumption made more recently in the theoretical section 3 in FR.

where the cost (at the benchmark probability of a crisis) and the benefit (from a reduction in probability of a crisis) now satisfy

$$C_t \equiv (1 - \bar{p}_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\Delta u)^2,$$
$$B_t \equiv (\bar{p}_t - p_t)[(\Delta u)^2 - (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2].$$

We note that the assumption of a fixed loss level in a crisis has the strange implication that the *cost of a crisis* (the loss *increase* in a crisis),

$$(\Delta u)^2 - (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2, \tag{3.20}$$

is *decreasing* in the magnitude of the expected non-crisis unemployment gap. In particular, if the expected non-crisis unemployment gap is larger than Δu, the crisis loss increase is negative; that is, it is better to have a crisis than a non-crisis. In contrast, under our main assumption that a crisis increases the unemployment gap by Δu, the loss increase in a crisis is given by (3.9), which is *increasing* in the expected non-crisis unemployment gap.

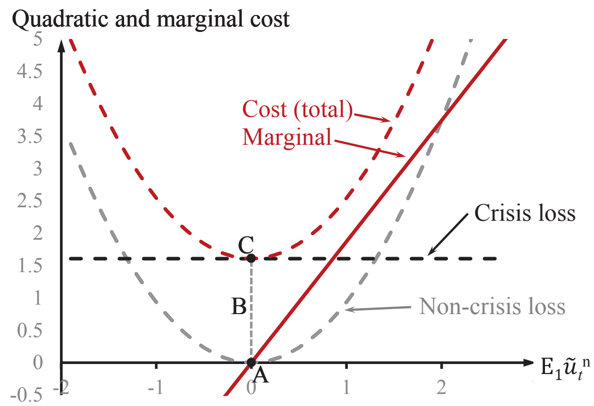

Figure 3.4: For a fixed loss level in a a crisis, the probability-weighted non-crisis loss (gray dashed line), probability-weighted fixed crisis loss (black dashed), and the (total) cost (red dashed) and marginal cost (red solid), as a function of the expected non-crisis unemployment gap (under the assumption that the benchmark probability of a crisis is 6.4 percent).

In figure 3.4 (the analogue of figure 3.2) the gray dashed line shows the benchmark-probability-weighted non-crisis loss, and the black dashed line shows the benchmark-probability-weighted fixed crisis loss, which is independent of the expected non-crisis unemployment gap. The red dashed and solid lines show the corresponding cost and marginal cost of deviating from a zero expected non-crisis unemployment gap.

The cost, benefit, and net benefit are shown in figure 3.5 (the analogue of figure 3.3). The red dashed line shows the cost,

$$C_t \equiv (1 - \bar{p}_t)(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\Delta u)^2 = 0.936\,(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + 0.064 \cdot 25 = 0.936\,(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2 + 1.6. \tag{3.21}$$

The red solid line shows the marginal cost of increasing the expected non-crisis unemployment gap,

$$\frac{dC_t}{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}} = (1 - \bar{p}_t) 2 \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = 1.872\, \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}. \tag{3.22}$$

The cost has a minimum (point C) for $\mathrm{E}_t \tilde{u}_t^{\mathrm{n}} = 0$ (point A). Because the crisis loss is independent of the expected non-crisis unemployment gap, a positive constant probability of a crisis does not induce any leaning with the wind, in contrast to when the crisis loss is increasing in the expected non-crisis unemployment gap.

The green dashed line shows the benefit as a function of the expected non-crisis unemployment gap,

$$B_t \equiv (\bar{p}_t - p_t)[(\Delta u)^2 - (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2] = 0.0086\, \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} [25 - (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2] = 0.215\, \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} - 0.0086\, (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^3, \quad (3.23)$$

where I use the linear approximation (3.15). The green solid line shows the marginal benefit of increasing the expected non-crisis unemployment gap,

$$\frac{dB_t}{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}} = 0.215 - \; 0.0258\, (\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2. \quad (3.24)$$

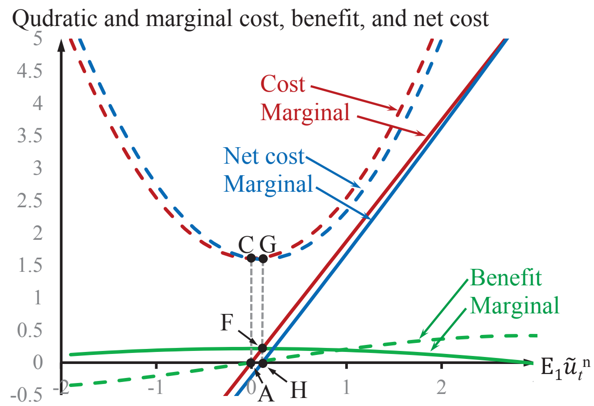

Figure 3.5: For a fixed loss level in a crisis, the cost (red dashed line), the marginal cost (red solid), the benefit (green dashed), the marginal benefit (green solid), the net cost (blue dashed), and the net marginal cost (blue solid) as a function of the expected non-crisis unemployment gap (under the assumption that the benchmark probability of a crisis is 6.4 percent).

The blue dashed line shows the net cost, $C_t - B_t$, the difference between the red and the blue lines. The blue solid line shows the net marginal cost of increasing the expected non-crisis unemployment gap. Because, for a zero expected non-crisis unemployment gap, the marginal cost is zero but the marginal benefit is positive, the net cost has a minimum at point G for a positive expected non-crisis unemployment gap at point H, for which the marginal cost and marginal benefit are equal, point F. That is, some LAW is optimal. However, it is quite small, corresponding to a 0.12 percentage point expected non-crisis unemployment gap, with a completely insignificant improvement in the net cost. This is consistent with the results of ALLN. The small impact of the possibility of affecting the probability of a crisis is illustrated by the fact that the benefit is so small relative to the cost in figure 3.5 and that the cost (the red dashed line) and the net cost (the blue dashed line) are so similar.

The case of a fixed loss level in a crisis is further examined in appendix I. There it is shown in more detail that the optimal LAW is very small and that the net gain from LAW is completely insignificant. In particular, it is shown that this result holds even under the assumption of monetary non-neutrality and a permanent effect on real debt and positive effect on cumulated marginal benefit.

3.5 The alternative assumption of a fixed loss *increase* in a crisis

A related alternative assumption is that there is a fixed loss *increase* in a crisis, independent of the non-crisis unemployment gap. Let the loss increase in a crisis, the cost of a crisis, be denoted by the constant c. Then the expected quarter-t loss can be written

$$\begin{aligned}\mathrm{E}_1 L_t &= (1-p_t)\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t[(\tilde{u}_t^{\mathrm{n}})^2 + c\,] = \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t\, c \equiv \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t(\Delta u)^2 \\ &= (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + p_t(\Delta u)^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}},\end{aligned} \tag{3.25}$$

where I have just *defined* Δu as the square root of c, $\Delta u \equiv \sqrt{c}$, so $(\Delta u)^2 \equiv c$. Thus Δu is no longer the crisis increase in the unemployment rate; it is just the square root of the unspecified cost of a crisis. Defining Δu this way allows us to see the similarity of the expected quarter-t loss for the case of a fixed loss *increase* in a crisis with the case of a fixed loss *level* in section 3.4.

Furthermore, the assumption that the loss increase in a crisis is fixed and independent of the unemployment gap implies that the expected crisis and non-crisis unemployment gaps must be equal,

$$\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} = \mathrm{E}_1\tilde{u}_t^{\mathrm{c}} = \mathrm{E}_1\tilde{u}_t, \tag{3.26}$$

otherwise the loss increase in a crisis would include an additional term beyond $c \equiv (\Delta u)^2$.

Comparing (3.25) and (3.19), we see that the only difference is that the term $(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2$ is not multiplied by the probability of a non-crisis, $1-p_t$, in (3.25). It follows that the cost (at the benchmark probability of a crisis) and the benefit (from a reduction in probability of a crisis) now satisfy

$$C_t \equiv (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + \bar{p}_t(\Delta u)^2 = (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 + 1.6, \tag{3.27}$$

$$B_t \equiv (\bar{p}_t - p_t)(\Delta u)^2 = 0.0086\,\mathrm{E}_1\tilde{u}_t\,25 = 0.215\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}, \tag{3.28}$$

where I have used the same assumptions about $\bar{p}_t$ and $dp_t/d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}$ as above and the assumption that the assumption that the crisis loss increase, $c \equiv (\Delta u)^2$, is 25. We see that (3.27) and (3.28) are simpler variants of (3.21) and (3.23). Then the marginal cost and marginal benefit of increasing the expected non-crisis unemployment gap satisfy,

$$\frac{dC_t}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} = 2\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}, \tag{3.29}$$

$$\frac{dB_t}{d\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}} = 0.215. \tag{3.30}$$

We see that (3.29) and (3.30) are simpler variants of (3.22) and (3.24).

Figure 3.6 shows the corresponding cost, marginal cost, benefit, marginal benefit, net cost, and net marginal cost. It is very similar to figure 3.5. Because, for a zero expected non-crisis unemployment gap, the marginal cost is zero but the marginal benefit is positive, the net cost has a minimum at point G for a positive expected non-crisis unemployment gap at point H, for which the marginal cost and marginal benefit are equal, point F. That is, some LAW is optimal. However, it is quite small, corresponding to a 0.11 percentage point expected non-crisis unemployment gap.[36] The optimal LAW is small because the marginal benefit is small and flat and the marginal cost is rising relatively rapidly. As a result, the improvement in the net cost is completely insignificant. The small impact of the possibility of affecting the probability of a crisis is illustrated by the fact that the benefit is so small relative to the cost in figure 3.6 and that the cost (the red dashed line) and the net cost (the blue dashed line) are so similar.

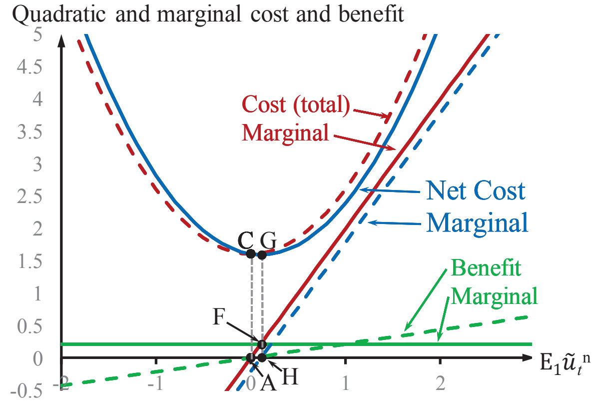

Figure 3.6: For a fixed loss *increase* in a crisis, the cost (red dashed line), the marginal cost (red solid), the benefit (green dashed), the marginal benefit (green solid), the net cost (blue dashed), and the net marginal cost (blue solid) as a function of the expected non-crisis unemployment gap (under the assumption that the benchmark probability of a crisis is 6.4 percent).

More precisely, the optimal non-crisis unemployment gap of 0.108 percentage points implies that the reduction in the probability of a crisis in the quarter is given by, $\bar{p}_t - p_t = 0.0086 \cdot 0.108 = 0.0093 = 9.3$ basis points. It follows that the annual probability of a crisis start, $4q_t = 4p_t/n = p_t/2$, falls by about 5 basis points from 3.2 percent to 3.15 percent, meaning one crisis in 31.75 years instead of one in 31.25 years. This is hardly an economically significant improvement.

3.6 Relation to some recent literature

After the first version of this paper was distributed in January 2016, FR and GKS have argued that LAW would be optimal and maintained that this contradicts my result that, given existing empirical estimates, the cost of LAW exceeds the cost. However, as far as I can see, their results are easily reconciled with the discussion above and can be explained by their assumption of a different loss function.

As explained in my discussion of FR, Svensson (2016a), in their theoretical section 3, they

[36] Setting (3.29) and (3.30) equal implies $E_1\tilde{u}_t^n = 0.215/2 = 0.11$.

assume a constant loss *level* in a crisis, as in ALLN and in section 3.4. Then, by the discussion in section 3.4, which was included in the first version of this paper, it is not surprising that they find that some LAW is optimal.[37] In a stripped down calibrated model in their section 4, they assume the slightly different case of a constant loss *increase* in a crisis. Then, by the discussion in section 3.5, it is not surprising that they find that a small amount of LAW is optimal.[38] If they had made the more realistic assumption that the crisis loss increase, the cost of a crisis, is larger for an initially weaker economy, following from an assumption of a fixed unemployment increase in a crisis, they would presumably have found the same result as mine, that the cost of LAW exceeds the benefit. Thus, their result does not contradict mine and is arguably equal or similar to a special case discussed in the first version of my paper.

GKS also make the assumption that the loss increase in a crisis is constant. They also find that a small amount of LAW is optimal with a very small gain. In their case, the gain is equivalent to an increase in average consumption of 6 to 8 basis points. Furthermore, in their case, the annual probability of a crisis start falls by 6 basis points from 2.08 percent to 2.02 percent, implying one crisis in 49.5 years instead of one crisis in 48.1 years. I think everyone would agree that this is a very small gain that is hardly economically significant, similar to the result in ALLN for the slightly different loss function of a fixed loss level in a crisis, and fully consistent with the discussion and result of section 3.5. In particular, there we found that the optimal policy implies a fall in the annual probability of probability of a crisis start by about 5 basis points, similar to the fall of the probability of a crisis start for for GKS

4 The marginal cost, marginal benefit, and net marginal cost of leaning against the wind

Let me now return to the main assumption that the cost of a crisis (the loss *increase* in a crisis) is not fixed but larger if the economy is initially weaker, represented by the assumption that a crisis implies that the unemployment gap, net of any policy response in the crisis, increases by Δu.

The discussion in section 3 focused on the cost and benefit of LAW in a given quarter, as a function of the expected non-crisis unemployment gap in that quarter. However, increasing the policy rate $\bar{i}_1$ in quarter 1–4 increases the expected crisis and non-crisis unemployment gaps in all quarters 2–40 and reduces the probability of a crisis mainly in quarters 12–24. Assessing the

[37] See Loss Function #3 and Simple Example #3 in Svensson (2016a).
[38] See Loss Function #2 and Simple Example #3 in Svensson (2016a).

cost and benefit from increasing the policy rate thus requires that all the costs and benefits in all relevant quarters are compared, in particular when assessing how robust the results are to changes in the relevant parameters.

Thus, let me consider the initial situation in which the expected non-crisis unemployment gap is equal to zero for all quarters, (3.7), and examine whether increasing the policy rate increases or reduces the intertemporal loss, when the impact in all future quarters are taken into account. This means to examine the derivative of the intertemporal loss function with respect to the policy rate during quarters 1–4, the marginal expected loss from increasing the policy rate,

$$\frac{d}{d\bar{i}_1}\mathrm{E}_1\sum_{t=1}^{\infty}\delta^{t-1}L_t = \sum_{t=1}^{\infty}\delta^{t-1}\frac{d\mathrm{E}_1 L_t}{d\bar{i}_1}. \tag{4.1}$$

If this marginal expected loss from increasing the policy rate is *negative*, it is optimal to *raise* the policy rate and *increase* the expected future unemployment gaps above zero, and thus lean *against* the wind. If the marginal expected loss is *positive*, it is optimal to *lower* the policy rate and *reduce* the expected future unemployment gaps below zero, and thus lean *with* the wind.

The marginal expected loss is equal to the discounted sum of the derivatives of expected future quarterly losses, the future quarter-t marginal expected losses. Let me examine the marginal expected loss for a given quarter t, starting from the expression (3.4) for the expected quarter-t loss and taking the derivative with respect to the policy rate,

$$\frac{d\mathrm{E}_1 L_t}{d\bar{i}_1} = 2(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + p_t\Delta u)\frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} - [(\Delta u)^2 + 2\Delta u\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}](-\frac{dp_t}{d\bar{i}_1}), \tag{4.2}$$

where I have used (3.9). I have also assumed sufficient linearity, such that the derivatives $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$ and $dp_t/d\bar{i}_1$ are independent of the non-crisis unemployment gap.

In order to examine this more closely, let me identify the left side of (4.2), the marginal expected loss from a policy-rate increase $d\mathrm{E}_1 L_t/d\bar{i}_1$, with the quarter-$t$ *net marginal cost*, NMC_t, of LAW. The first term on the right side of (4.2) can be identified with the quarter-t *marginal cost* of increasing the policy rate, MC_t. It consists of the marginal cost of increasing the expected non-crisis unemployment gap (3.13) multiplied by the effect of the policy rate on the expected unemployment rate, $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$. The second term can be identified with the quarter-t *marginal benefit* of increasing the policy rate, MB_t. It consists of the crisis loss increase, $(\Delta u)^2 + 2\Delta u\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}]$, multiplied by the negative of the effect of the policy rate on the probability of a crisis, $-\,dp_t/d\bar{i}_1$. Thus we can write

$$\mathrm{NMC}_t = \mathrm{MC}_t - \mathrm{MB}_t, \tag{4.3}$$

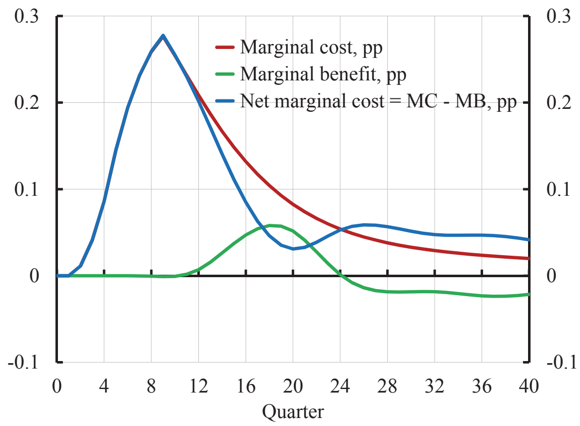

Figure 4.1: The marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap equals zero. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

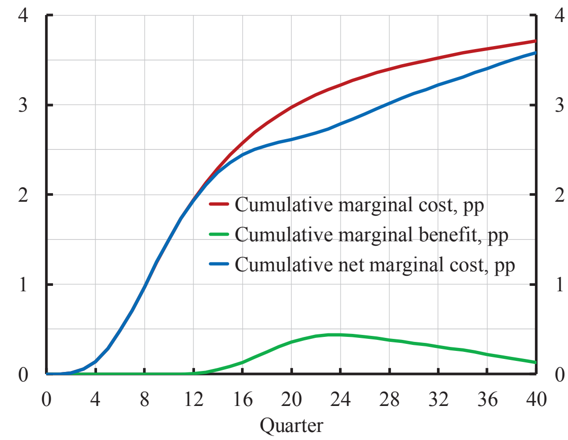

Figure 4.2: The cumulative marginal cost, marginal benefit, and net marginal cost of LAW, when the expected non-crisis unemployment gap equals zero. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

where

$$\mathrm{MC}_t \equiv 2[\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + p_t\Delta u]\frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1}, \tag{4.4}$$

$$\mathrm{MB}_t \equiv [(\Delta u)^2 + 2\Delta u\,\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}](-\frac{dp_t}{d\bar{i}_1}). \tag{4.5}$$

When the expected non-crisis unemployment gap is zero, (3.7), we have

$$\mathrm{MC}_t = 2\bar{p}_t\Delta u\frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1}, \tag{4.6}$$

$$\mathrm{MB}_t = (\Delta u)^2(-\frac{dp_t}{d\bar{i}_1}), \tag{4.7}$$

where the probability of a crisis equals the benchmark probability of a crisis, (3.12).

Given this and (3.7), the marginal cost, the marginal benefit, and the net marginal benefit in are shown for each quarter 1–40 in figure 4.1. The red line in figure 4.1 shows the marginal cost, (4.6). From quarter 9, when p_t is constant, it is proportional to $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$ (the red line in figure 2.1) and positive. For quarter 1–8, the marginal cost is affected by the fact that p_t is increasing, giving it a sharper and later peak than $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$. The green line in figure 4.1 shows the marginal benefit, (4.7). It is proportional to $-\,dp_t/d\bar{i}_1$ (the green line in figure 2.2). The blue line shows the net marginal cost, (4.3), the difference between the red and the green lines in the figure.

Importantly, from (2.8) we know that cumulated effects of the policy rate on the probability of a crisis is approximately zero. This means that the undiscounted sum of the marginal benefits

(4.7) is approximately zero,

$$\sum_{t=1}^{40} \mathrm{MB}_t \approx 0. \tag{4.8}$$

This implies that the undiscounted sum of the net marginal costs is approximately equal to the undiscounted sum of the marginal costs,

$$\sum_{t=1}^{40} \mathrm{NMC}_t = \sum_{t=1}^{40} \mathrm{MC}_t - \sum_{t=1}^{40} \mathrm{MB}_t \approx \sum_{t=1}^{40} \mathrm{MC}_t > 0. \tag{4.9}$$

The cumulative marginal cost, marginal benefit, and net marginal cost are shown in figure 4.2.

Discounting the sums will not affect this result much, so it is clear that, for (3.7), the intertemporal expected loss is increasing in the policy rate. This means that optimal policy involves leaning *with* the wind, not leaning against.[39]

Furthermore, at a closer look, the assumption about monetary neutrality and the resulting negative marginal benefit in later years do not seem essential for rejecting LAW. From figure 4.1, it is apparent that if the marginal benefit would be zero instead of negative beyond quarter 24, the conclusions would not change. This is also the case if we would disregard the positive marginal cost beyond quarter 24 and only consider marginal cost and benefit up to quarter 24. The role of monetary neutrality and non-neutrality is further examined in section 6.

4.1 The sensitivity to the initial state of the economy

The above examination is for an initial situation with a zero expected non-crisis unemployment gap, (3.7). Some advocacy for LAW seems to recommend it more or less regardless of the initial state of the economy (for instance, Bank for International Settlements (2014)). But an initial positive expected non-crisis unemployment gap – an initially weaker economy – dramatically increases the cost of LAW.

In figure 4.3, the dashed lines show the marginal cost, marginal benefit, and net marginal benefit of LAW when the expected non-crisis unemployment gap is positive and equal to a small 0.25 percentage point for all quarters, whereas the solid lines show these variables when the expected non-crisis unemployment gap equals zero (as in figure 4.1). With a non-zero expected non-crisis unemployment gap, the marginal cost is given by (4.4) rather than (4.6). This small expected non-crisis unemployment gap has a substantial impact on the marginal cost (because in (4.4) the

[39] We can look more closely at quarter 18, when the marginal benefit is the largest. Because for that quarter, $dp_{18}/d\bar{\imath}_1 = -0.23$ percentage point, and we have $\Delta u = 5$ percentage points, by (4.7), $\mathrm{MB}_{18} = 0.0023 \cdot 5^2 = -0.058$. But for quarter 18, $d\mathrm{E}_1 u^n_{18}/d\bar{\imath}_1 = 0.16$ and, by (4.7), $\mathrm{MC}_{18} = 2 \cdot 0.064 \cdot 5 \cdot 0.16 = 0.10$, still larger than MB_{18}.

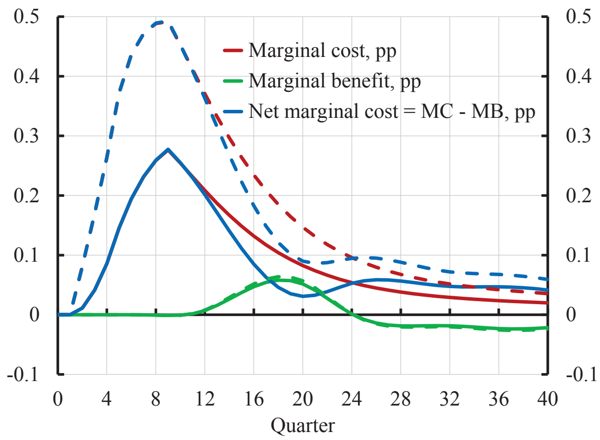

Figure 4.3: The marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap is positive and equals 0.25 percentage point for all quarters. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

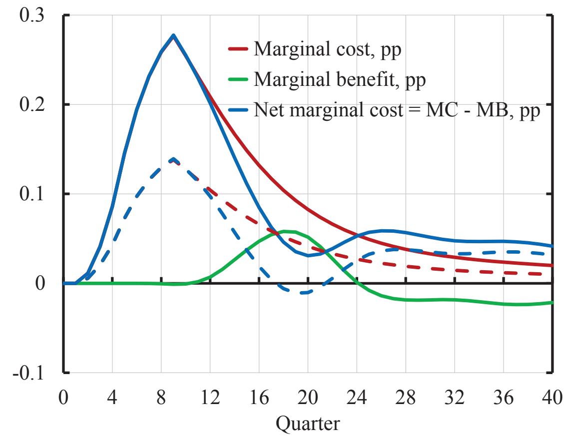

Figure 4.4: The effect of a reduction in the policy-rate effect on the expected non-crisis unemployment rate from the benchmark (solid lines) by a half (dashed lines) on the marginal cost and the net marginal cost of LAW, when the expected non-crisis unemployment gap is zero. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

term $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = 0.25$ percentage point is of a similar order of magnitude as the term $p_t \Delta u$ (which rises from 0 in quarter 1 to 0.32 percentage point in quarter 9). The marginal benefit is given by (4.5) rather than (4.7), but the expected non-crisis unemployment gap has a quite small impact on it (because in (4.5) the term $2\Delta u\, \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = 2.5$ is small relative to $(\Delta u)^2 = 25$). The net marginal cost therefore shifts up substantially and the cost of LAW exceeds the benefit by an even larger margin.

Assuming that initially the expected non-crisis unemployment gap is positive and the same for all future quarters allows us to examine the impact on the marginal cost and benefit at all quarters. A more realistic initial situation is arguably one in which the expected non-crisis unemployment gap is positive for the first few quarters and approaches zero in later quarters. From figure 4.3 we realize that we still get a substantial increase in the marginal cost of LAW if, for instance, the expected non-crisis unemployment gap is positive and equal to 0.25 percentage point for only the first 8 quarters and then falls and equals zero from quarter 12 and onwards, in which case the dashed lines for the marginal cost and net marginal cost are equal to the solid lines from quarter 12 onwards.

Because the cost of LAW exceeds the benefit with a zero initial expected non-crisis unemployment gap, the cost exceeds the benefit even more for an initial positive expected non-crisis unemployment gap. The marginal and net marginal cost of LAW increase substantially with a higher initial expected non-crisis unemployment gap.

4.2 The sensitivity to the effect of the policy rate on the non-crisis unemployment rate

The marginal cost and net marginal cost of LAW depend by (4.4) on the initial expected non-crisis unemployment gap ($\mathrm{E}_1\tilde{u}_t^{\mathrm{n}}$), the probability of a crisis (p_t), the crisis increase in the unemployment gap (Δu), and the effect of the policy rate on the expected non-crisis unemployment rate ($d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$). The sensitivity to the initial expected non-crisis unemployment gap has been examined in section 4.1. The sensitivity to the probability of a crisis and the crisis increase in the unemployment gap will be examined in section 5. Here I look at the sensitivity to the effect of the policy-rate increase on the expected non-crisis unemployment rate.

As a benchmark, I have used the Riksbank estimate of the effect shown in figure 2.1. In figure 4.4, the dashed lines show the marginal cost and net marginal cost when benchmark policy-rate effect on the expected non-crisis unemployment gap is reduced to a half of the Riksbank estimate, whereas the solid lines show the benchmark case. The marginal cost shifts down by a half, the marginal benefit (4.7) is not affected, and the net marginal cost shifts down with the marginal cost but remains substantially positive, except in quarters 18–21 where it is slightly negative. Clearly, the cost of LAW still exceeds the benefit by a substantial margin.

4.3 A preliminary note on the sensitivity to the probability of a crisis

We will look more closely at the sensitivity to the probability of a crisis in section 5, but we can already here make a preliminary note about the sensitivity to the probability of a crisis. From (4.6) we have seen that the marginal cost is two times the product of the probability of a crisis (p_t), the crisis increase in unemployment rate (Δu), and the effect of the policy rate on the expected non-crisis unemployment rate ($d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$). This means that figure 4.4 can alternatively be seen as the result of the *full* (instead of the half) benchmark effect of the policy rate on the expected non-crisis unemployment rate in figure 4.4 and the *half* (instead of the full) probability of crisis in figure 3.1. Thus, even if the probability of a crisis start in a particular quarter was only 0.4 percent (instead of 0.8 percent), so the probability of crisis from quarter 9 onward was only 3.2 percent (instead of 6.4 percent), in which case the marginal cost would be half of the benchmark case, but still larger than the benefit. We realize that for an even slower rise of the probability of a crisis than half of that in figure 3.1, there is still a substantial margin for marginal cost to dominate over marginal benefit.

The above note is under the simplifying assumption that a lower probability of a crisis does not affect the effect of the policy rate on the probability of a crisis ($-\,dp_t/d\bar{i}_1$) and thereby not the marginal benefit. However, when we look more closely at this in section 5, we will see that, under the logistic relation between the probability of a crisis start and real debt growth, the effect on the probability of a crisis and the marginal benefit varies slightly with the probability of a crisis and is actually slightly lower with a lower probability of a crisis.

5 Does less effective macroprudential policy increase the benefit and reduce the cost of leaning against the wind?

A common view is that macroprudential policy should provide the first line of defense of financial stability but that monetary policy may have a role as a second line of defense, in case macroprudential policy is not sufficiently effective. In line with this view, one might ask whether less effective macroprudential policy might increase the benefit and reduce the cost of LAW. Let me examine this issue in the present framework.

What would a less effective macroprudential policy imply in the present framework? Such macroprudential policy would in general imply less resilience of the financial system to shocks, for instance through weaker balance sheets with less loss-absorbing capital. Less effective macroprudential policy may result in more credit growth and credit booms with more "bad" credit growth due to lower credit standards. All together this might increase the probability of a crisis start, q_t. It might also increase the magnitude of a crisis, in the sense of implying a large crisis increase in the unemployment rate, Δu, or a longer duration of a crisis, n.

Consequently, in order to assess whether less effective macroprudential policy reduces the cost and increases the benefit of LAW, I examine how the marginal cost, marginal benefit, and thus the net marginal cost of LAW shifts, if the probability of crisis start is higher due to higher credit growth, the increase in the unemployment rate is larger, or the duration of a crisis is longer. This way I also conduct some further sensitivity analysis of the results.

5.1 A higher probability of a crisis start due to higher credit growth

Let me first examine the consequences of a higher probability of a crisis start. So far I have assumed an annual probability of a crisis start of 3.21 percent (corresponding to a crisis start on average

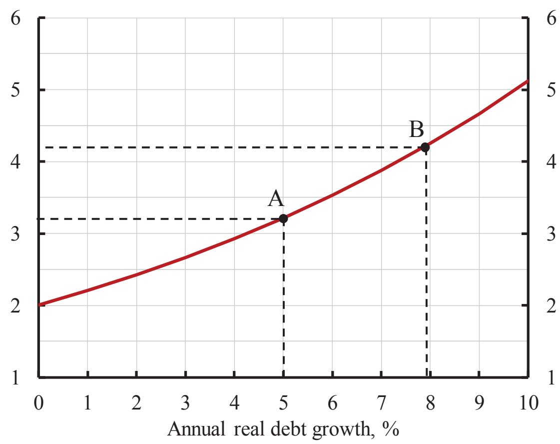

Figure 5.1: The annual probability of a crisis start (percent) as a function of real debt growth during the previous five years. (Source: Schularick and Taylor (2012) and own calculations.)

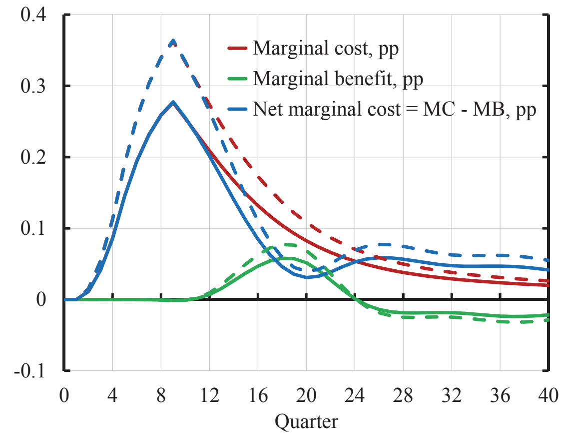

Figure 5.2: The effect of an increase in the annual probability of a crisis start from 3.21 percent (solid lines) to 4.21 percent (dashed lines) on the marginal cost, the marginal benefit, and the net marginal cost of LAW. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

every 31 years), which for the estimates in (2.6) is consistent with a steady annual growth rate of real debt of 5 percent. This corresponds to point A in figure 5.1, which shows how the annual probability of a crisis start depends on the steady annual real debt growth during the previous five years. Let me now consider an increase in the annual probability of a crisis start by 1 percentage point to 4.21 percent (corresponding to a crisis start on average every 24 years). This is consistent with an annual steady growth rate of 7.9 percent, corresponding to point B in the figure. Thus, we might think of less effective macroprudential policy resulting in a credit boom with higher real debt growth, which in turn increases the probability of a crisis start.

In figure 5.2, dashed lines show the marginal cost, marginal benefit, and net marginal cost from LAW for the higher annual probability 4.21 percent of a crisis start, to be compared with the solid lines for the benchmark case of an annual probability of 3.21 percent. A higher probability of a crisis start q_t leads by (2.2) to a higher probability of a crisis p_t. We see in (4.6) that the marginal cost of LAW is proportional to p_t. A higher p_t thus shifts up the marginal cost from the solid to the dashed red line in the figure.

What is the effect on the marginal benefit? A higher steady growth rate of real debt will increase the marginal effect of steady real debt growth on the probability of a crisis start, because the logistic function with the estimates in (2.6) is convex for growth rates in this range (see figure 5.1).[40] This

[40] For the benchmark steady annual growth rate of 5 percent, the marginal effect on the annual probability of a

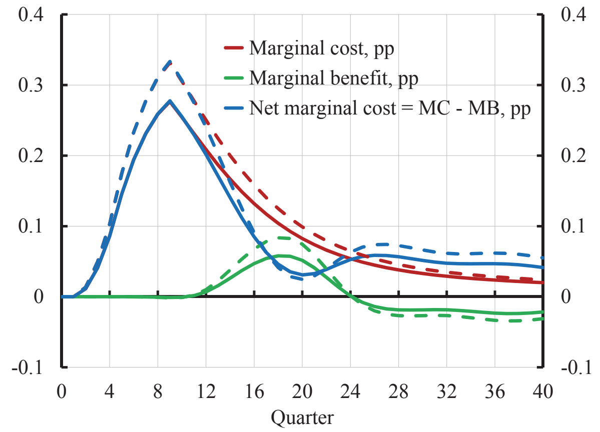

Figure 5.3: The effect of an increase in the crisis increase in the unemployment rate from 5 (solid lines) to 6 percentage points (dashed lines) on the marginal cost, the marginal benefit, and the net marginal cost of LAW. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

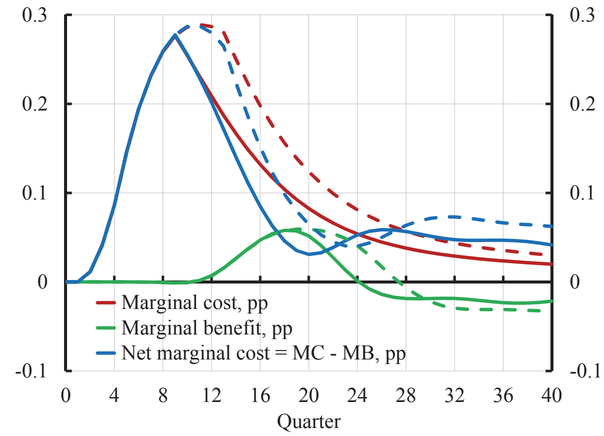

Figure 5.4: The effect of an increase in crisis duration from 8 (solid lines) to 12 quarters (dashed lines) on the marginal cost, the marginal benefit, and the net marginal cost of LAW. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

will increase the magnitude of the effect of the policy rate on the probability of a crisis start and on the probability of a crisis, $-dp_t/d\bar{i}_1$. We see in (4.7) that the marginal benefit is proportional to $-dp_t/d\bar{i}_1$, so this will increase the magnitude of the marginal benefit and shift it from the solid to the dashed green line in the figure. We see in figure 5.2 that the net effect on the net marginal cost is a significant increase in the net marginal cost, from the solid to the dashed blue line.

It follows that the discounted net marginal cost increases. Thus, less effective macroprudential policy, to the extent that it leads to higher real debt growth and a higher probability of a crisis start, increases the cost of LAW more than the benefits and make the cost exceed the benefit by an even larger margin.

We may interpret this result more generally. In this framework, a credit boom with higher real debt growth and a higher probability or larger magnitude of a crisis, whether caused by an ineffective macroprudential policy or anything else, would, everything else equal, tend to increase the marginal cost of increasing the policy rate more than it increases the marginal benefit, thereby increasing the net marginal cost of LAW.[41]

crisis start is 0.30. For a steady annual growth rate of 7.9 percent, the marginal effect is 0.39. See appendix B for details.

[41] Helpful discussions with Helge Berger alerted me to this more general interpretation of the results.

5.2 A larger crisis increase in the unemployment rate

In figure 5.3, the dashed lines show the marginal cost, marginal benefit, and net marginal cost for a larger the crisis increase Δu in the unemployment rate of 6 percentage points, to be compared with the solid lines for the benchmark crisis increase in the unemployment rate of 5 percentage points. We see in (4.6) and (4.7) that the marginal cost is linear in Δu and the marginal benefit is quadratic in Δu. Thus, the magnitudes of the marginal cost and marginal benefit increase with Δu. We see that the net effect is an increase of the net marginal cost except around quarter 19 where the marginal benefit increases slightly more than the marginal cost.

It follows that, also in this case, the sum of discounted net marginal costs increases. Less effective macroprudential policy, to the extent that it implies a larger crisis increase in the unemployment rate, again increases the cost of LAW more than the benefit.

5.3 A longer duration of a crisis

Finally, in figure 5.4, dashed lines show the marginal cost, marginal benefit, and net marginal cost for a longer crisis duration of $n = 12$ quarters, to be compared with the solid lines for the benchmark crisis duration of 8 quarters. A longer duration means by (2.2) that the probability of a crisis, for the linear approximation used here, is the sum over a few more previous quarterly probabilities of a crisis start, implying a shift to the right of the marginal cost and marginal benefit of LAW.[42] As a result, the net marginal cost shifts up, except around quarter 24, where the marginal benefit increases slightly more than the marginal cost. The sum of discounted net marginal costs increases. Thus, to the extent that less effective macroprudential policy increases the crisis duration, it again increases the cost of LAW more than the benefit.

Overall, for this section's intuitive assumptions about the consequence of a less effective macroprudential policy, such a less effective policy consistently makes the cost of LAW exceed the benefit by an even larger margin. The presumption that a less effective macroprudential policy would make the benefit exceed the cost does not stand up to scrutiny.

[42] For the linear approximation (2.2), the probability of a crisis increases from zero in quarter 1 to 9.6 percent in quarter 13 and then stays at 9.6 percent. For the relevant Markov process discussed in appendix A, the probability of a crisis increases from zero in quarter 1 to 9.1 percent in quarter 13 and then converges to 8.8 percent in quarter 20.

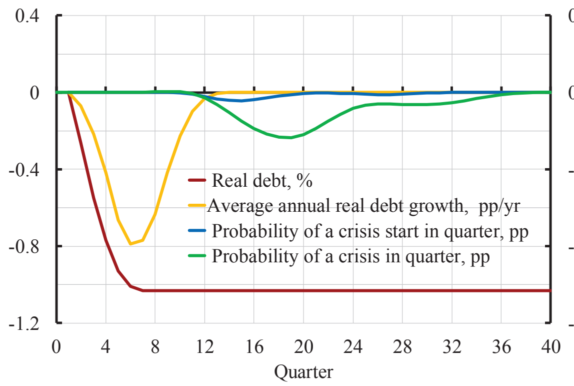

Figure 6.1: For a permanent effect on real debt, the effect on real debt, the average annual real debt growth, the probability of a crisis start in quarter, and the probability of being in a crisis in quarter of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

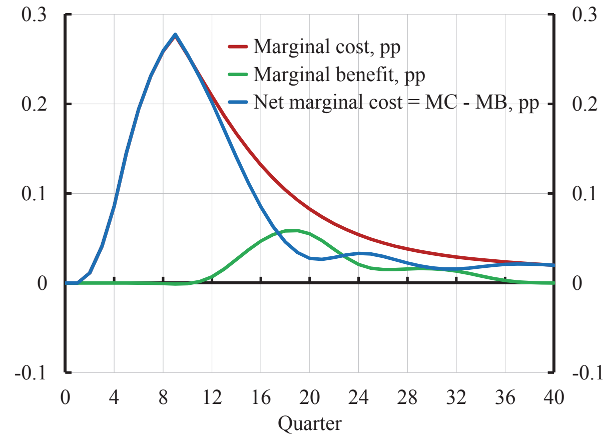

Figure 6.2: For a permanent effect on real debt, the marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap is zero. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

6 Non-neutral monetary policy: a permanent effect on real debt

Monetary neutrality implies that monetary policy has no effect on real debt in the long run, and therefore no effect on average and cumulated real debt growth over a longer period. Thus there is no effect on average and cumulated probabilities of a crisis over a longer period. One might think that, if monetary policy would be non-neutral and would have a permanent effect on the real debt level, this might make the benefit of LAW exceed the cost. Thus, in order to examine this, assume that the effect of the policy rate on real debt is permanent.

More precisely, suppose that real debt permanently stays down at its maximum deviation from the baseline in figure 2.2 (-1.03 percent), from quarter 8 onwards, as shown in figure 6.1.

As seen in the figure, there is a large and persistent, but not permanent, reduction in the probability of a crisis. As seen in figure 6.2, the marginal benefit is larger and more persistent. Nevertheless, this marginal benefit is not sufficient to prevent the net marginal cost from being positive and the discounted sum of the net marginal cost to be positive and large. Thus LAW still has a large positive net marginal cost.

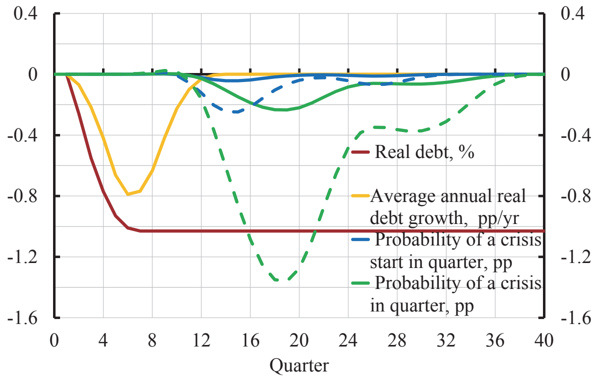

Figure 6.3: For a 5.8 times as large effect on the probability of a crisis start than the benchmark and a permanent effect on real debt, the effect on real debt, the average annual real debt growth, the probability of a crisis start in quarter, and the probability of being in a crisis in quarter of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

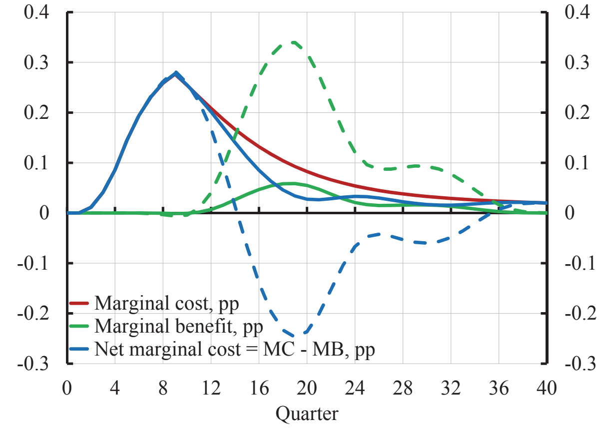

Figure 6.4: For a 5.8 times as large effect on the probability of crisis start than the benchmark and a permanent effect on real debt, the marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap is zero. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

6.1 How much larger an effect on the probability of a crisis start is needed to make the benefit exceed the cost?

Under the assumption of a permanent effect on real debt of a 1 percentage point higher policy rate during quarters 1–4, the cumulated marginal benefit in figure 6.2 is positive and equal to 0.64. The cumulated marginal cost is 3.71, about 5.8 times as large. We then realize that, for the benefit to exceed the cost, the effect on the policy rate on the probability of a crisis must be more than 5.8 times as large as the estimates in (2.6). If the largest coefficient, 7.138, on the two-year lag of the annual growth rate, would be two standard deviations larger, it would be 12.4, that is 1.74 times as large as 7.138. This is very far from 5.8 times as large. The dashed lines in figures 6.3 and 6.4 show the case when the effect on the probability of a crisis is 5.8 larger and the cumulated marginal cost and marginal benefit are equal.

Clearly, even under the extreme assumption of a large permanent effect on real debt, we need an extreme assumption on the effect of the policy rate on the probability of a crisis for the cumulated net marginal cost not being positive but zero.

7 Results for a dataset of Laeven and Valencia (2012)

So far I have used the estimates in Schularick and Taylor (2012) for their dataset covering 14 developed countries for 1870–2008. During the work on International Monetary Fund (2015), IMF staff used a dataset of Laeven and Valencia (2012) to estimate the quarterly probability of a crisis start for banking crises in 35 advanced countries 1970–2011.[43] The equation and estimates are

$$q_t = \frac{\exp(X_t)}{1+\exp(X_t)},$$

where[44]

$$X_t = -\underset{(1.008)}{5.630^{***}} - \underset{(3.171)}{5.650^{*}}\, g_t + \underset{(3.580)}{4.210}\, g_{t-4} + \underset{(5.408)}{12.342^{**}}\, g_{t-8} - \underset{(3.591)}{5.259}\, g_{t-12}. \tag{7.1}$$

As in the Schularick and Taylor (2012) estimates, the annual growth rate of the average annual debt lagged two years is the major determinant of the probability of a crisis start, q_t. For 5 percent steady real debt growth, the annual probability of a crisis start is 1.89 percent, approximately equal to the frequency of crises starts in the sample. It implies a crisis start on average every 53 years. The corresponding constant quarterly probability of a crisis start, q, is thus about 0.47 percent. The coefficients in (7.1) sum to 5.64, implying that the marginal effect on the annual probability of a crisis start over all lags is equal to 0.11, implying the summary result that 1 percentage point lower steady real debt growth reduces the annual probability of a crisis by about 0.1 percentage point.

Figure 7.1 shows the resulting effect of the policy rate on the probability of a crisis start and of a crisis. Comparing with the previous figure 2.2 for the Schularick and Taylor (2012) estimates, we see that now the effect on the probability of a crisis start ($dq_t/d\bar{i}_1$, the blue line) fluctuates more. As a result, the effect on the probability of a crisis ($dp_t/d\bar{i}_1$, the green line) also fluctuates more: first it increases relative to the baseline before it falls to a negative peak of -0.27 percentage point in quarter 17, after which it increases and reaches a positive

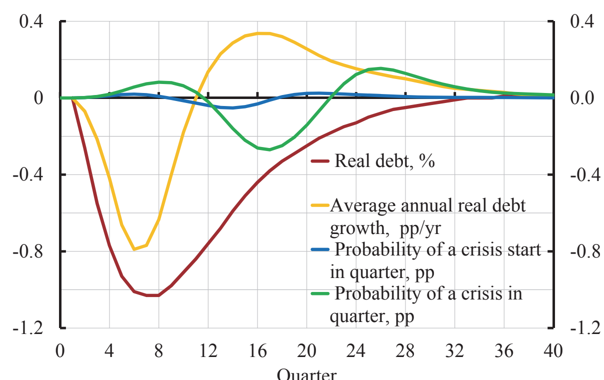

Figure 7.1: The effect on real debt, the average annual real debt growth, the probability of a crisis start in quarter, and the probability of being in a crisis in quarter of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: IMF staff estimates, Sveriges Riksbank, and own calculations.)

[43] I am grateful to Damiano Sandri for several discussions about the estimates.

[44] One, two, and three stars denote significance at the 10, 5, and 1 percent level, respectively.

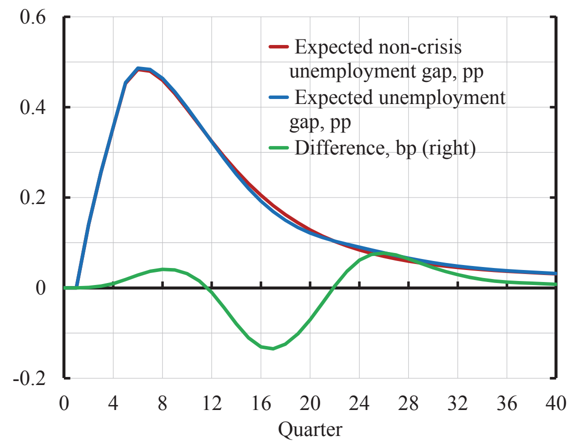

Figure 7.2: The effect on the expected unemployment rate and the expected non-crisis unemployment rate of a 1 percentage point higher policy rate during quarters 1–4; deviations from baseline. (Source: IMF staff estimates, Sveriges Riksbank, and own calculations.)

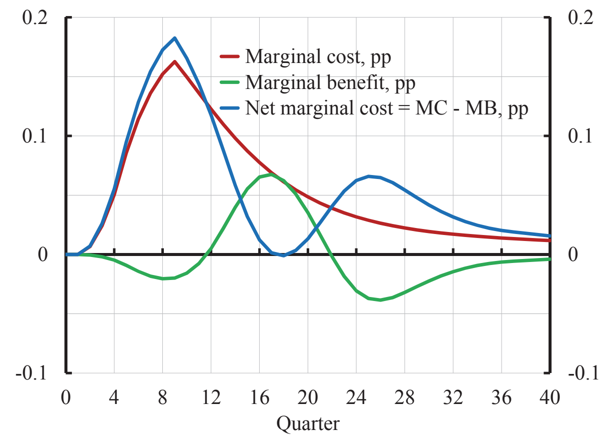

Figure 7.3: The marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap equals zero. (Source: IMF staff estimates, Sveriges Riksbank, and own calculations.)

peak of 0.15 percentage point in quarter 26, after which it finally falls to zero in quarter 40. It lacks the long positive tail that shows in figure 2.2. The cumulated effect on the probability of a crisis is of course still approximately zero, (2.8).

Figure 7.2 shows the resulting effect on the expected future unemployment rate, which is still very similar to the effect on the expected future non-crisis rate. Clearly, a higher policy rate increases the expected unemployment rate at all horizons. The effect on the expected unemployment rate does not provide any support for LAW.

Figure 7.3 shows the corresponding marginal cost, marginal benefit, and net marginal cost according to (4.3)-(4.7). The marginal cost depends on p_t, which in this case, by (3.12) increases from 0 in quarter 1 to 1.89 percent in quarter 9, after which it stays at 1.89 percent. As a result, the marginal cost has a lower peak and is smaller than in the previous figure 4.1. Compared with the previous figure, the marginal benefit now fluctuates more. In quarters 17-19, it is equal to the marginal cost, making the net marginal cost equal to zero for those quarters. However, around quarter 8 and, in particular, around quarter 26, the marginal benefit is negative and adds to the net marginal cost. The sum of the marginal benefits over the 40 quarters is -0.02 percentage point and thus very close to zero (so the sum of the net marginal costs over the 40 quarters is approximately equal to the sum of the marginal costs, as in (4.9)). Again, the net marginal cost of LAW is clearly positive.

8 Conclusions

The conclusions from this analysis are quite strong: For existing empirical estimates and reasonable assumptions, the marginal cost of LAW is much higher than the marginal benefit. Thus, the cost of LAW exceeds the benefit by a large margin. Indeed, for the benefit to exceed the cost, in this situation, a small leaning *with* the wind, in the sense of a somewhat lower policy rate, is actually required.

The main component of the marginal cost of LAW is the marginal cost of increasing the crisis unemployment gap. LAW increases both the non-crisis and the crisis unemployment gaps. Even if the initial non-crisis unemployment gap is zero, in which case the marginal cost of increasing the non-crisis unemployment gap is zero, the crisis unemployment gap is not zero, and the marginal cost of increasing the crisis unemployment gap is positive.

The main component of the marginal benefit is the reduction in the expected cost of a crisis due to a possibly lower probability of a crisis from a higher policy rate. For existing empirical estimates and channels, this possible effect of the policy rate on the probability of a crisis is too small to match the marginal cost of a higher policy rate.

The main empirical channel through which the policy rate might reduce the probability of a crisis is via an effect on the growth rate of real debt. As discussed in section 1, this channel is subject to several limitations in that it represents a reduced-form and correlation result, may not be statistically significant, is likely to be small, and may be of either sign. Nevertheless, for the sake of the argument, and in order to implicitly stack the cards in favor of LAW, the channel is taken for granted in this paper.

Even so, if monetary policy is neutral in the long run, there is no effect on the cumulated real debt growth over the longer run. A possibly lower real debt growth rate and a lower probability of a crisis for a few years is then followed by a higher growth rate and a higher probability of a crisis in later years. The probability of a crisis is shifted between periods, but there is no effect on the average and cumulated probability of a crisis over the longer run. Then neither is there any effect on the average and cumulated marginal benefit over the longer run.

But even if monetary policy would be non-neutral and able to reduce the real debt level and thereby the cumulated debt growth in the longer run, so the cumulated marginal benefit would be positive in the longer run, empirically the marginal benefit is still too small to match the marginal cost. For the benefit of LAW to exceed the cost, the effect of the policy rate on the probability of a crisis must be so large as to be completely unrealistic.

It is sometimes argued that LAW is justified if macroprudential policy is less effective. But if macroprudential is less effective and this results in a crisis being more likely, having a larger magnitude, or having a longer duration, the marginal cost of a crisis increases more than the marginal benefit, making the cost of LAW exceed the benefit by an even larger margin. Similarly, and more generally, if the economy is in a credit boom that implies a higher probability or larger magnitude of a crisis, again the cost of LAW exceeds the benefit by a larger margin.

The sensitivity analysis presented shows that the results are robust to a several alternative assumptions, including using an alternative dataset of Laeven and Valencia (2012) with more recent data and more countries than the benchmark Schularick and Taylor (2012) dataset.

Furthermore, some results for the unrealistic assumption of the loss *level* or loss *increase* in a crisis being fixed and independent of the initial state of the economy are reported. Then, if the initial non-crisis unemployment gap is zero, the marginal cost of LAW is zero, whereas the marginal benefit is small but positive. Then *some* LAW is optimal. But, for existing empirical estimates, the optimal LAW is extremely small and correspond to only a few basis points higher policy rate and non-crisis unemployment gap (this is in line with the results of Ajello, Laubach, Lopez-Salido, and Nakata (2015) and Gourio, Kashyap, and Sim (2016)). The reduction in the probability or magnitude of a crisis and the net gain from LAW is completely insignificant. This is the case even under the assumption of monetary non-neutrality and a permanent effect on real debt and positive effect on cumulated marginal benefit.

A possible objection to the analysis in this paper is that LAW need not be an unanticipated temporary increase in the policy rate as represented here in most of the analysis (except in the discussion of optimal policy for alternative loss functions in section 3) but could instead be a different hypothetical policy regime, where the policy rate systematically responds to indicators of financial instability for financial-stability purposes and where this systematic response is incorporated into private-sector expectations and changes private-sector behavior.

However, first, if such a systematic LAW is a good and robust policy, it should be beneficial also when it is done as a temporary increase in the policy rate, and the policy should pass the test conducted in this paper. Indeed, if a new systematic policy of LAW would be introduced, it would not be immediately credible but for some time, perhaps several years, rather correspond to an unexpectedly high policy rate compared to previous policy.

Second, the temporary policy-rate increase used here can be seen in the light of standard socalled "calculus of variations," the generalization of calculus used in optimization theory. According to calculus of variations, the optimality of any policy can be checked, and the first-order conditions for optimality can be derived, from the effects on the total loss of any deviation from the policy in focus, including the temporary policy-rate increase that I use. The optimality condition is then that any policy deviation must not reduce the total loss. If the total loss increases for a particular deviation and falls for the opposite deviation, this indicates that the optimal policy lies in the direction of the opposite deviation. In this paper, the deviation examined is a temporary policy-rate increase, which increases the total loss, and the opposite deviation is a temporary policy-rate reduction, with reduces the total loss by a small amount.

Third, it may of course be of interest to examine the consequences of a systematic policy of LAW and how it might affect expectations. However, one must be wary of the fact that any such examination of a systematic policy of LAW would require a complicated model and the results would be heavily model-dependent and not very robust. A simple and minimalist approach as the one taken in this paper should everything else equal be a more reliable and robust examination of the cost and benefit of LAW. Its simplicity also has the advantage that anyone can easily reproduced it with other assumptions and estimates than the ones I have used, especially if new relevant empirical estimates would be found. Finally, the substantial margin by which the cost of LAW exceeds the benefit in the simple and robust cost-benefit analysis done here makes it rather unlikely that the outcome for a systematic such policy would be much different.

In summary, the cost of LAW is found to exceed the benefit by a large margin, even under assumptions strongly biased in favor of it. Given the robustness of this result, it seems that the burden of proof, including a thorough cost-benefit analysis, should be on the advocates of LAW.

The main reason for the result that the cost of LAW exceeds the benefit is that the policy rate empirically has such a small effect on the probability and magnitude of a crisis. Given this, when it comes to reducing the probability or magnitude of a financial crisis, so far there seems to be no choice but to use other policies than monetary policy, such as micro- and macroprudential policy, housing policy, or fiscal policy, depending on the nature of the problem. For instance, results of Dagher, Dell'Ariccia, Laeven, Ratnovski, and Tong (2016, figures 3 and 7) indicate that around 20 percent bank capital relative to risk-weighted assets would have been enough to avoid about 80 percent of the historical banking crises in the OECD countries since 1970. Thus, sufficient capital may lead to a much larger reduction in the probability of a crisis than the small fluctuations in the probability that monetary policy can achieve according to the analysis in this paper.

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Appendix

A A Markov process for crisis and non-crisis states

Consider the situation in which the probability of a crisis start is q and the duration of a crisis is n quarters. We can model this as a Markov process with $n+1$ states, where state 1 corresponds to a non-crisis and state j for $2 \leq j \leq n+1$ corresponds to a crisis in its $(j-1)$th quarter.[45]

Let the $(n+1) \times (n+1)$ transition matrix be $P = [P_{ij}]$, where $P_{ij} = \Pr(j|i)$ is the probability of a transition from state i in quarter t to state j in quarter $t+1$. The transition probabilities will be zero except for $P_{11} = 1-q$, $P_{12} = q$, $P_{i,i+1} = 1$ for $2 \leq i \leq n$, and $P_{n+1,1} + 1$. As an illustration, for $n = 3$ the 4×4 transition matrix is

$$P = \begin{bmatrix} 1-q & q & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}.$$

Let the row vector $\pi_t = (\pi_{ti})_{i=1}^{n+1}$ denote the probability distribution in quarter t, and let $\pi_1 = (1, 0, ..., 0)$, corresponding to a non-crisis in quarter 1. Then the probability distribution in quarter $t \geq 1$, conditional on a non-crisis in quarter 1, is given by

$$\pi_t = \pi_1 P^t,$$

and the probability of crisis in quarter t, p_t, is given by

$$p_t = 1 - \pi_{t1} \quad \text{for } t \geq 1. \tag{A.1}$$

Figure A.1 shows the result for the linear approximation (2.2) (as in figure 3.1) and the Markov process (A.1), when $q = 0.8$ percent and $n = 8$ quarters. The probability of a crisis converges to 6.4 percent for the linear approximation and to 6.0 percent for the Markov process. The linear approximation thus exaggerates the probability of a crisis somewhat.

The main advantage with the linear approximation (2.2), is that the effect of the policy rate on the probability of a crisis is easy to calculate. Given the effect on the probability of a crisis start, $dq_t/d\bar{i}_1$ for $t \geq 1$, from figure 2.2, it simply satisfies

$$\frac{dp_t}{d\bar{i}_1} = \sum_{\tau=0}^{n-1} \frac{dq_t}{d\bar{i}_1}. \tag{A.2}$$

[45] I am grateful for helpful discussion with Stefan Laséen and David Vestin on the Markov process of crisis and non-crisis states.

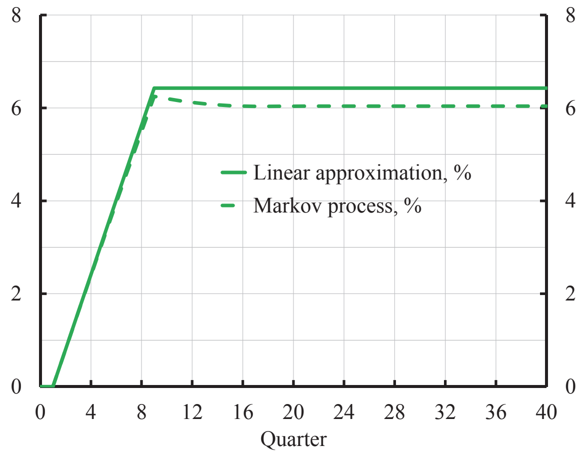


Figure A.1: The probability of a crisis in quarter by the linear approximation (2.2) and by the Markov process (A.1) for $q = 0.8$ percent and $n = 8$ quarters.

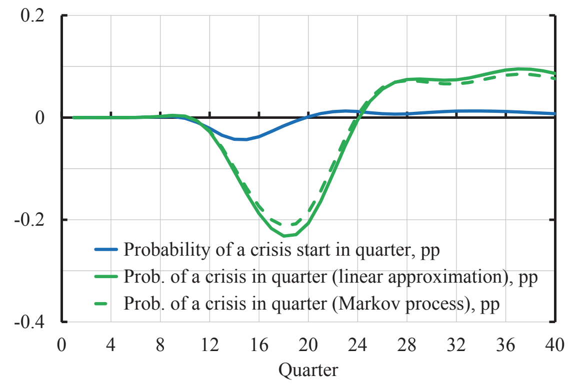


Figure A.2: The effect on the probability of a crisis for the linear approximation (A.2) and the Markov process (A.3) (for $q = 0.8$ percent and $n = 8$ quarters) of a 1 percentage point higher policy rate during quarters 1–4.

For the Markov process, the calculation is a bit more complicated. Let $P_t = [P_{t,ij}]$ for $t \geq 1$, denote the transition matrix from states in quarter t to states in quarter $t+1$, where $P_{t-1,11} = 1 - q_t$, $P_{t-1,12} = q_t$ and $P_{t-1,ij} = P_{ij}$ for $(i,j) \neq (1,1), (1,2)$. Furthermore, we can write

$$\pi_t = \pi_{t-1} P_{t-1} \text{ for } t \geq 2.$$

Then the effect of the policy rate on the probability distribution satisfies

$$\frac{d\pi_t}{d\bar{i}_1} = \frac{d\pi_{t-1}}{d\bar{i}_1} P_{t-1} + \pi_{t-1} \frac{dP_{t-1}}{d\bar{i}_1} \quad \text{for } t \geq 2,$$

where $dP_{t-1,11}/d\bar{i}_1 = -\,dq_t/d\bar{i}_1$, $dP_{t-1,12}/d\bar{i}_1 = dq_t/d\bar{i}_1$, and $dP_{t-1,ij}/d\bar{i}_1 = 0$ for $(i,j) \neq (1,1), (1,2)$. Then

$$\frac{dp_t}{d\bar{i}_1} = -\frac{d\pi_{t1}}{d\bar{i}_1} \text{ for } t \geq 2. \tag{A.3}$$

Figure A.2 shows the effect of a higher policy rate on the probability of a crisis, for the linear approximation (A.2) (as in figure 2.2) and the Markov process (A.2). The linear approximation exaggerates somewhat the effect on the probability of a crisis and thus the marginal benefit of LAW.

B The logistic function

Consider the logistic function

$$q = \frac{\exp(a + bg)}{1 + \exp(a + bg)} = \frac{1}{1 + \exp[-(a + bg)]}, \tag{B.1}$$

where q here is the *annual* probability of a crisis start, g is a the steady annual growth rate of real debt and a and b are constants. In a logit regression of crises starts on current and lagged annual growth rates of real debt, b corresponds to the sum of the coefficients on the lagged annual growth rates.

The derivative of q with respect to g, the marginal effect of steady real debt growth on the probability q, satisfies

$$\frac{dq}{dg} = bq(1-q). \tag{B.2}$$

The sum of coefficients in (2.6) is $b = 9.698$. Given the $dq/dg = 0.30$ reported by Schularick and Taylor (2012), it follows from (B.2) that $q = 0.032$. (To be precise, the values used are $dq/dg = 0.3016$ and $q = 0.0321$.) Given b and q, if $g = 0.05$ it follows from (B.1) that $a = -3.890$.

Section 5.1 examines the case when $g = 0.079$. Then $q = 0.0421$, and $dq/dg = 0.3914$.

C The simple loss function

Assume a quadratic loss function of inflation and unemployment,

$$L_t^*(\pi_t, u_t) \equiv \pi_t^2 + \lambda(u_t - \bar{u})^2, \tag{C.1}$$

where π_t denotes the gap between the inflation rate and and a fixed inflation target in quarter t, and $u_t - \bar{u}$ is the gap between the unemployment rate u_t in quarter t and the long-run sustainable unemployment rate $\bar{u}$. Assume a simple Phillips curve,

$$\pi_t = -\kappa(u_t - \bar{u}) + \varepsilon_t, \tag{C.2}$$

where ε_t is a zero-mean stochastic process representing cost-push shocks that cause a tradeoff between achieving an inflation rate equal to the inflation target and an unemployment rate equal to the long-run sustainable rate. A positive (negative) ε_t implies that a zero inflation gap requires a positive (negative) unemployment gap.

By combining (C.1) and (C.2), the loss function incorporating the Phillips curve can be written

$$\begin{aligned} L_t^0[(u_t - \bar{u}); \varepsilon_t] \equiv L_t^*[-\kappa(u_t - \bar{u}) + \varepsilon_t, u_t] \;&=\; [-\kappa(u_t - \bar{u}) + \varepsilon_t]^2 + \lambda(u_t - \bar{u})^2 \\ &= (\kappa^2 + \lambda)(u_t - \bar{u})^2 - 2\kappa\varepsilon_t(u_t - \bar{u}) + \varepsilon_t^2 \\ &= (\kappa^2 + \lambda)\{(u_t - \bar{u})^2 - 2[u^*(\varepsilon_t) - \bar{u}](u_t - \bar{u}) + (1 + \lambda/\kappa^2)[u^*(\varepsilon_t) - \bar{u}]^2\} \\ &= (\kappa^2 + \lambda)\{[u_t - u^*(\varepsilon_t)]^2 + (\lambda/\kappa^2)[u^*(\varepsilon_t) - \bar{u}]^2\}, \end{aligned} \tag{C.3}$$

where

$$u^*(\varepsilon_t) - \bar{u} \;\equiv\; \frac{\kappa\varepsilon_t}{\kappa^2 + \lambda}. \tag{C.4}$$

It follows from (C.3) that $u^*(\varepsilon_t)$, given by (C.4), is the unemployment rate that for given ε_t minimizes the loss function (C.1) subject to the Phillips curve (C.2). Furthermore, it is clear that choosing u_t to minimize the *simple* quadratic loss function

$$L_t(u_t; u_t^*) \equiv (u_t - u_t^*)^2, \tag{C.5}$$

where $u_t^* \equiv u^*(\varepsilon_t)$ is equivalent to choosing u_t to minimize the loss function $L_t^0(u_t; \varepsilon_t)$ incorporating the Phillips curve. I call u_t^* the *benchmark unemployment rate*.

A crisis is considered to be a negative demand shock that, net of possible conventional and unconventional policy actions during the crisis to reduce its costs, increases the unemployment gap, $\tilde{u}_t \equiv u_t - u_t^*$, by the fixed amount $\Delta u > 0$. The demand shock and the cost-push shock are assumed to be independent. Then u_t^* is independent of a crisis and Δu is the crisis increase in the unemployment rate, u_t.

By (C.3)-(C.5), we can write the the quarter-1 expectation of the quarter-t loss *increase* in a crisis, the *cost* of a crisis, as

$$\begin{aligned} &\frac{1}{\kappa^2 + \lambda} \left(\mathrm{E}_1\{L_t^0[(u_t - \bar{u}); \varepsilon_t]|\mathrm{c}\} - \mathrm{E}_1\{L_t^0[(u_t - \bar{u}); \varepsilon_t]|\mathrm{n}\} \right) = \\ &\qquad \mathrm{E}_1[(u_t - u_t^*)^2|\mathrm{c}] - \mathrm{E}_1[(u_t - u_t^*)^2|\mathrm{n}] + \frac{\lambda}{(\kappa^2 + \lambda)^2}\{\mathrm{E}_1[\varepsilon_t^2|\mathrm{c}] - \mathrm{E}_1[\varepsilon_t^2|\mathrm{n}]\}, \end{aligned} \tag{C.6}$$

where c and n denote, respectively, crisis and non-crisis, and where the last term is zero and can be disregarded if the cost-push shock is uncorrelated with the crisis, which is the maintained assumption.

If instead the cost-push shock is assumed to be correlated with the crisis, that last term in (C.6) is not zero but has to be included in the cost of a crisis. Furthermore, then u_t^* is not independent of whether there is a crisis or not. With the non-crisis and crisis unemployment gaps satisfying $\tilde{u}_t^{\mathrm{n}} \equiv u_t^{\mathrm{n}} - u_t^{*\mathrm{n}}$ and $\tilde{u}_t^{\mathrm{c}} \equiv u_t^{\mathrm{c}} - u_t^{*\mathrm{c}}$, for them to satisfy $\tilde{u}_t^{\mathrm{c}} = \tilde{u}_t^{\mathrm{n}} + \Delta u$, Δu has to satisfy $\Delta u \equiv [(u_t^{\mathrm{c}} - u_t^{\mathrm{n}}) - (u_t^{*\mathrm{c}} - u_t^{*\mathrm{n}})]$. That is, Δu is then defined as the crisis increase in the unemployment rate, u_t, *less* the crisis increase in the optimal unemployment rate, u_t^*. With these modifications, the analysis in the paper can be done also for a cost-push shock correlated with a crisis.[46]

[46] I am grateful to Simone Manganelli for alerting me to this issue.

D The effect of the policy rate on the crisis increase in the unemployment rate

A possible benefit of a higher policy rate might be a smaller increase in the unemployment rate in a crisis. According to Flodén (2014), for the OECD countries, a lower household debt-to-income ratio in 2007 is associated with a lower increase in the unemployment rate during 2007-2012. More precisely, a 1 percentage point lower debt-to-income ratio is associated with a 0.02 percentage point lower increase in the unemployment rate. This is a small effect. It is statistically significant for the sample of all OECD countries but not for the sample of OECD countries for which housing prices fell.

Furthermore, Jordà, Schularick, and Taylor (2013, table 8), with a dataset for 14 advanced countries 1870–2008, report the effect on the GDP downturn in a financial recession of a 1 percentage point higher "excess credit." Here, excess credit denotes the yearly percentage point excess rate of change of aggregated bank loans relative to GDP in the preceding expansion phase (previous through to peak, where excess is determined relative to the previous mean). The average effect on GDP over 5 years is -0.8 percentage point (the average of the coefficients in the table). Assuming an Okun coefficient of 2, this means an average increase in the unemployment rate of 0.4 percentage point.

Post-WWII, the average duration of an expansion phase is 9.46 years in the sample (JST, table 3).[47] A 1 percentage point higher excess credit over 9.46 years implies that the cumulative bank-loans-to-GDP ratio is about 10 percent higher.[48] This means that a 1 *percent* higher bank-loans-to-GDP ratio is associated with a $0.4/10 = 0.04$ percentage point larger unemployment increase. If the bank-loans-to-GDP ratio is about 100 percent, 1 percent is about 1 percentage point.[49] Then, 1 *percentage point* higher bank loans is associated with about 0.04 percentage point larger unemployment increase, about twice as large as the Flodén estimate but still small.

Finally, Krishnamurthy and Muir (2016, table 4), with a dataset for 14 countries 1869–2014, show that a 1 percentage point higher 3-year growth in the credit-to-GDP ratio is associated with an (insignificant) 0.05 percentage point larger GDP decline from peak to trough in a financial crisis. With an Okun coefficient of 2, a 0.05 percentage point decline in GDP is associated with a 0.025

[47] JST (table 3) reports an expansion-phase duration of 6.9 years for 30 observations of "Low excess credit" and a duration of 11.8 years for 32 observations of "High excess credit." The average, taking the numbers of observations into account, is then 9.46 years

[48] $1.01^{9.46} - 1 = 0.0987$.

[49] According to Bank for International Settlements (2016b, table F2.3), for advanced economies, bank loans to the private non-financial sector were 83 percent of GDP in 2016Q1.

percentage point rise in the unemployment rate, a small estimate similar to Flodén's.

If a higher policy rate would lower the debt-to-income ratio, a higher policy rate might through this channel reduce the magnitude of a crisis, by reducing the crisis increase in the unemployment rate, $d\Delta u_t/d\bar{i}_1 < 0$, where the subindex t denotes that the policy-rate effect on the magnitude will be time-varying. Taking such a possibility into account, the effect of the policy rate on the expected unemployment rate, (2.4), will by (2.3) have a third term.

$$\frac{d\mathrm{E}_1 u_t}{d\bar{i}_1} = \frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} + \Delta u \frac{dp_t}{d\bar{i}_1} + p_t \frac{d\Delta u_t}{d\bar{i}_1}. \tag{D.1}$$

Furthermore, the effect of a higher policy rate on the expected quadratic loss, (4.2), will by have an additional term,

$$\frac{d\mathrm{E}_1 L_t}{d\bar{i}_1} = 2[\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} + p_t \Delta u] \frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} + [(\Delta u)^2 + 2\Delta u \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}] \frac{dp_t}{d\bar{i}_1} + 2p_t[\Delta u + \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}] \frac{d\Delta u_t}{d\bar{i}_1}.$$

This leads to an additional term in the marginal benefit, (4.5),

$$\mathrm{MB}_t \equiv [(\Delta u)^2 + 2\Delta u\, \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}](-\frac{dp_t}{d\bar{i}_1}) + 2p_t[\Delta u + \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}](-\frac{d\Delta u_t}{d\bar{i}_1}).$$

For (3.7), the marginal benefit is then given by

$$\mathrm{MB}_t \equiv (\Delta u)^2(-\frac{dp_t}{d\bar{i}_1}) + 2p_t \Delta u(-\frac{d\Delta u_t}{d\bar{i}_1}). \tag{D.2}$$

I wrote "*if* a higher policy rate would lower the debt-to-income ratio," because, as discussed in section 1, it his highly uncertain what the direction is of any effect of the policy rate on the debt-to-income ratio.

As an example and benchmark, I nevertheless use the Sveriges Riksbank (2014a) estimate of the effect on the Swedish household debt-to-income ratio of a 1 percentage point higher policy rate during four quarters, the point estimate of which is shown as the red line in figure D.1. It shows the debt-to-income ratio falling below baseline from a policy-rate increase. However, as discussed in Svensson (2014, 2015), the 90-percent uncertainty band around the estimate is very

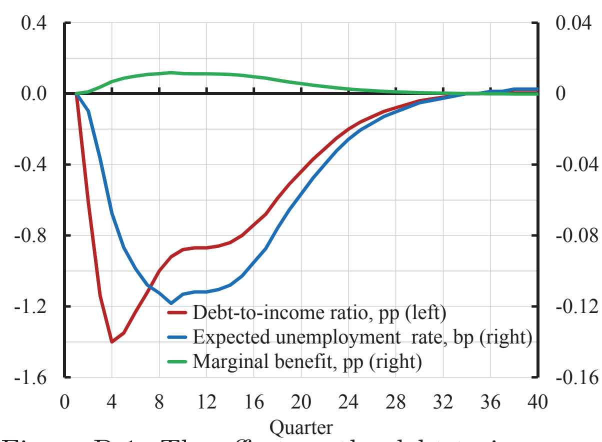


Figure D.1: The effect on the debt-to-income ratio and, via the effect on the crisis increase in the unemployment rate, on the expected unemployment rate and the marginal benefit of LAW; deviations from baseline. (Source: Flodén (2014), Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

wide, and the estimate is not statistically significant and could be of the opposite sign. Nevertheless, for the sake of the argument, I take it as given and examine the resulting effects.[50]

We see that the largest effect, a negative peak of -1.4 percentage points, occurs already after 4 quarters. Given the estimate of Flodén (2014), this would imply that the crisis increase in the unemployment rate would be $-\, d\Delta u_t/d\bar{i}_1 = 0.02 \cdot 1.4 = 0.28$ percentage point lower, that is, the crisis increase would be 4.72 percentage points rather than 5 percentage points. However, after 5 years, in quarter 20, the debt-to-income ratio is only 0.44 percentage point below the baseline, meaning that the increase in the crisis unemployment rate would be $-\, d\Delta u_t/d\bar{i}_1 = 0.088$ percentage point less.[51]

Furthermore, to get the effect on the expected unemployment rate, the third term in (D.1), these numbers should be multiplied by the probability p_t of a crisis in quarter t, (3.12). This results in very small effects, shown as the blue line in figure D.1. The largest effect is a negative peak in quarter 9, when the probability of a crisis has increased to 6.4 percent. The peak is $-\,0.12$ *basis* points $= -\,0.0012$ percentage point, which is only a tenth of the largest difference in figure 2.3, which difference is already very small. Clearly, the effect through this channel on the expected future unemployment rate can be disregarded.

In order to calculate the additional third term in the marginal benefit (D.2), we simply have to multiply this third term in the expected unemployment term (D.1) by $2\Delta u = 10$ percentage points and switch the sign to get the green line in figure D.1. It thus has a positive peak at 0.012 percentage point for quarter 11, which is small relative to the peak of the marginal benefit in figure 4.1.

Figure D.2 shows the effect on marginal benefit and net marginal cost of including the effect on the crisis increase. It seems clear that the conclusions of this paper are not affected by disregarding this (doubtful) effect of the policy rate on the crisis increase in the unemployment rate.

[50] Furthermore, the Riksbank's point estimate of the policy-rate effect on the debt-to-income ratio in figure D.1 is not consistent with the point estimate of the effect on real debt in figure 2.2 and the effect on the unemployment rate in figure 2.1. With an Okun coefficient of about 2, the effect on GDP would be such that GDP would fall by about 1 percentage point in quarter 6, about the same as the fall in real debt in figure 2.2. This implies that the effect on debt to income (assuming income varies ono-to-one with GDP) would be close to zero, not around minus 1.2 percent as in figure D.1. Thus, the point estimate effect on the debt-to-income ratio appears unrealistically large.

[51] This is the summary results I have used in Svensson (2014, 2015).

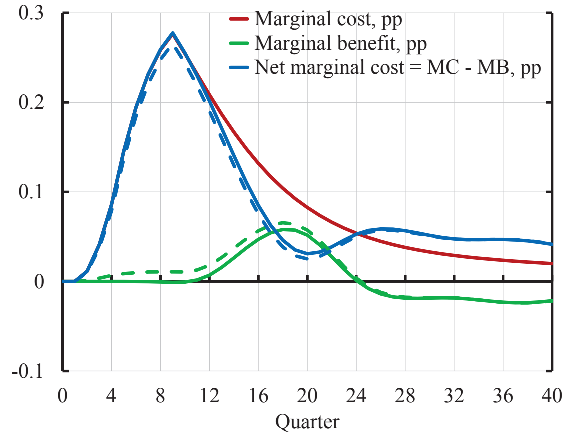


Figure D.2: The marginal cost, the marginal benefit, and the net marginal cost of LAW, with the modification (dashed lines) from including the effect on the crisis increase (Source: Flodén (2014), Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

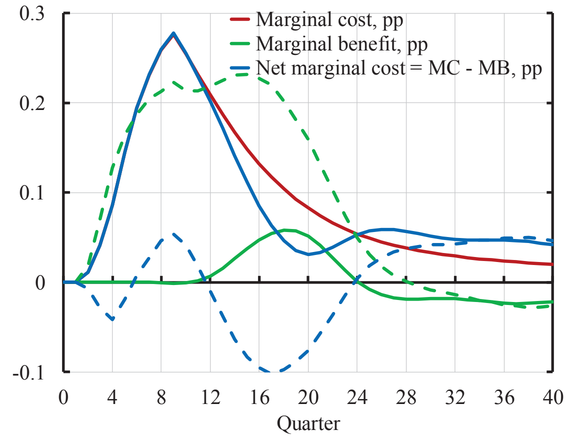


Figure D.3: The marginal cost, the marginal benefit, and the net marginal cost of LAW, with the modification (dashed lines) from including the effect on the crisis increase (Source: Flodén (2014), Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

D.1 The effect on the crisis increase in unemployment required to make benefit exceed the cost

Nevertheless, one may ask how much the policy rate would have to reduce the crisis increase in order to make the cumulated marginal benefit larger than the cumulated marginal cost. It turns out the magnitude of the derivative has to be more than 19 times as large as what follows from the Sveriges Riksbank (2014a) (not statistically significant) point estimate of the policy-rate effect on the household DTI ratio and the (barely significant) Flodén (2014) point estimate of the DTI-ratio effect on the crisis increase in the unemployment rate for OECD countries. For instance, the Flodén (2014) estimate would have to be that 1 percentage point higher DTI ratio would increase the unemployment rate by more than 0.38 percentage point instead of 0.02 percentage point. This would imply more than 3.8 percentage points higher unemployment increase for a 10 percentage points higher DTI ratio, more than 7.6 percentage points for a 20 percentage points higher DTI ratio, and so on. These are not very plausible numbers.

Figure D.3 shows the marginal benefit and net marginal cost when when the DTI ratio effect on the unemployment-rate increase is 19 times times the Flodén (2014) estimate, in which case the cumulated marginal benefit equals the cumulated marginal cost and cumulated net marginal cost is zero.

E Kocherlakota on the value of eliminating the possibility of a crisis

An early and innovative cost-benefit analysis of LAW is provided by Kocherlakota (2014). He assesses the value of eliminating the probability of a crisis, in the sense of reducing the probability of a crisis to zero. He assumes that the crisis increase in the unemployment rate is 4 percentage points, that the expectation in 2014 of the 2017 unemployment rate is equal to a natural unemployment rate of 5 percent, and that a crisis would therefore imply that the unemployment rate would reach 9 percent. As an estimate of the upper limit of the probability of a crisis, he then uses the probability of the 2017 unemployment rate exceeding 9 percent that can be inferred from the 2014Q1 Survey of Professional Forecasters. This probability is 0.29 percent. It is considered an upper limit because the unemployment rate could exceed 9 percent for other reasons than a crisis. We immediately notice that this probability is much smaller than the probability of crisis beyond quarter 9 of 6.4 percent used here. Given Kocherlakota's estimate, the expected loss increase of a crisis is $0.0029 \cdot 4^2 = 0.0464 = 0.22^2$. That is, eliminating the possibility of a crisis is worth an expected non-crisis unemployment gap from zero to only 0.22 percentage point.

With a crisis increase in the unemployment rate of 5 percentage points, as assumed in the present paper, the expected loss from a crisis would be $0.0029 \cdot 25 = 0.0725 = 0.27^2$, in which case it is worth an increase in the expected non-crisis unemployment gap from zero to 0.27 percentage point.

For the benchmark assumptions in the present paper, the steady-state probability of a crisis is 6.4 percent, so the expected loss equals $0.064 \cdot 25 = 1.6 = 1.26^2$ under the benchmark assumptions. Thus, reducing the probability of a crisis from 6.4 percent to zero is under the benchmark assumptions worth an increase in the non-crisis unemployment gap from zero to 1.26 percentage points, a substantial increase.

For the IMF staff estimates discussed in section 7, the steady-state probability of a crisis is 3.78 percent, implying that the expected loss due to the possibility of a crisis is $0.0378 \cdot 25 = 0.945 = 0.97^2$. Then eliminating the possibility of a crisis is worth an increase in the expected non-crisis unemployment gap of 0.97 percentage points, still a substantial increase.

These numbers are much higher than the estimate in Kocherlakota (2014). The main difference is that the estimates of a probability of a crisis that follow from Schularick and Taylor (2012) or the IMF staff estimates, 6.4 and 3.8 percent, respectively, are much higher than the estimate from

Survey of Professional Forecasters, 0.29 percent. However, I am not sure that the forecasts in the Survey of Professional Forecasters take the possibility of a crisis into account. If they don't, they can obviously not be used to infer the professional forecasters' estimate of a probability of a crisis.

F The reduction of the probability of a crisis per expected non-crisis unemployment gap increase for each quarter

Figure F.1 shows, for each future quarter, the reduction in the probability of a crisis per increase in the expected non-crisis unemployment gap, the negative of the ratio (3.16), for the two datasets, Schularick and Taylor (2012) and Laeven and Valencia (2012). The derivative $dp_t/d\bar{i}_1$ are given by the green lines in figures 2.2 and 7.1, respectively. The derivative $d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1$ is given by the red line in figure 2.1. Taking the average over quarters 12-24, as is done in section 3.4 for the Schularick and Taylor (2012) case, clearly exaggerates the estimate of the magnitude of the average reduction of the probability of a crisis per unemployment rate increase, something that exaggerates the benefit and stacks the cards in favor of LAW.

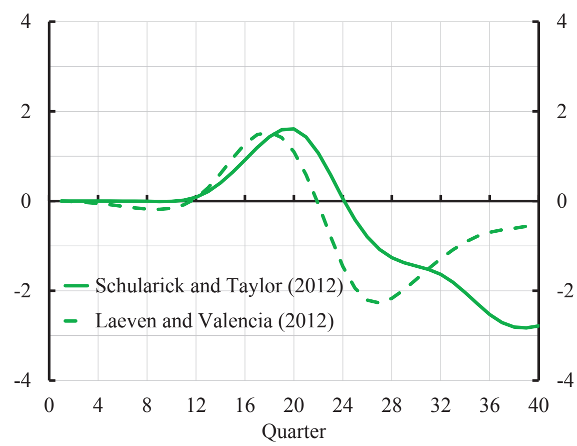


Figure F.1: The percentage-point reduction in the probability of a crisis per percentage-point increase in the expected non-crisis unemployment gap for the datasets of Schularick and Taylor (2012) and Laeven and Valencia (2012).

G The case of a random crisis increase in the unemployment rate

In the benchmark case, the crisis increase in the unemployment rate is taken to be deterministic and given by $\Delta u > 0$ (and assumed to equal 5 percentage points in the benchmark case). Alternatively, the crisis increase in the unemployment rate could be a random variable $\widetilde{\Delta u}$ with mean Δu and variance $\sigma^2_{\Delta u}$. In that case, we have

$$\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}} + \widetilde{\Delta u})^2 = \mathrm{E}_1[\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u + (\tilde{u}_t^{\mathrm{n}} - \mathrm{E}_1\tilde{u}_t^{\mathrm{n}}) + (\widetilde{\Delta u} - \Delta u)]^2 = (\mathrm{E}_1\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}} + \sigma^2_{\Delta u},$$

so the expected quarter-t loss satisfies

$$\mathrm{E}_1 L_t = (1-p_t)\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}} + \widetilde{\Delta u})^2 = (1-p_t)\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2 + p_t[\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}} + \Delta u)^2 + \sigma^2_{\Delta u}] + \mathrm{Var}_1\tilde{u}_t^{\mathrm{n}},$$

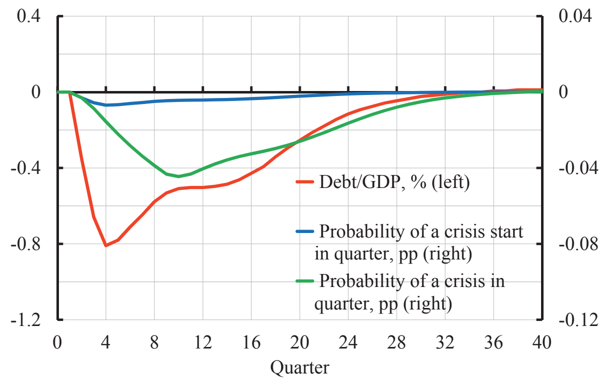


Figure H.1: The effect on the debt-to-income ratio and the separate effect on the probability of a crisis start and of a crisis. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

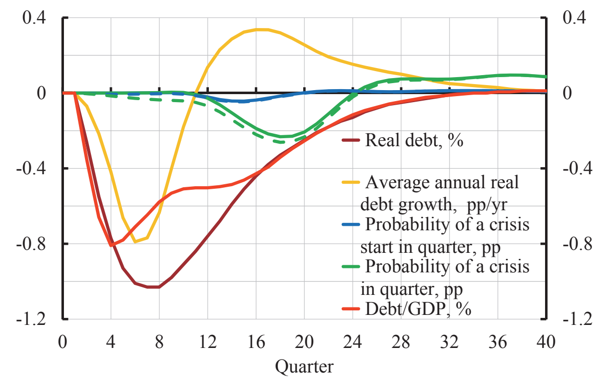


Figure H.2: The estimates of the policy-rate effect on the unemployment rate, real debt and the debt-to-GDP ratio. (Source: Schularick and Taylor (2012), Sveriges Riksbank, and own calculations.)

where the covariance between the crisis increase in the unemployment rate and the non-crisis unemployment rate is taken to be zero. Compared with (3.6), the additional term $p_t \sigma^2_{\Delta u}$ enters on the right side. This will not affect the results.

H The debt-to-GDP term in Schularick and Taylor (2012, table 7)

Schularick and Taylor (2012, table 7, specification 22) contains a logit regression of the annual probability of a crisis start, where the log of debt-to-GDP ratio is added as an explanatory variable. The coefficient is 1.1 with a standard error of 0.624 and is significant at the 10 percent level. The estimates of the coefficients of the lagged real debt growth rates and of the sum of these coefficients do not change much: the sum is 9.984 rather than 9.698. We can represent this variant as

$$q_t = \frac{1}{4} \frac{\exp(X_t + \kappa h_t)}{1 + \exp(X_t + \kappa h_t)},$$

where q_t is a quarterly probability, $\kappa = 1.1$ and h_t is the log of the debt-to-GDP ratio. The derivative of q_t with respect to h_t is

$$\frac{dq_t}{dh_t} = \frac{1}{4} \kappa 4 q_t (1 - 4q_t) = \kappa q_t (1 - 4q_t).$$

With $q_t = 0.008$ and $\kappa = 1.1$, $dq_t/dh_t = 1.1 \cdot 0.008 \cdot 0.968 = 0.0085$. That is, 1 percentage point lower debt-to-GDP ratio lowers the probability of a crisis start by 0.0085 percentage point.

Figure H.1 shows the Riksbank's estimate of the effect of the policy rate on the debt to GDP ratio (expressed in the percentage change) and the resulting separate effect on the probabilities of a crisis start and of a crisis in each quarter. We see that the effect is very small. In figure H.2, the dashed blue and green lines shows the total effect on the probability if a crisis start and the probability of a crisis, when this additional effect via a lower debt-to-GDP ratio is taken into account. We see that the total effect is only marginally larger than the effect via real debt growth only.

I The alternative assumption of a fixed loss level in a crisis

This appendix further examines the unrealistic case of a fixed loss level in a crisis, discussed in section 3.4. Under that assumption, the expected crisis unemployment gap equals Δu,

$$\mathrm{E}_1 \tilde{u}_t^{\mathrm{c}} = \Delta u,$$

regardless of the expected non-crisis unemployment gap,

The expected unemployment gap is then given by

$$\mathrm{E}_1 \tilde{u}_t = (1 - p_t)\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} + p_t \Delta u \tag{I.1}$$

and the effect of the policy rate is

$$\frac{d\mathrm{E}_1 \tilde{u}_t}{d\bar{i}_1} = (1 - p_t)\frac{d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}}{d\bar{i}_1} + (\Delta u - \mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})\frac{dp_t}{d\bar{i}_1}. \tag{I.2}$$

Figure I.1 shows the effect on the expected non-crisis unemployment gap ($d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}/d\bar{i}_1$, the red solid line), the expected unemployment gap for an exogenous probability of a crisis ($(1 - p_t)d\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}/d\bar{i}_1$, the red dashed line), and the expected unemployment gap ($d\mathrm{E}_1 \tilde{u}_t/d\bar{i}_1$, the blue line). The green line shows the difference between the last two, that is, the difference due to the effect on the probability of a crisis, when the expected non-crisis unemployment gap is zero ($\Delta u dp_t/d\bar{i}_1$, measured along the right in basis points). The difference is the same as in figure 2.3 and thus equally small.

The quarter-t the net marginal cost of LAW, is then

$$\begin{aligned}\mathrm{NMC}_t \equiv \frac{d\mathrm{E}_1 L_t}{d\bar{i}_1} &= (1 - p_t)2\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}\frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1} - [(\Delta u)^2 - \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2](-\frac{dp_t}{d\bar{i}_1}) \\ &\equiv \mathrm{MC}_t - \mathrm{MB}_t,\end{aligned}$$

where the marginal cost and marginal benefit of LAW satisfy

$$\mathrm{MC}_t \equiv 2(1 - p_t)\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}}\frac{d\mathrm{E}_1 u_t^{\mathrm{n}}}{d\bar{i}_1}, \tag{I.3}$$

$$\mathrm{MB}_t \equiv [(\Delta u)^2 - \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2](-\frac{dp_t}{d\bar{i}_1}). \tag{I.4}$$

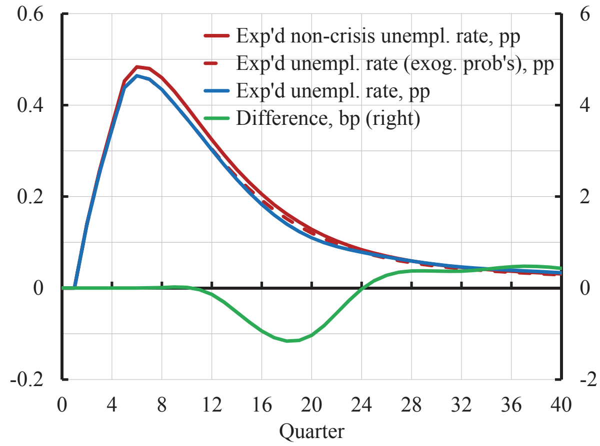


Figure I.1: For a fixed loss level in a crisis, the effect on the expected unemployment gap and its component of a 1 percentage point higher policy rate during quarters 1–4, when the expected unemployment gap is zero.

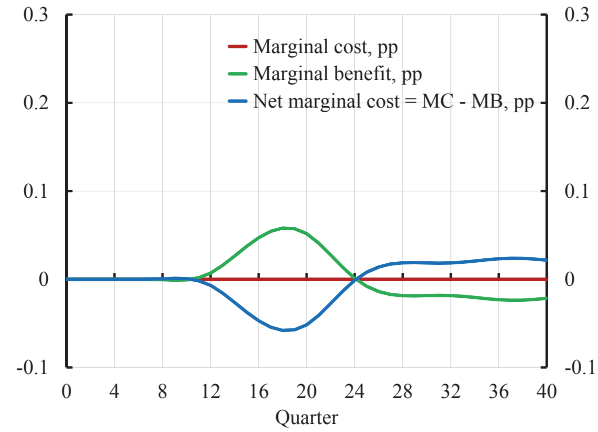


Figure I.2: For a fixed loss level in a crisis, the marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap is zero.

Furthermore, for (3.7),

$$\mathrm{MC}_t = 0, \tag{I.5}$$

$$\mathrm{MB}_t = (\Delta u)^2 (-\frac{dp_t}{d\bar{i}_1}). \tag{I.6}$$

That is, if the expected non-crisis unemployment gap is zero, the marginal cost is now zero, not positive as in (4.6), whereas at the marginal benefit is the same as in (4.7) and positive if the probability of a crisis is decreasing in the policy rate.

We also note that the loss increase in a crisis, the term in the square bracket in (I.4), is decreasing in $(\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}})^2$. It is at its maximum when the expected non-crisis unemployment gap is zero and becomes negative when the expected non-crisis unemployment gap exceeds Δu, $\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} > \mathrm{E}_1 \tilde{u}_t^{\mathrm{c}} = \Delta u$. Of course, in the (unlikely) situation in which the expected non-crisis unemployment gap is greater than the expected crisis unemployment gap, it is better to be in a crisis (under the maintained assumption that the conditional variance of the crisis unemployment gap is not larger than that of the non-crisis unemployment gap).

Figure I.2 shows the marginal cost, marginal benefit, and net marginal cost of LAW, when the expected non-crisis unemployment gap is zero and the loss in a crisis is fixed. Because the marginal cost is zero, the net marginal cost is simply the negative of the marginal benefit and thus negative for quarters 1–23 and positive for quarter 24 and beyond. Because of the neutrality of monetary policy, the cumulated marginal benefit and net marginal cost over a long horizon are approximately

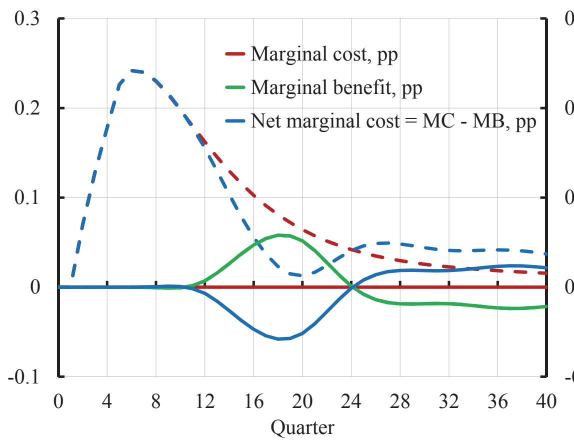


Figure I.3: For a fixed loss level in a crisis, the marginal cost, the marginal benefit, and the net marginal cost of LAW, when the expected non-crisis unemployment gap is positive and equal to 0.25 percentage point for all quarters.

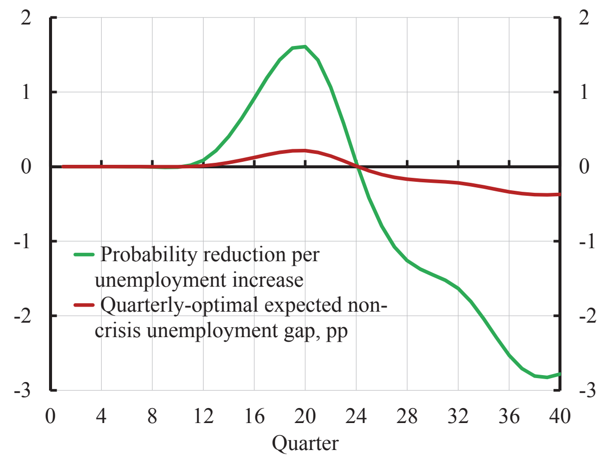


Figure I.4: The reduction in the probability of a crisis per increase in the expected non-crisis unemployment gap and, for a fixed loss level in a crisis, the quarterly-optimal expected non-crisis unemployment gap

zero. However, because the marginal benefit is positive earlier and negative later, the sum of the discounted marginal benefits would be positive, whereas the sum of the discounted marginal costs would be zero. Then a small amount of LAW would be optimal.

If the expected non-crisis unemployment gap is not zero but positive, by (I.3) the marginal cost of LAW is no longer zero but positive. In figure I.3, the dashed lines show the marginal cost, marginal benefit, and net marginal cost when the expected non-crisis unemployment gap is 0.25 percentage point for all quarters. The solid lines show the same, when the expected non-crisis unemployment gap is zero for all quarters. There is a substantial increase in the marginal cost but no noticeable change in the marginal benefit (because in (I.4) the term $(\mathrm{E}_1\tilde{u}_t^{\mathrm{n}})^2 = 0.25^2 = 0.0625$ is so small relative to the term $(\Delta u)^2 = 25$). Clearly, sum of discounted net marginal costs is positive. This shows that a small positive expected unemployment gap makes the cost exceed the benefit, also in the case when the loss in a crisis is fixed. We realize that this would be the case also if the expected non-crisis unemployment gap would be 0.25 percentage point just for the first 12 quarters (or even for the first 8 quarters) and then zero after.

This indicates that any optimal LAW is very small, definitely much smaller than that resulting in an expected non-crisis unemployment gap of 0.25 percentage point.

I.1 The "quarterly-optimal" expected non-crisis unemployment gap

We can illustrate how small the optimal LAW is in the following way. Consider the quarter-t marginal cost with respect to an increase in the expected non-crisis unemployment gap (rather than with respect to an increase in the policy rate, therefore the subindex u),

$$\mathrm{MC}_{ut} = 2(1 - p_t)\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}},$$

and the corresponding marginal benefit from an increase in the non-crisis unemployment gap,

$$\mathrm{MB}_{ut} = [(\Delta u)^2 - \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2](-\frac{dp_t}{d\mathrm{E}_1 u_t^{\mathrm{n}}}).$$

Here

$$\frac{dp_t}{d\mathrm{E}_1 u_t^{\mathrm{n}}} \equiv \frac{dp_t/d\bar{i}_1}{d\mathrm{E}_1 u_t^{\mathrm{n}}/d\bar{i}_1}$$

denotes the decrease in the probability of a crisis in quarter t associated with an increase in the expected quarter-t unemployment gap. We can think of this as a measure of the tradeoff between a higher expected non-crisis unemployment rate and a lower probability of a crisis, the marginal transformation of a higher expected unemployment rate into a lower probability of a crisis.

Let the *quarterly-optimal* expected non-crisis unemployment gap be the unemployment gap that equalizes the quarter-t marginal cost and benefit, that is, the expected non-crisis unemployment gap that is optimal when quarter t is considered in isolation. This is the solution to this second-order equation,

$$2(1 - p_t)\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = [(\Delta u)^2 - \mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2](-\frac{dp_t}{d\mathrm{E}_1 u_t^{\mathrm{n}}}).$$

However, the term $\mathrm{E}_1(\tilde{u}_t^{\mathrm{n}})^2$ will be very small relative to $(\Delta u)^2$ and can be disregarded. (Because this means slightly increasing the marginal benefit, it will slightly increase, and therefore be an upper bound of, the quarterly-optimal expected non-crisis unemployment gap.) Then the quarterly-optimal expected non-crisis unemployment gap is given by

$$\mathrm{E}_1 \tilde{u}_t^{\mathrm{n}} = \frac{(\Delta u)^2}{2(1 - p_t)}(-\frac{dp_t}{d\mathrm{E}_1 u_t^{\mathrm{n}}}). \tag{I.7}$$

Figure I.4 shows for each quarter $1 \leq t \leq 40$ the reduction in the probability of a crisis per increase in the expected non-crisis unemployment gap and the quarterly-optimal expected non-crisis unemployment gap. We see that the most favorable probability-unemployment tradeoff occurs for quarter 20, and equals a probability reduction of 1.6 percentage points for an 1 percentage point expected non-crisis unemployment increase. That is, the probability of a crisis falls by 0.016 for an increase of 1 percentage point in the expected non-crisis unemployment gap. Given this, together with $\Delta u = 5$ percentage points and $p_{20} = 6.4$ percent, the quarterly-optimal expected non-crisis unemployment gap in (I.7) equals a small 0.22 percentage point for the quarter when it is the largest. Again, it is striking how small the maximum quarterly expected non-crisis unemployment gap is. (Because $0.22^2 \approx 0.05$ is a small fraction of $(\Delta u)^2 = 25$, the above approximation is justified.)

J Comments on Box IV.B, "Analytical case for a 'leaning against the wind' monetary policy," in Bank for International Settlement (2016), *86th Annual Report*

Bank for International Settlements (2016a, Box IV.B, pp. 76–77) attempts to provide an analytical case for LAW and implicitly and explicitly provides some criticism of my paper. The main criticism seems to be that my paper (1) relies on credit growth rather than a "financial cycle" as a predictor of crisis, (2) assumes that the magnitude of a crisis is exogenous and independent of the policy rate, and (3) just discusses a one-off policy-rate increase instead of a systematic and optimal policy of LAW. Furthermore, as suggested in Juselius, Borio, Disyatat, and Drehmann (2016, p. 3), such a policy-rate increase would (4) involve "[r]esponding to financial stability risks only when they become evident would inevitably lead to doing too little too late, as it would ignore the cumulative impact of policy over the whole financial cycle."

Regarding (1), I use real credit growth only because the results of Schularick and Taylor (2012) and those from a dataset used in International Monetary Fund (2015) provide empirical support for real credit growth being related to the probability of a crisis. But there is no principle difference between using credit growth and a "financial cycle." The crucial issue is what is the best predictor of future crises and what the impact of the policy rate on that predictor is. This is an empirical issue. Given any empirical estimates of the impact of a financial cycle on the probability of a crisis and the impact of the policy rate on the financial cycle, my analysis can easily be redone using those.

Regarding (2), a possible endogenous magnitude of the crisis is not disregarded in my paper but is actually examined in appendix D. Empirically, the impact of the policy rate on the magnitude is too small to affect the results.

Regarding (3), my sections 3.3 and 3.4 actually examine optimal policy, not a one-off policy tightening. The result is that, for the empirical estimates used, the optimal policy involves a small amount of leaning *with* the wind, not against. (However, the optimal amount of leaning with the wind and the reduction in loss is quantitatively so small that it is not worth bothering about.)

In particular, Box IV.B refers to Filardo and Rungcharoenkitkul (2016) providing a quantitative case for LAW. However, as discussed in Svensson (2016a), that paper seems to get other results than mine not because it relies on an assumption of a financial cycle but because it assumes a different loss function, namely that the cost of a crisis (the loss *increase* when a crisis occurs) is constant and independent of the state of the economy, in contrast to my arguably more realistic assumption that the cost of a crisis is higher if initially the economy is weaker. With a similar loss function as mine it seems that the paper would get similar results as mine.

Regarding (4), that the policy-rate increase that I consider would imply responding too late and would ignore the cumulative impact of the policy, on the contrary, in the main text I actually do indeed examine the cumulative effect of the policy-rate increase on the probability of crisis (in the main text) and the magnitude of a crisis (in appendix D) over a horizon as long as 10 years. As seen in figure 4.1, the main benefit of the policy-rate increase occurs between quarters 12–24, a substantial lag that is obviously taken into account in the analysis.

J.1 Detailed comments

Below this appendix quotes the text of Box IV.B in in full (with original footnotes, references, and figure) and adds my comments. Numbers in brackets, referring to my comments, have been inserted.

> **Box IV.B Analytical case for a "leaning against the wind" monetary policy**
>
> A growing body of research is employing numerical simulations to evaluate the benefits and costs of monetary policy leaning against the build-up of financial imbalances. The various approaches assess the benefits of leaning in terms of a reduction in the likelihood of a crisis, and in its magnitude; and they assess the costs in terms of lower output or higher unemployment in the leaning phase.[1] The results are critically sensitive to three sets of factors: (i) the process driving the evolution of the likelihood of a crisis and its magnitude; (ii) the impact of a tighter monetary policy during the boom on the likelihood of a crisis and its magnitude; and (iii) how a policy easing affects output during the bust. This box discusses the sensitivity of cost-benefit assessments to the modelling approaches.

[1] A small point about the box's footnote 1: The Phillips curve used in my appendix C to derive an indirect loss function in terms of unemployment includes cost-push shocks, so a possible tradeoff

[1] Deviations of inflation from target may also be included. But since these studies do not consider the possibility of negative supply side shocks, there is no trade-off between stabilising output and inflation.[1]

between stabilizing inflation and stabilizing unemployment is actually taken into account.

> Clearly, as long as monetary policy cannot completely undo the costs of a crisis by "cleaning up" afterwards (ie point (iii) above) and it can reduce its probability or magnitude (ie point (ii) above), then leaning would produce some benefits. Intuitively, it would then pay to sacrifice *at the margin* a bit of output today to avoid possible future output losses. Thus, ignoring the potential role of other tools (eg prudential measures) and broader considerations, the question concerning optimal policies is less about whether to lean than about how much.[2]

[2] The intuition suggested in the box is that a possible beneficial impact on the probability or magnitude of financial crises would justify at least some marginal LAW, compared to a starting point of an optimal policy that treats the probability and magnitude as *exogenous*. But that starting point may, if optimal for an exogenous *positive* probability and magnitude of a crisis, involve some initial leaning *with* the wind, as insurance against the positive probability of a negative shock from a future financial crisis. Thus, the question, emphasized in my section 3.3, is whether the possible impact of monetary policy on the probability or magnitude of crises is sufficiently large so as make leaning *against* the wind that dominate over the initial leaning *with* the wind. In my paper, for the empirical estimates used, this is not the case.

Whether or not the optimal policy with exogenous probability and magnitude of crises involves any leaning with or against the wind depends on whether the exogenous probability of crises is zero or positive. If the probability is zero, no leaning (zero leaning) is optimal. If the probability is positive, some leaning *with* the wind ("negative" leaning) is optimal.

> Some studies find that the net benefits of leaning are small or - in the case of a one-off policy tightening at some stage in the boom[3] - even negative.[2] Certain assumptions underpinning the calibration contribute to this conclusion, including the assumption that there is no permanent loss in output (Chapter V).[4] But a key assumption involves the evolution of the likelihood of a crisis and its magnitude. Some models assume both that the magnitude of a crisis is independent of the size of the financial boom ahead of distress[5] *and* that the crisis risk is not expected to grow over time[6]. For instance, the typical variable used to track the evolution of the likelihood of a crisis is credit growth, which itself is naturally mean-reverting.[7] These assumptions effectively imply that there is little or no cost to delaying to lean. And they encourage consideration of counterfactual experiments in which the authorities simply deviate temporarily from their policy rule to influence the variable of interest, here credit growth, with a short horizon.[8]

[2] See eg L Svensson, "Cost-benefit analysis of leaning against the wind: are costs larger also with less effective macroprudential policy?", IMF Working Papers, no WP/16/3, January 2016; and A Ajello, T Laubach, D Lopez-Salido and T Nakata, Financial stability and optimal interest-rate policy", Board of Governors of the Federal Reserve System, mimeo, February 2015.

[3] My sections 3.3 and 3.4 actually examine optimal policy, not a one-off policy tightening, and finds that, for the empirical estimates used, the optimal policy involves a small amount of leaning *with* the wind, not against. (However, the optimal amount of leaning with the wind and the reduction in loss is quantitatively so small that it is not worth bothering about.) The first version (January 2015) of the paper also, in an appendix not included in later versions, examines optimal policy, when the policy rate is constrained to be constant for four quarters. The constrained optimal policy is a lower, not higher, policy rate, corresponding to some leaning *with* the wind rather than against.

[4] My paper uses the unemployment increase in a crisis as a measure of the magnitude of a crisis. The cumulative present value of (quadratic) loss increase may be large but will be finite. A permanent increase in the unemployment rate is less plausible, but with a positive discount rate, the present value of the loss would still be finite. The crisis increase in the unemployment rate, Δu, should be interpreted as the unemployment-increase equivalent of the negative shock that is associated with a crisis, net of any mitigating policy response following the crisis. Using an output fall as a measure of the magnitude of a crisis, in particular if it is assumed to be permanent, introduces tricky issues of the determination of productivity, in particular whether a financial crisis would have a permanent effect on productivity. With a positive discount rate, a permanent output fall would also have a finite present value.

[5] A possible endogenous magnitude of the crisis is not disregarded in my paper but is examined in appendix D. Empirically, the impact of the policy rate on the magnitude is too small to affect the results.

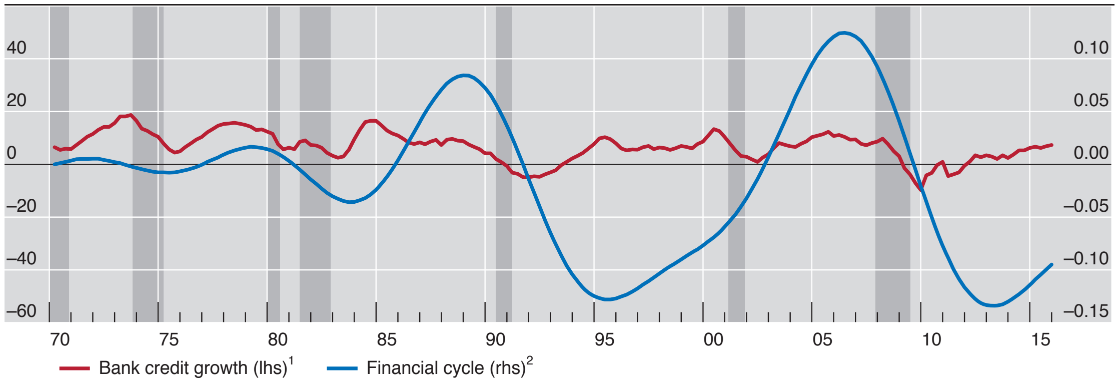
[6] The probability of a crisis is allowed to vary over time in my paper and nothing prevents it from growing over time, depending on the empirical estimates. However, for the empirical estimates used, a higher probability of a crisis increases the cost of LAW more than the benefit.

[7] The "financial cycle" discussed in Box IV.b would seem to be approximately stationary and hence mean-reverting in expectation, as indicated in Graph IV.B. Importantly, there would seem to be no principle difference between credit growth and the "financial cycle," especially when the scales of the two variables are standardized to their standard deviations so as not give a misleading visual impression in the graph. The crucial issue, again, is which empirically is the best predictor of crises.

[8] If policy is optimal (at least optimal under discretion), a necessary condition for optimality is that any deviation from the policy, temporary or of longer duration, should not reduce the intertemporal loss, in line with the standard "calculus of variations" in optimization theory. There

The financial cycle is much more persistent than bank credit growth

Graph IV.B



The shaded areas indicate recession periods as defined by the National Bureau of Economic Research.

1 US private non-financial sector; year-on-year changes, in per cent. 2 Measured by frequency-based (bandpass) filters capturing medium- term cycles in US real credit, credit-to-GDP ratio and real house prices.

Sources: M Drehmann, C Borio and K Tsatsaronis, "Characterising the financial cycle: don't lose sight of the medium term!", *BIS Working Papers*, no 380, June 2012; national data; BIS calculations.

is thus no problem with examining the marginal intertemporal loss from temporary deviations from a zero-leaning policy. If the marginal cost of a temporary tightening exceeds the marginal benefit, it is clear that optimal policy does not involve tightening but easing.

> But the dynamics underlying crisis risks may be different. Credit growth has been found to be a good leading indicator,[3] although by no means the only one. Other indicators put more emphasis on the gradual build-up of vulnerabilities; these are captured by the cumulative increases in debt stocks and, relatedly, in cumulative deviations of asset prices, especially property prices, from historical norms. In particular, cumulative deviations of the ratio of private sector credit to GDP or debt service ratios from such norms have been found to be especially important (see Box III.A and references therein). The idea of the financial cycle generalises these dynamics: it reflects prolonged credit and asset price booms followed by busts, with banking stress typically taking place close to the peak of the cycle.[9] The contrast with the evolution of credit growth is obvious (Graph IV.B). The persistent nature of the stock variables highlights the importance of understanding crisis dynamics, and economic fluctuations more generally, through the lens of the cumulative process of the financial cycle.[10]

[9] An assumption that crises would only occur at the peak of a financial cycle, employed in Filardo and Rungcharoenkitkul (2016), is likely to be too restrictive and to be rejected by the data.

[10] There is no principle difference between credit growth as a predictor of financial crises and a "financial cycle" combining several predictors. There is no principle difference between credit growth, debt to GDP, or debt service to GDP. The crucial issue is, first, which indicator or combination

[3] M Schularick and A Taylor, "Credit booms gone bust: monetary policy, leverage cycles, and financial crises, 1870-2008", American Economic Review, vol 102, no 2, 2012, pp. 1029–61.

of indicators is the best predictor of crises in the sense of having an impact on the probability or magnitude of crises and, second, what the impact the policy rate has on these indicators and hence, indirectly, on the probability and magnitude of a crisis. This is an empirical issue. The method I develop in my paper allows for any combination of indicators having an empirical impact on the probability or magnitude of crisis and any empirical impact of the policy rate on these indicators. Indeed, appendix H incorporates the possible impact of debt to GDP on the probability of crises according to Schularick and Taylor (2012, table 7, specification 22) and appendix D examines the possible impact of debt to income on the magnitude of crises according to Flodén (2014). The conclusion is that, for these empirical estimates, the impact of the policy rate through these channels on the probability and magnitude of crises is too small to matter for the results.

> The policy implications are significant. If the evolution of financial stability risks is more akin to the financial cycle view, then failing to lean has a cost. In the absence of any action, the risks increase over time, and so do the costs if larger imbalances lead to larger busts.[11] This puts a premium on early action and on a through-the-cycle, long-term perspective. Recent work has formalised this intuition.[4] By calibrating a model to a stylised financial cycle, the benefits from leaning can increase considerably relative to those found in other approaches: it pays to lean early and systematically.[12] This evidence is consistent with that based on a more granular financial cycle calibration (Box IV.C).

[11] It follows from the previous comments that there are no different policy implications and that it does not follow that marginal cost and benefit are any different. It is all an empirical issue about estimates about costs and benefits of LAW, no different in principle from the issues discussed in my paper.

[12] As shown in some detail in my discussion of Filardo and Rungcharoenkitkul (2016), Svensson (2016a), the reason their paper gets different results from mine does not depend on a "financial cycle view" but on an assumption that the cost of a crisis (the loss increase in crisis) is constant, regardless of the initial state of the economy. In contrast, my paper assumes, arguably more realistically, that the cost of a crisis is higher if the economy initially is weaker and the unemployment rate initially is higher. Their assumption about the loss function is similar to that of Ajello, Laubach, Lopez-Salido, and Nakata (2015), which explains why they get a similar result as that paper, namely that a small amount of LAW. If they instead would assume the same loss function as I use in my paper, they would most likely get the same result as I get.

> Obviously, the analysis here is a partial one and leaves out many considerations. These include credit growth associated with financial deepening and innovation; aspects

[4] A Filardo and P Rungcharoenkitkul, "Quantitative case for leaning against the wind", BIS, mimeo, 2016.

of the uncertainty about the state of the economy and its behaviour; and the effectiveness of alternative instruments, notably prudential policies. In addition, it abstracts from the general equilibrium effects, especially important in small open economies, through which monetary policy can have an impact on exchange rates and capital flows and complicate a leaning strategy (see the main text). Nevertheless, the analysis sheds light on the importance of properly characterising crisis risks over time when assessing the costs and benefits of leaning against financial booms and busts. It thus sharpens the questions that need to be addressed both analytically and empirically.