The Friedman rule in today's perspective

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The Friedman rule in today's perspective[1]

A new theory of optimal inflation and perspectives on financial stability

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Abstract

So far approaches to optimal inflation are still based on the assumption of a currency which is printed and spend by a central authority. From this perspective central banks' inflation targets and optimal inflation targets are at odds with those suggested by economic theory. The so-called Friedman-rule, the common core of optimal inflation theory, determines optimal inflation via the (opportunity) cost of producing currency. This basic approach is amended by "external effects", e.g. the impact of monetary non-neutrality or wage rigidities and so on. However, even under consideration of external effects the standard literature contests a significant gap between actual inflation targets and optimal rates as suggested by theory.

Central banks like the Bank of England or the Bundesbank have highlighted recently that the supply of currency is achieved not by means of printing and spending but by means of credit. This clarification raises further issues. This article addresses the issue of optimal inflation. If currency is issued by means of lending and borrowing, a revision of the Friedman rule becomes necessary. In essence, the revised Friedman-rule incorporates a mark-up for expected losses such that returns and losses from lending net to zero and establish a "risk free" interest rate of zero. The nominal rate targeted needs to supersede the risk free component exactly by the risk mark-up. This article explores the effect of interest rates and inflation targets below these revised-Friedman rule optima. It is shown that interest rates and inflation targets below their new optima create an externality and welfare losses. Hence, while actual losses in central banking might be very rare events, central banks should stick to optimal policies for welfare reasons.

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A new theory of optimal inflation

Central banks' inflation targets are all strictly positive. The lowest are around 2%. Most central banks define a range somewhere between 2% and 8%. Only a few countries have (temporarily) departed from this range, aiming at higher rates, like Argentina, Belarus, Malawi, Ukraine in 2016 (see Siklos 2008 and Central Bank News 2016).

Table 2: Central banks' inflation targets

Country	Mean Target
Euro Area, Switzerland	<2.00%
Canada, Czech Republic, Israel, Japan, New Zealand, Peru, South Korea, Sweden, United Kingdom, USA, West African States	2.00%
Australia, Iceland, Norway, Romania, Poland, Thailand	2.50%
Samoa, China	3.00%
Albania, Armenia, Chile, Colombia, Costa Rica, Dominican Republic, Guatemala, Hungary, Indonesia, Mexico, Samoa, Serbia, Phillipines, Russia	4.00%
Paraguay, Botswana, Brazil, South Africa	4,50%
Georgia, Kenia, Moldova, Uganda, Uruguay, Turkey	5,00%
Jamaica, Mozambique, Azerbaijan	5,50%
Bangladesh, Pakistan	6,00%
Kazakhstan, Kyrgyzstan, Mongolia, Vietnam, Zambia	7.00%
Nigeria	7,50%
Ghana, India	8,00%
Belarus, Ukraine	12.00%
Argentina, Malawi	14.20%
Reference: http://www.centralbanknews.info/p/inflation-targets.html	

Some economists, like Phelps (1973) and his followers, have supported "higher" inflation rates on the basis of utility based concepts. Krugman (1997) for instance remarks, "one of the dirty little secrets of economic analysis is that even though inflation is universally regarded as a terrible scourge, efforts to measure its costs come up with embarrassingly small numbers." Blanchard "derives" an optimal 4% target (Blanchard, Dell'Ariccia, and Mauro 2010), and Rogoff even proposed up to 6% (Rogoff 2013).

More theoretically oriented approaches, however, come up with significantly lower numbers. Admittedly, there is no generally accepted approach to determine optimal inflation. But there is a common core. In general analyses start from the Friedman-rule and "add" further external effects, i.e. the impact of monetary non-neutrality, incomplete taxation, or wage rigidities. The difficulty for monetary policy posed by a lower bound of zero on the nominal interest rate has received some special attention in the latest publications, which identify a trade-off between the inflation objective and macroeconomic stability (see Coenen, Orphanides, and Wieland 2004 or Reifschneider and Williams 2000).

Stephanie Schmitt-Grohe's and Martin Uribe's contribution to the third volume of the *Handbook of Monetary Economics* (Schmitt-Grohe and Uribe 2011) provides a good overview. They determine the cost optimal inflation according to the Friedman rule and then add the different external effects. For all of them they derive an optimal inflation close to or below zero. Hence they conclude that from a theoretical point of view the gap between the actual inflation targets of central banks and the theoretically optimal inflation target cannot be explained even if various external effects are considered (see Schmitt-Grohe and Uribe 2011, p. 715).

Table 2: Optimal inflation as suggested by theory

Assumption	Optimal rate of inflation
Friedman rule	-î
+ distortionary taxes	<0%
+ untaxed income	<0%
+ foreign demand for domestic currency	<2%
+ price stickiness	≤0%
+ size and Elasticity of Money Demand	<0%
+ zero lower bound	<-0,4%
+ downward nominal rigidities	<0,35%
+ sticky nonquality-adjusted prices	=0%
+ sticky quality-adjusted prices	=k%
Reference: Schmitt-Grohe and Uribe 2011	

One of the few exceptions is a high foreign demand for domestic currency. The incentive to tax foreign holdings of domestic currency explains inflation targets up to 2%, an argument which applies to countries whose currencies circulate widely outside of their borders. The United States or the Euro area would qualify as such examples. However, these countries are those with the lowest inflation targets (see Schmitt-Grohe and Uribe 2010, p. 32). In other words, the actual target rates of central banks are considerably above the rate suggested by economic theory.

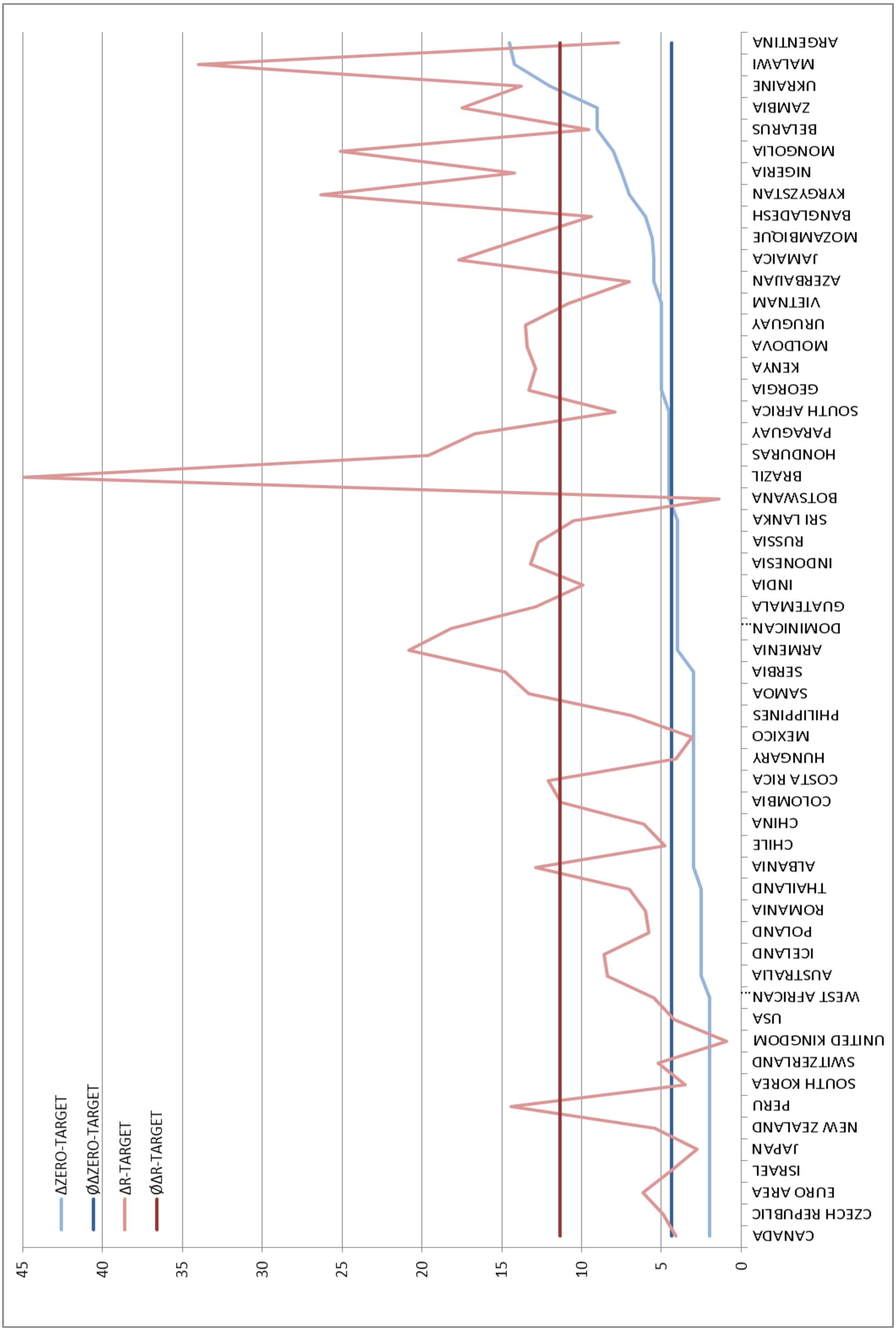
> "The two leading sources of monetary nonneutrality in modern models of the monetary transmission mechanism—the demand for money and sluggish price adjustment—jointly predict optimal inflation targets of at most zero percent per year. Additional reasons frequently put forward in explaining the desirability of inflation targets of the magnitude observed in the real world—including incomplete taxation, the zero lower bound on nominal interest rates, downward rigidity in nominal wages, and a quality bias in measured inflation—are shown to deliver optimal rates of inflation insignificantly above zero" (Schmitt-Grohe and Uribe 2010, p. 65).

As a result there is a gap between actual inflation targets as pursued by central banks optimal rate of inflation ($\Delta ZERO - TARGET = \pi^*_{CB}$) and theoretical estimates of optimal inflation targets. This gap may be estimated either by the difference between inflation targets and negative real interest rates ($\Delta R - TARGET = \hat{\imath}_B + \pi^*_{CB}$) or by the difference between inflation targets and zero (π^*_{CB}). The difference between target rates and zero are directly observable as stated in table (1). The difficulty with real interest rates is their determination. Combining World Bank Data on real interest rates with the IMF World Economic Outlook yields the following figure (see Figure 1).

The average difference is about 4,4 percentage points with respect to zero and about 11(!) percentage points with respect to the real interest rate. Hence inflation targets are on average 4,4 or 11 percentage points above optimal rates as suggested by the Friedman rule for a fiat currency. The actual nominal inflation target are quite heterogeneous and range from close but below 2% (European Central Bank and Swiss National Bank) to values above 10% (Central Bank of Argentina, the Reserve Bank of Malawi or the National Bank of Ukraine).

As shown above, the perceived gap between targeted inflation rates and theoretical optima exists irrespective of how it is calculated. Nominal targets diverge significantly from zero or real interest rates. While central bankers are known to apply economic theory and to rely upon it they have reaffirmed their inflation targets. Leading central bankers like Weidman or Yellen reaffirmed their targets (see Weidmann 2015 and Yellen 2015). Nonetheless central bankers take the theoretical results serious. Even though a theoretical estimate of an optimal inflation target is regarded as "a rough approximation", it "likewise seems crucial to making good policy in the next few years" (see Bernanke 2004, p. 166). If this is supposed to be consistent central bankers have to adjust their target inflation rates or economists would have to adjust their theoretical results. In this essay I argue in favour of the latter. I argue that targeted rates can be aligned with theory by reassessing the underlying Friedman rule.

FIGURE 1 Difference inflationtargets and zero and real interest rates



1 The Friedman-rule in a very simple model

The common core of modern approaches to determine the optimal inflation is the Friedman-rule. In earlier works Friedman had argued for a constant rate of currency growth. Friedman argued that anticipated inflation is safer to unanticipated inflation (due to the risk of an upward inflationary pressure in the latter). A government should make its monetary policy transparent and stick to it. A fixed-growth rule would assist the formation of a constant level of prices, which was regarded as a worthwhile goal in itself. This view was revised in his essay on the *Optimum Quantity of Money*. Here Friedman challenged the goal of a constant level of prices and embeds the problem in a theoretical framework (Friedman 1969, pp. 1-50).

Historically economists addressed the issue of optimal inflation under the heading of seigniorage. The supply of currency was judged according to the same logic as commodities. The supply of commodities is optimal if the price paid in the market equals the (marginal) cost of production. The orientation on cost of production can be justified, as national legal tender fulfils the properties of private goods. Currency is rivalrous, i.e. ownership of one prevents ownership of another, and it is excludable, i.e. owners can exercise their property rights. The government is asked to maintain a functioning currency regime, a common unit of account, and the currency's purchasing ability, but there is no reason why a currency units' price should deviate from its cost of production. With respect to optimal seigniorage and optimal inflation economists concluded – in a long tradition – that seigniorage is optimal if it is cost-covering (see Reich 2017 Chapter 2 on the History of Economic Thought).

For a commodity currency this approach is straight forward. The purchasing power of the issued coins must be equal to the price of the contained currency-commodity, e.g. gold, plus charging the additional cost for minting. The government must offer to coin gold deliveries freely, charging a fee for minting. The difference between the cost of production of a coin and those of the gold contained in it would then, in the end, be determined solely by the cost of minting. Fiscal seigniorage accordingly is zero. For negligible costs of "minting" there should be no difference between the cost for buying and selling the currency-commodity.

Friedman departs from this tradition and instead introduces two critical assumptions as a starting point to his analysis. He assumes firstly that money renders productive services ("marginal productive service of real balances as a factor of production"; Friedman 1969, p. 18). This assumption reflects the arguments in the aftermath of the Keynesian Revolution. In neoclassical general equilibrium theory there is no role for money to play (the so called Hahn Problem; see Hahn 1965). To be able to introduce money and to ensure that the price of money is positive one of several assumptions were introduced. It was either assumed that money enters the utility function (see Sidrauski 1967), that transactions require cash-in-advance (see Clower 1967) or variants thereof, i.e. assuming shopping time or transaction cost technology (see Feenstra 1986). Such arguments can be applied to introduce a use value. Friedman introduces the "marginal productive service of real balances" such that there is an optimum quantity of real balances and hence money. He seems to believe that there is an optimal real *quantity* of currency which renders the production and exchange of commodities as optimal. Such a believe requires that the velocity of circulation is a surprisingly inflexible variable.

Secondly, he assumes zero cost of production of currency. Friedman departs from the assumption of a commodity currency and instead assumes a fiat currency. For him this means a paper based currency supplied by discrete choices on the part of government. The government uses the printing press to finance its spending. The costs of production of such fiat currency units, he assumes, are negligible.

From these two assumptions Friedman derives his rule for optimal inflation. He argues that the optimal stock of money is given where the "marginal productive service" is equal to the cost of production, i.e. zero. This optimum requires that the opportunity costs of currency are as well zero. If currency can be borrowed and lent then the rental price, i.e. the interest rate (i_B^F)[2] at which it can be borrowed or lent, establishes the opportunity cost of holding currency. Friedman introduces this rate as the return on risk free bonds which can be issued at no cost. To be able to reduce the marginal productive service of currency to be means of expanding the currency supply requires furthermore that opportunity costs are zero.[3] Otherwise the demand for real cash balances would be too low. Instead of holding currency it would be lent at the – assumedly risk free – interest rate. In other words, the opportunity costs of holding currency have to be lowered until the demand for currency is such that the marginal productive services of currency are zero. As a result he demands to supply currency until the nominal risk free interest rate on currency is pushed to zero.

> "Our final rule for the optimum quantity of money is that it will be attained by a rate of price deflation that makes the nominal rate of interest equal to zero" (Friedman 1969, p. 34).

To summarize, Friedman's result requires zero cost of production, a risk free interest rate at which everyone can invest or borrow, and the assumption of an optimal (absolute) quantity of real currency and a very inflexible velocity of circulation respectively.

The optimal rate of inflation (π_B^{F*}) follows directly. For a zero interest rate it must – according to

2 "B" refers to the underlying legal tender currency or base money and the letter "F" refers to assumed supply mechanism of a fiat currency.

3 It is not clear whether this policy is possible without lowering the purchasing power of currency to zero. The rental price and the relative price of an entity have to correspond in some way. It is not clear that it is possible to lower the rental price of something to zero – by means of excessive supply – without reducing its relative price to zero.

the simple Fisher equation – be equal to the negative "real" interest rate ($\hat{\imath}_B$):

$$i_B^{F*} = 0 = \pi_B^{F*} + \hat{\imath}_B \quad (1)$$

$$\text{or} \quad \pi_B^{F*} = -\hat{\imath}_B$$

This is the so called Friedman rule. It is usually not translated into a currency growth rule in the literature. Yet there is no difficulty in doing so. According to the quantity equation, currency growth equals the change in liquidity demand (g_k), plus inflation, plus the growth in trade (g_q). If inflation is equal to the negative real interest rate one obtains:

$$g_B^{F*} = -\hat{\imath}_B + g_k + g_q \quad (2)$$

Using the Cambridge Equation, there is a simple way to reformulate this result. The Cambridge Equation states that the rate of economic growth (g_Y) (which is therefore assumed to be identical to the growth in trade (g_q)[4] equals the real rate of interest ($\hat{\imath}_B$) times the rate of savings out of profits (s_P) for constant capacity utilization (g_u). For a saving rate from profits of one ($s_P = 1$) and constant capacity utilization ($g_u = 0$) the growth rate equals the real rate of interest, the so-called golden rule:[5]

$$\hat{\imath}_B = g_k \; for \; s_P = 1 \; and \; g_q = 0. \quad (3)$$

If the real rate of interest corresponds to the rate of economic growth (g_Y) then the optimal currency growth rate is, as suggested by Friedman, given by changes in liquidity preference:

$$g_B^{F*} = g_k, \quad (4)$$

$$\text{where} \quad \pi_B^{F*} = -\hat{\imath}_B = -g_Y.$$

Thus the optimal real currency growth is zero except for changes in liquidity demand; thus for changes in the currency demand function. Whenever the demand for currency rises it pushes the interest rate up, and hence the government is supposed to issue more currency to reduce the nominal rate of interest. For a stable currency demand function the currency growth rate should be zero.

The optimal rate of inflation is the negative real interest rate or – following the Cambridge equation – the negative growth rate of the economy.

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4 In many presentations it is assumed that the volume of trade is linear with respect to the national income (see Gebauer 2004, pp. 154-155 or Issing 2011, pp. 31-32). Replacing the quantity of transactions with National Income is rather problematic. The quantity of transactions might be different from the national income, and national income is usually a weighted measure, thus a price weighted index, of the total volume of transactions. Transforming the vector **q** into a scalar is highly problematic since it assumes the neutrality of money. It should therefore always be kept in mind that in fact it is the volume of transactions that is meant, and that National Income is only a rough approximation.

5 Instead of assuming constant capacity utilization, a variant of the Cambridge Equation could be used, where the growth rate equals the real rate of interest times the rate of savings from profits plus the change in capacity utilization. It states that growth is determined by the retained earnings from profits plus changes in capacity utilization. If the golden rule does not apply, hence if capacity utilization changes (i.e. $g_u \neq 0$), for example because a monetary expansion induces growth by a rise in capacity utilization, Friedman's result will not hold. A growth in currency supply which induces non-inflationary economic growth by rising capacity utilization leaves the real rate of interest unaffected. Consequently, the optimal currency growth rate is higher for economies below full employment.

A simple model suffices to illustrate the practical implications of the Friedman rule. Following the standard approach it is assumed that the demand for currency B^D can be expressed as:

$$B^D = k_B^Q(i_B^F)\boldsymbol{p}_B \, \boldsymbol{Y}. \tag{5}$$

The demand for currency is often determined by empirically estimated demand functions. Theoretically the demand depends according to the quantity equation on liquidity demand (k_B^Q) times the level of transactions, output or income ($\boldsymbol{p}_B\mathbf{Y}$).[6] In real terms, the demand for real currency, i.e. divided by prices, one gets:

$$\boldsymbol{p}_B^{-1}B^D = k_B^Q(i_B^F)\, \boldsymbol{Y}. \tag{1}$$

The supply of currency (B^S) is determined by the supply of fiat currency (B_F^S). The supply of fiat currency depends on the discrete choice of the central government, as the government chooses to print and spend a certain amount of currency (B_F^G). The real currency supply hence depends on the amount of government purchases financed by means of the printing press ($\boldsymbol{p}_B\boldsymbol{A}_G^M$). In real terms the supply of currency ($\hat{B}$=$\boldsymbol{p}_B^{-1}B$) is given as:

$$\hat{B}^S = \hat{B}_F^S = \hat{B}_F^G = \boldsymbol{A}_G^M. \tag{2}$$

If the central government follows the Friedman rule it needs to adapt its currency supply to the demand for currency such that the rate of inflation is equal to the negative real interest rate, or if that is equivalent equal to then negative growth rate of the economy. As a side note, the revenue from seigniorage can be positive even though the optimal level of inflation might be negative (see Reich 2017).

$$\hat{B}_F^{S*} = \boldsymbol{A}_G^{M*} = k_B^Q(i_B^{F*})\boldsymbol{Y}. \tag{3}$$

The amount of real resources finance by means of the printing press is optimal if it is in proportion to the gross domestic product, such that the corresponding rate of inflation is equal to the negative growth rate of the gross domestic product.

The following figure (2) pictures a currency supply of this sort which adapts to currency demand. If currency demand changes (dotted curve) the supply has to be adapted (dotted curve), such that the interest rate does not rise permanently.

6 The refer to real currency demand is tricky. $\boldsymbol{p}_B^{-1}$ is usually referred to as the level of prices. That means it is the price of currency p_B in terms of the vector of all prices $\mathbf{p}$, or inversely, the level of prices in terms of currency. Except for a one good world, the level of prices is therefore a vector of prices or a certain aggregated index.

Figure 2: Optimal fiat currency supply

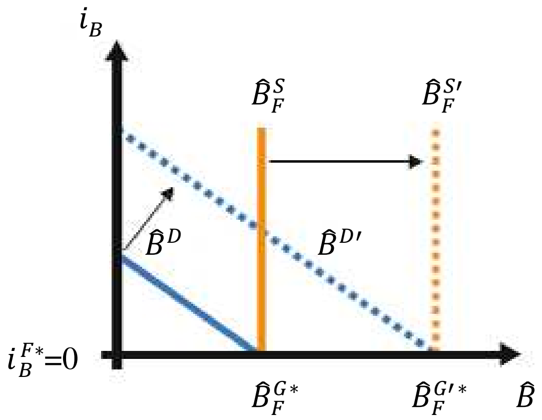


Illustration based on this research

The conflict between theory and central banks' practice which was shown to exist in the first section is due to this analysis. It is the peculiar perspective introduced by Friedman and the Friedman-rule which builds the theoretical basis for this perception.

There are different ways to resolve this perceived gap. Friedman's result depends on his crucial assumptions of zero cost of production, a risk free interest rate at which everyone can invest or borrow, and the assumption of an optimal (absolute) quantity of real currency and respectively a very inflexible velocity of circulation. One way is to resolve the gap is to remove the assumption of negligible cost of production. The higher these cost the lower the perceived gap. And indeed, central bankers have stressed the costs of supplying and maintaining the currency: "resource costs, associated functions, competitiveness, inventory costs, volume of regular (liquidity) traders, extent of exposure to informed insiders and risk of being caught by an unobservable shift in underlying value" (Goodhart 1989, p. 10). Admitting cost of production furthermore allows applying the historical approach to optimal inflation. Optimal inflation and currency supply can be determined where the purchasing power of currency covers its cost of production (see Reich 2017, pp. 57-59).[7]

The alternative path is to question the existence of risk free bonds as an alternative to currency. This second argument which has so far not been developed shall be put forward in the following section. Friedman assumes that a risk free asset or liability (in his words a "bond"; Friedman 1969, p. 24). Such a liability does not exist. All liabilities (or assets) face some risk of default. The Friedman rule suggests that the interest rate received on a *risk free* liability should be pushed down to zero. The return on a risky liability should – respectively – be pushed down until the return covers expected losses on this liability. This difference was not at the heart of Friedman's inquiry. Friedman assumes

[7] The "cost of production"-approach requires either neglecting marginal productive services of currency and instead interpret these services as the use-value of currency or alternatively to explicitly incorporate such effects as a positive externality.

a fiat currency which is issued by printing and spending on behalf of a central government. Hence he assumes that the currency is printed and distributed by the famous parable of a helicopter. There is no risk in this process and hence the reference to a risk free rate is unproblematic. Leading central banks have however stressed more recently that the supply of currency is not organized in such a way by the treasury. Instead the Bank of England (2014) or Bundesbank (2017) maintain that modern currency supply is organized by crediting private banks' accounts held at the central bank. This endogenous theory of a credit currency which is present in several macroeconomic models and textbooks is still not applied issues such as seigniorage or the theory of optimal inflation. Criticizing central banks for their inflation targets and hence their pursued interest targets are judged with reference to risk free rates. However, central banks maintain their target rates by means of credit. Lending currency involves risk of default and consequently targeted refinancing rates cannot be criticized directly by reference to risk free rates. In other words, criticising central bank targets on the basis of the Friedman rule assumes that lending by central banks is risk free. It will be shown in the next section that taking the actual currency supply mechanism into account changes the optimal inflation as suggested by economic theory in a way which renders the theoretical result much closer to economic reality.

2 Optimal inflation and modern central banking

In a credit currency framework the responsible authority, usually a public central bank, determines interest rates at which the currency can be borrowed, and maintains these rates by accommodating the corresponding demand. An increasing number of economists have put forward analyses assuming a refinancing central bank. There are early contributors, like Wicksell (1898 or 1922), Keynes in his Treatise (1930 [1971]), Hahn (1930), Hawtrey (1962), Davidson (1972), Black (1987), or Moore (1991). Recently many more contributions around this topic have been made. A (not always homogeneous) shift in assumptions, or simply the assumption of a credit currency can be found in the work of New Keynesians (Woodford 2003), Post-Keynesians (Arestis and Sawyer 2008, Lavoie and Godley 2012), other economists (see Binswanger 2013, Gebauer 2004, Nautz 2000), and Central Banks (Bank of Canada 2010, Bundesbank 2010, European Central Bank 2011, Bank of England 2014, and Bundesbank 2017). Surprisingly, these authors either omit the issue of seigniorage and so provide no analysis of it, or revert to the standard assumption of a fiat currency. Hence, regarding optimal seigniorage and optimal inflation there is no shift in perception. The gap between economic theory and central bank policy – it will be argued – is due to the fact that this theoretical shift has not yet been completely digested by economists.

This is surprising in so far as empirical research of the money supply and its revenue already suggested that the actual monetary system has progressed to a credit currency regime. The most valuable empirical contribution to the changed institutional framework was provided during the introductory phase of the Euro. A small group of German authors resurrected the issue of seigniorage in connection with the creation of the European Monetary Union (see Gros 1989, 1990, 1996, 1998, Klopfleisch 2000, Lange 1995, p. 25, Neumann 1992 and 1996, Rosl 2002, pp. 37-42, Sinn and Feist 2000, Wesche and Weidmann 1995, p. 27). Trying to estimate the gains and losses from seigniorage for the individual national states these authors note that the traditional approach of a fiat currency is inappropriate to the modern institutional framework. Instead of dropping the assumption of a fiat currency right away they assume that seigniorage is earned as a mix of the revenue from printing and spending currency and in form of printing and spending it on private interest bearing assets by a central bank, thus interest payments to the central bank. The institutional perspective and the issue of the optimal rate of inflation is of minor interest to the pursued empirical estimations by the above authors. As these authors therefore do not question the institutional framework the approach was initially labelled *extended* monetary seigniorage (Neumann 1992) and later *total* seigniorage (Neumann 1996, p. 107). From an institutional perspective, the recognition of the seigniorage revenue from interest payments to the central bank is however the first important step into the direction of acknowledging an institutional change.

In a credit currency regime seigniorage stems from interest payments made by those demanding credit currency from the monetary authority. The monetary authorities supplying the currency receive the monetary seigniorage and, after allowing for certain costs, transfer the net revenue, the fiscal seigniorage, to the government (the treasury).

For a credit currency, the supply of currency depends on the interest rates which the central bank both wishes to sustain, and is able to. Usually a central bank distinguishes a main (i_B^{CB}) and a marginal refinancing rate (i_B^{CB-}) and a deposit facility (i_B^{CB+}) for balances beyond the minimum reserves.

The marginal refinancing rate is usually a mark-up on the main refinancing rate. At this rate central banks provide in principle unlimited amounts of currency (against security). For simplicity, the main and marginal refinancing rate may be referred to as “the central bank rate”. Positive balances on central banks’ accounts are usually paid a deposit rate close to the main refinancing rate for balances due to minimum reserve requirements. The central bank deposit rate constitutes the lower and the central bank lending rate the upper bound of the currency or money rate of interest (i_B). Depending on central bank policy and alternative currency supplies, the currency rate of interest may vary between these rates. If there is no alternative currency supply the currency rate of interest will be close to the central bank's main refinancing rate. Hence, by controlling the central bank rate and the deposit rate the central bank may more or less precisely determine the currency rate of interest. Put the other way around and slightly simplified, the supply of credit currency follows endogenously from the currency rate target pursued by the central bank (Bundesbank 2017).

With respect to seigniorage and optimal inflation the main difference between a printing-and-spending fiat currency on the one hand and a lending-against-interest credit currency is the risk of default. Lending the currency and demanding interest for this loan involves the risk that the borrower defaults during this time. The difference is obvious with respect to seigniorage. For a fiat currency the seigniorage is completely and finally realized in the moment of issuance. Paying by means of printing and spending makes the government realize the seigniorage revenue completely in the moment of issuance. Lending a credit currency means to realize seigniorage partially, i.e. over time as interest payments while lending the whole amount. Hence, while the seigniorage revenue from fiat currency cannot be negative this is possible for a credit currency (see Reich 2017).

In other words, what is usually overlooked is that the supply of credit currency involves a default risk, the risk of bankruptcy. In another context Stiglitz and Greenwald highlight that the probability of bankruptcy is an often omitted variable. Reflecting on macroeconomics as taught before the publication of their book they note:

> "There was a single, crucial variable that was omitted from the analysis: the probability of bankruptcy, the variable which we have argued, is at the center of all monetary analysis. If everyone always repaid their loans, then there would be little role for financial institutions. Credit would be a trivial matter. It was understandable, perhaps, for economists who had been trained in macro-economics a quarter of a century ago to have failed to pay attention to that variable. Even today, the term 'bankruptcy' does not appear in the indices of most macro-economics textbooks. Yet, for policy makers the mistake is unforgivable" (Stiglitz and Greenwald 2003, p. 265).

This applies also to the theory of seigniorage (see Reich 2017) and optimal inflation as will be shown.

The lending operations of every bank are connected to risks, in particular default risk. That is the risk that a borrower goes bankrupt. Whatever the quality of the securities, every private bank demands interest, partly to cover the risks incurred, and partly to cover other costs. The same is true for central banks and central bank rates. Central banks face the risk that their debtors will default, and hence they may be confronted with losses from their credit currency supply (Φ_B^K). Indeed, central banks demand good security. However, only the loss given default, not the risk of default, can be reduced by the central bank demanding good security prior to issuing currency. As a result, the risk of default and the loss given default, that is expected losses, have to be taken into account in the calculation of optimal seigniorage and optimal inflation.

Friedman argued that the nominal interest rate should be zero, assuming that this rate is risk free. To transfer the Friedman to a credit currency requires some adjustment. One may, for reasons of comparison, decompose the interest rate charged by central banks into a risk free interest rate and a risk component. Following the Friedman rule the risk free component should be zero. The risk component however needs to cover expected losses.[8]

If the expected loss on a unit of currency is constant over all issued currency units, then the first derivative of the "risk function", i.e. marginal risk, is a constant:

$$\frac{d\Phi_B^K(B_K)}{dB_K} = \Phi_B^{K\prime}(B_K) = \varphi_{B_K}. \tag{4}$$

This assumes that expected losses do not depend on the size of the stock of issued currency. In a simplified example, where the central bank lends a certain sum to the public with an expected loss of 1 % per unit of currency per annum of credit granted, then the central bank would be required to demand a central bank rate of at least 1 %. If the central bank demands a lower rate it will, on average, run a deficit and hence push the risk free rate below zero. The optimal interest rate target has to be such that it permits to cover expected losses (and the cost of production and maintenance if not neglected). The same applies to the optimal rate of inflation. As a result, equation (1) becomes:

$$i_B^{K*} = \varphi_{B_K} \tag{5}$$

Following the simple Fisher equation the optimal rate of inflation hence becomes:

$$\varphi_{B_K} = \pi_B^{K*} + \hat{\imath}_B \tag{6}$$

$$\text{or } \pi_B^{K*} = \varphi_{B_K} - \hat{\imath}_B.$$

As a result, Friedman's claim of a zero interest rate does not apply for a credit currency, even if cost of production and maintenance costs are neglected. The central bank rate charged has to cover expected losses. The cost-optimal seigniorage rule has therefore to be adapted for a credit currency even if other costs are – as suggested by Friedman – neglected. For the credit currency optimality requires a central bank rate (i_B^{K*}) to exceed the optimal rate for a fiat currency as suggested by the Friedman rule (i_B^{F*}) by a mark-up to cover expected losses:

$$i_B^{K*} = i_B^{F*} + \varphi_{B_K}. \tag{7}$$

Similarly the optimal rate of inflation for a credit currency exceeds the optimal inflation for a fiat currency regime by the allowance for expected losses.

$$\pi_B^{K*} = \pi_B^{F*} + \varphi_{B_K}. \tag{8}$$

Hence, even if all other costs are neglected a positive central bank rate target can be required for a credit currency if expected losses are positive. Depending on expected losses and the real interest rate, a positive inflation target can be justified according to equation (10) if expected losses exceed the real interest rate or according the Cambridge equation the growth rate. In general it may be said

8 Expected losses are the product of the probability of default and the loss given default.

that, with a credit currency, the targeted rate of inflation and the currency rate of interest have to be higher than in a fiat currency in order to cover expected losses from the supply of credit currency.

The simple model for a fiat currency of section (2) can easily be adapted to a credit currency. Currency demand is assumed to remain the same, as given in equation (5). The supply of currency is however not exogenously determined by the discrete choice of the government but by the actual demand at a given currency rate of interest. The supply is therefore expressed as a function depending on the interest rate.

The central bank determines its targeted currency rate of interest and supplies the currency necessary to defend this rate. Assuming that it is capable of achieving this rate the currency rate of interest enters directly into the supply function.

In the simplest case the supply function is a horizontal, depending on the currency rate of interest:

$$B^S = B_K^S(i_B). \tag{9}$$

In a slightly more complex version the deposit and marginal lending facility can be added, still assuming that the central bank's main refinancing rate is equal to currency rate of interest. This yields a "z" shaped supply curve.

$$B^S = B_K^S\left(i_B^{\mathrm{CB}+}, i_B^{CB}, i_B^{\mathrm{CB}-}\right) \tag{10}$$

If the central bank aims at the optimal rate of inflation as determined in section (3) it sets the main, deposit and marginal lending rates such that the currency rate of interest is equal to the percentage of expected losses as stated in equation (11) and such that the rate of inflation is equal to the difference between expected losses and the real interest rate. This applies in both cases, the very simple (13) and the simple supply function (14). The optimal supply is therefore:

$$B^{S*} = B_K^{S*}(i_B^{K*}) = k_B^Q(\mathrm{i}_B^{K*})\, Y. \tag{11}$$

The following figure (3) pictures an endogenous credit currency supply. The dotted line shows a change in the supply due to a rise in expected losses per unit of currency.

Figure 3: Optimal credit currency supply

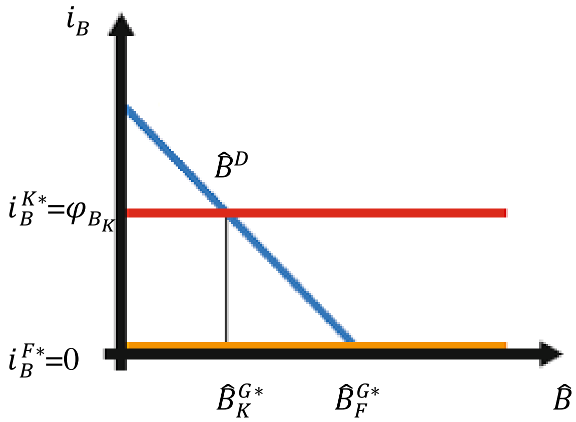


Illustration based on this research

The optimal currency rate of interest and the optimal rate of inflation depend on expected losses per unit of currency lent. Depending on estimates of these losses the optimal currency rate and the optimal inflation rate for a credit currency exceed the rates for a fiat currency. Any judgement on central banks' targets hence crucially depends on the underlying assumptions regarding the currency supply. The perceived gap between central banks inflation targets and optimal inflation for a fiat currency are due to the fact that currency is supplied by means of credit. Hence the assumption of a fiat currency is not applicable and as a result the respective interest and inflation optima for a fiat currency do not apply to the supply of credit currency of modern central banks. The perceived gap is therefore rather due to an outstanding update on economic assumptions regarding the supply of currency. The gap should disappear or decrease substantially if expected losses are taken into account. The next section corrects actual inflation targets by a rough estimate of expected losses.

3 Loss corrected inflation targets

The purpose of this section is to correct the perceived difference between actual inflation targets and optimal inflation target. To repeat, according to the Friedman rule inflation should be equal to the negative real interest rate for a fiat currency or at least be zero if further effects are considered. It was shown above that inflation targets are on average 4,4 percentage points above an optimum of zero or 7 percentage points above real interest rates.

Section 1 demonstrated that expected losses are not part of this consideration. And it was shown in section 3 that expected losses should be considered for currency which is supplied by means of granting credit. The purpose of this section is to provide an estimate of expected losses, to revise theoretical optima, and to compare these to central banks' inflation targets.

The approach taken here is to estimate expected losses for central banks by the respective countries' government bond risk. Central banks accept national government bonds as security or deal in government securities. Hence their operations depend either way on the solvency of their respective central government. And therefore the expected loss of a central bank will be estimated by the expected loss on respective government bonds. This, it is argued, applies in both cases where central banks issue currency by means of buying such securities or by means of granting credit to private companies (i.e. banks) against government bonds as security.

This raises the problem of estimating the expected loss from government bonds. For purposes of simplicity the expected losses on government bonds are inferred from the average country rating of Moody's, S&P, and Fitch. Average country ratings are then translated into Basel weights. Ratings are classified in groups of different risk weights according to Basel rules. These risk weights here are used to roughly estimate expected losses. Countries with an average A+ to A- rating are attributed a 20% weight. Against such collateral 20%*8% of equity have to be held. This is interpreted such that on average 20%*8% might be lost by holding this asset; hence an expected loss of 1,6%. This yields the respective expected loss per unit of currency (φ) lent by a central bank (see Table 3).

Table 3: Country rating, respective risk weight and loss estimate

Country Rating	Basel risk weight	φ(B)
AAA to AA-	0%	0,00%
A+ to A-	20%	1,60%
BBB+ to BBB-	50%	4,00%
BB+ to B-	100%	8,00%
below B-	150%	12,00%
without rating	100%	8,00%
Reference: http://countryeconomy.com/ratings		

This is admittedly a very rough estimate of expected losses. If it is taken into account the former results change. Correcting inflation targets yields a considerably lower gap as usually perceived. This applies for the zero target as well as for the real interest rate target.

Inflation targets (π_{CB}^*) are compared first to the zero target and a zero target corrected for expected losses. The difference between targets and optima is given by the nominal target itself and the difference to the corrected target by the difference between inflation targets ($\Delta ZERO - TARGET = \pi_{CB}^*$)and expected losses ($\Delta Phi - TARGET = \pi_{CB}^* - \varphi_{B_K}$). The difference between targets and optima with respect to real interest rates is given by the difference between negative real interest rates and central bank targets ($\Delta \mathrm{R} - \mathrm{TARGET} = \hat{\imath}_B + \pi_{CB}^*$) and for corrected optima by the difference between negative real interest rates, inflation targets and expected losses ($\Delta R - Phi - TARGET = \hat{\imath}_B + \pi^*_{CB} - \varphi_{B_K}$).

Taking the risk of government bonds into account changes the result dramatically. On average the target rate minus expected losses is negative. Hence, deducting expected losses inflation due not ensure a positive return on the supply of currency. The average difference between optima and target rates changes from 4,4 percentage points to (on average) minus 1,2 percentage points. Individual rates as compared to expected losses are much more heterogeneous. Nominal target rates varied between 2% and 14,2%. Correcting for expected losses yields corrected targets between -9% and 6,5%. To avoid a netting of positive and negative deviations the average of absolute differences can be estimated. In this case the average difference changes from former 4,4 percentage points to 2,8 percentage points.

Figure 4 Difference between inflation targets and zero and corrected optima

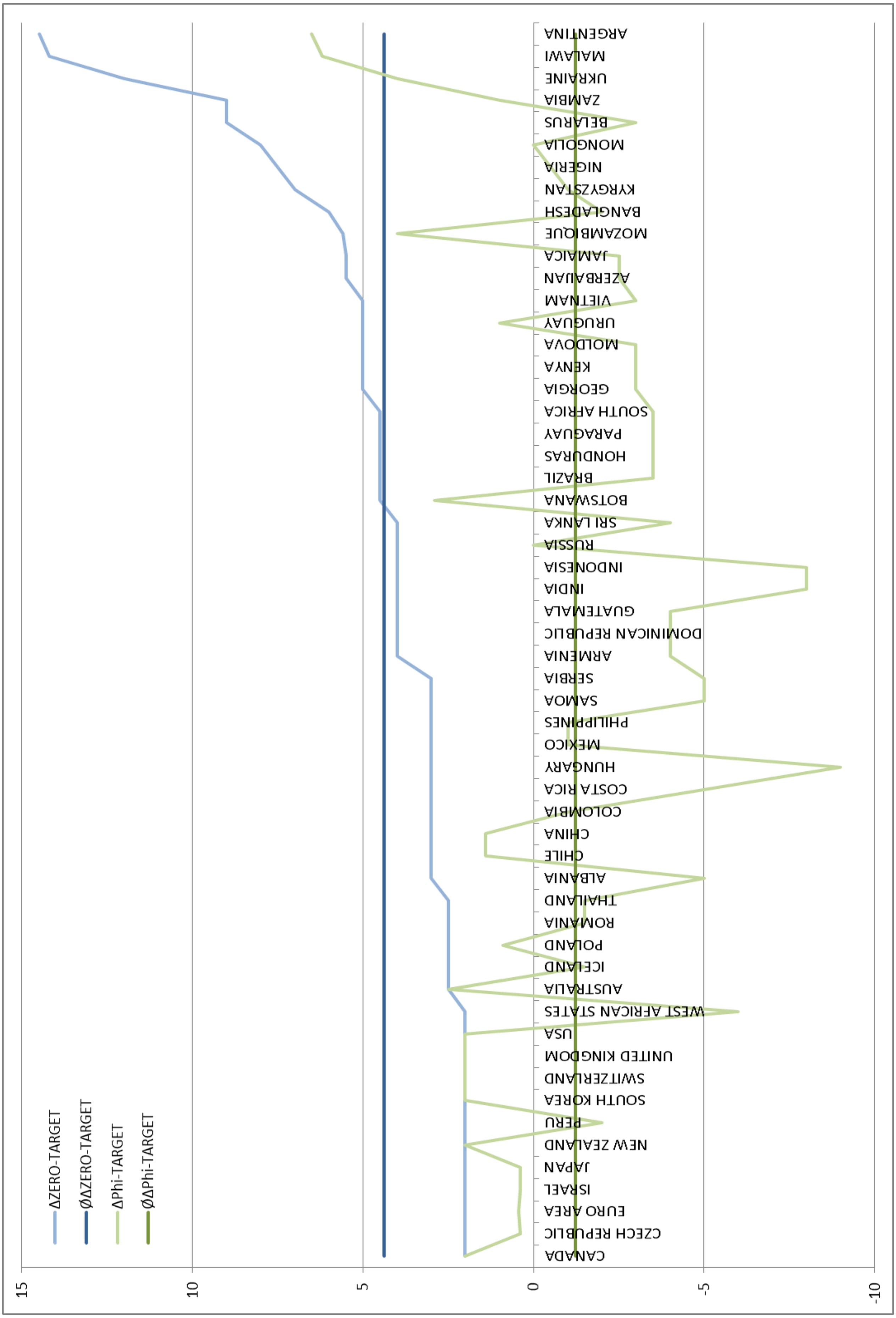
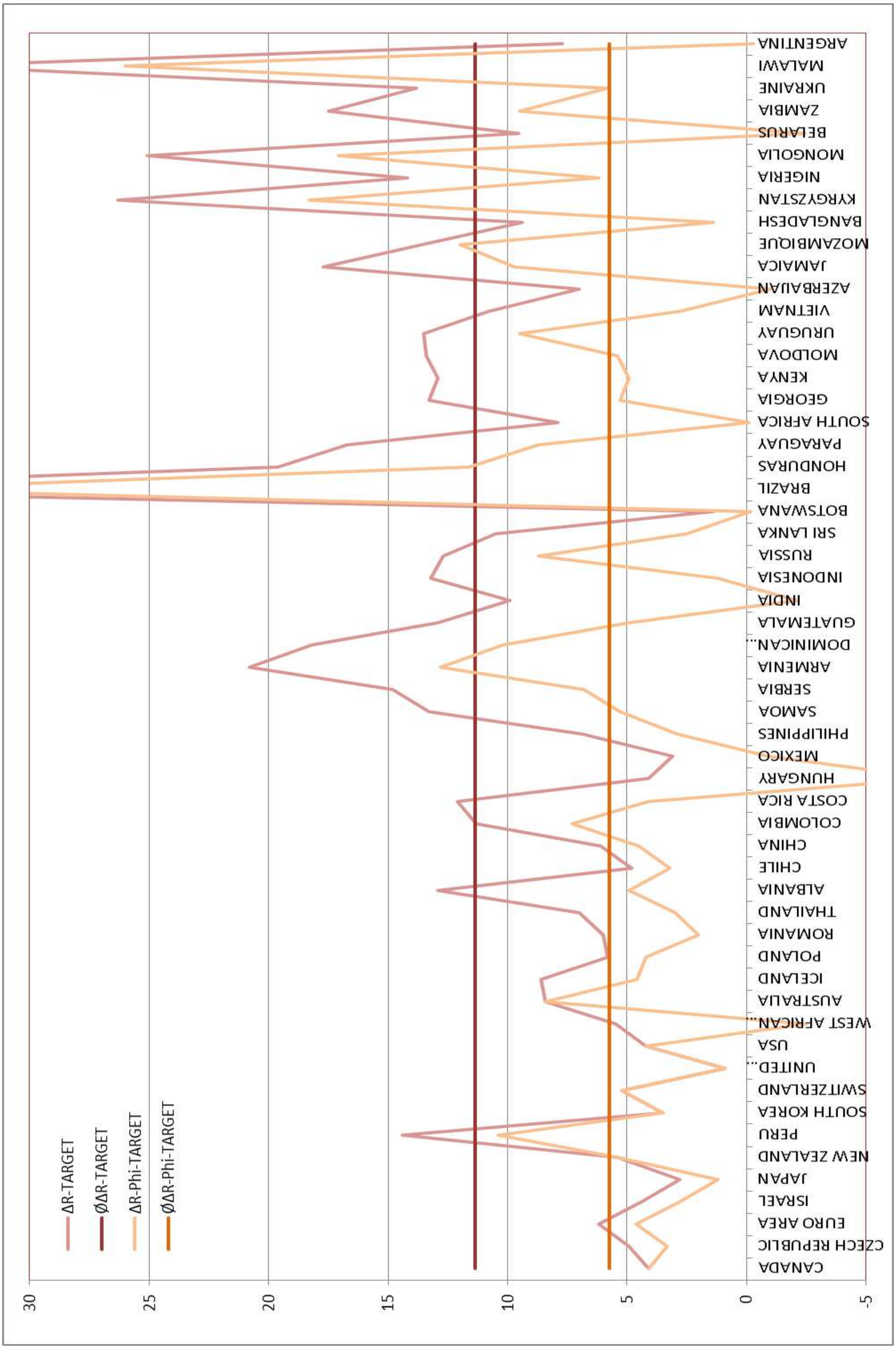


Figure 5 Difference between inflation targets and real interest rates and corrected optima



The picture is different if real interest rates are taken as optima. Central bank targets differed on average 11,3 percentage points from real interest rates. Taking expected losses into account yields corrected optima from which inflation targets differ on average by only 5,7 percentage points. Furthermore there is almost no undershooting. The average of absolute differences is 6,3 percentage points. That means the average difference is lower due to individually lower differences between corrected optima and target rates, not because of a netting between positive and negative deviations from optima.

In other words, taking expected losses into account shrinks the perceived gap between central banks' targeted inflation rates and those rates suggested by economic theory. In comparison to the zero target the average difference shrinks to 63%. In comparison to the real interest rate target the average difference shrinks to 55,7%.

4 Externalities of a non-optimal inflation and interest rate policy

From the standpoint of the original Friedman rule the question is: why do central banks in practice target such high inflation rates. Once risks are taken into consideration a revised Friedman-rule needs to be derived which fits much better to central banks pursue inflation targets. The subsequent question is: what are the economic effects if central banks actually apply the original Friedman-rule and hence demand to low interest rates and target too low inflation rates.

Following the revised Friedman-rule, central banks should target refinancing rates and accordingly inflation rates which suffice to cover expected losses from lending operations. If the nominal rate charged covers expected losses the risk free rate is pushed to zero. If the central bank has a good estimate of expected losses and hence a sound estimate of the optimal refinancing rates and hence the optimal rate of inflation it avoids – on average – losses from its lending operations. The same logic applies to asset purchases. Asset should be purchased only if the return covers expected losses on the asset class. Otherwise the charged bank rate is either too high or too low. To estimate expected losses the probability of default of the borrower, the expected loss given a default, and the value of the security which was received as collateral have to be considered.

Friedman was worried that interest rates would be set to high such that general welfare losses occur due to a low supply of money. In case the interest rate was too high, Friedman argued, the demanded quantity of money would be too low from a welfare theoretical perspective. He did not consider the possibility of negative interest rates, as they can occur in a risky world and zero nominal rates. Therefore, Friedman did not consider the welfare theoretical effects of interest rates that are too low. Hence, the welfare theoretical impact of a central bank which targets an interest rate below its optimum, i.e. the rate necessary to cover expected losses, is not answered or even discussed in his works.

From a seigniorage perspective losses to the central bank have a straight forward interpretation. Issuing currency against assets which are later written off or granting credit which is not repaid reduces a central bank's return. In case of aggregate losses defaults have direct effects on central banks' equity. This is mitigated by the security underlying the initial credit. However, losses can be incurred and this reduces annual revenues. Losses may even push a central bank's annual return and consequently even its equity below zero. The losses or the negative equity indicate the distribution of the seigniorage revenue among market participants. [9]

To analyse the welfare effects of non-optimal inflation targets a small model will be introduced. Following the standard approach it is assumed that the demand for currency B^D can be expressed as:

$$B^D = k_B^Q(i_B^F)\boldsymbol{p}_B\,\boldsymbol{Y}. \tag{1}$$

Qualitatively the demand depends on the demand for legal tender, whether in the form of cash or reserves by private banks. Quantitatively the demand for currency is often derived from empirically estimated demand functions. From a theoretical point of view the demand follows the quantity equation on liquidity demand (k_B^Q) times the level of output ($\boldsymbol{p}_B\mathbf{Y}$).[10] In real terms, the demand for real currency ($\hat{B}^D$), i.e. divided by prices, one gets:

$$\hat{B}^D = \boldsymbol{p}_B^{-1}B^D = k_B^Q(i_B^F)\,\boldsymbol{Y}. \tag{2}$$

In Friedman's original contribution, the supply of currency (B^S) is determined by the discrete choice of the central government, as the government chooses to print and spend a certain amount of currency (B_F^G) and thereby determines the supply of fiat currency (B_F^S). The real currency supply hence depends on the amount of government purchases financed by means of the printing press ($\boldsymbol{p}_B\boldsymbol{A}_G^M$) (see Reich 2018 Chapter 2). If however a central bank supplies currency by means of lending, the supply of credit currency depends on the targeted interest rate ($i_B^K = i_B$). The supply of currency follows the central bank's choice on this rate and currency supply follows this rate:

$$B^S = B_K^S(i_B). \tag{3}$$

The effective supply of currency depends on the demand for currency. Combining the supply

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[9] Despite the effect that defaults may have on a central banks seigniorage, they have furthermore an effect on the currency structure. The currency may be supplied by means of lending, i.e. credit currency, or by means of printing/minting and spending, i.e. fiat currency. The currency structure is the composition of currency from its components of fiat and credit currency. Defaults on issued credit currency present a supply of non-borrowed reserves to the economy. If currency is borrowed, spent by the borrower, and the debt becomes irredeemable, then the economy is supplied with non-borrowed currency to the extent of the central bank's losses. The supply of credit currency to defaulting borrowers or worthless assets constitutes in effect a supply of fiat currency, i.e. non-borrowed currency, and hence changes the currency structure. If the central bank does not or cannot absorb the fiat currency supplied from defaults it may lose control over the currency rate of interest. In other words, non-borrowed currency starts dominating the system. An analysis of the currency structure deserves a separate treatment, due to its neglect in the literature.

10 Referring to real currency demand is tricky. $\boldsymbol{p}_B^{-1}$ is usually referred to as the level of prices. That means it is the price of currency p_B in terms of the vector of all prices $\mathbf{p}$, or inversely, the level of prices in terms of currency. Except for a one good world, the level of prices is therefore a vector of prices or a certain aggregated index.

equation as stated in equation (3) and the demand function as stated in equation (2), the real supply of currency becomes:

$$\hat{B}^S = \hat{B}_K^S(i_B) = k_B^Q(\mathrm{i}_B)\,\boldsymbol{Y}. \tag{4}$$

The effective quantity of money depends on the central bank's target. If the central bank ignores risks and sticks to the Friedman-rule it sets its bank rate such that the nominal rate of interest becomes zero ($i_B = i_B^{F*} = 0$). The resulting stock of money ($\hat{B}_F^G$) is optimal for a fiat currency regime. If however the central bank follows the revised Friedman-rule it targets a rate according to the revised Friedman-rule ($i_B = i_B^{F*}$). Hence it sets its nominal interest rate such that the risk free rate becomes zero. The optimal supply of credit currency ($\hat{B}_K^{G*}$) follows the demand for currency at the optimal currency rate of interest and is lower than the optimal supply of fiat currency. Any judgement on central banks' targets hence crucially depends on the underlying assumptions regarding the currency supply and in particular expected losses. In general it may be said that, with a credit currency, the targeted rate of inflation and the currency rate of interest have to be higher than in a fiat currency in order to cover expected losses from the supply of credit currency.

Figure (2) pictures the simple case of a perfectly endogenous credit currency supply function in which the supply is drawn as simply horizontals, depending on the currency rate of interest. The negatively sloped curve is the demand curve according to equation (2). The upper (red) curve resembles the optimal supply function of credit currency, following the revised Friedman rule. The central bank targets a currency rate of interest such that expected losses are covered (i_B^{K*}). The lower (orange) curve represents the optimal supply of credit currency, according to the original Friedman rule, i.e. the Friedman rule for a fiat currency (i_B^{F*}).

Figure 2: Optimal credit currency supply

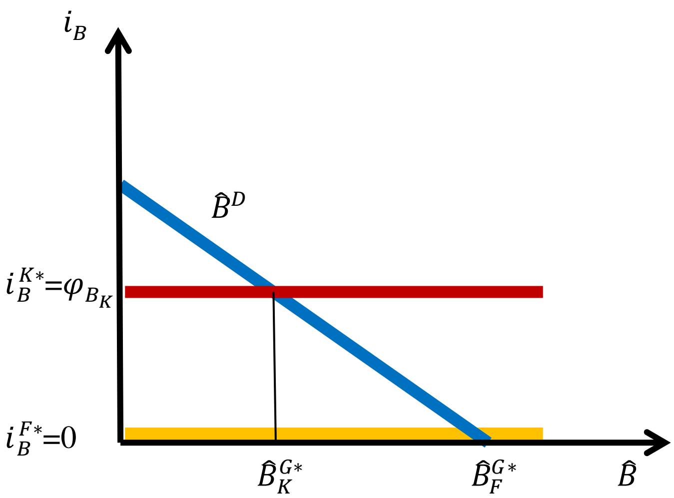

Illustration based on this research

Central banks stressed recently that they supply currency by means of lending and setting and controlling interest rates (see Bank of England 2014 or Bundesbank 2017). Hence, it should be clear that the assumption of a fiat currency is not applicable to modern central banks. Neither do they make use of the printing press nor do they operate in a risk free world. But what if central banks stick to the original Friedman-rule even though they supply credit currency?

If central banks pursue a low interest rate according to the Friedman rule ($i_B = i_B^{F*}$) the interest rate will be below its optimum ($i_B = i_B^{F*} < i_B^{K*}$) and the demand for currency will be higher than it would be, if the default risks were priced in ($\hat{B} = \hat{B}_K^{G*} < \hat{B}_F^{G*}$). In this setting the central bank will on average incur losses on its lending operations. These losses are to the benefit of its debtors. To some part this redistributes welfare from the central bank to its debtors, i.e. private banks and their customers.

The redistribution and the welfare effects of a non-optimal interest rate and inflation policy can be included in figure 2. The overall losses to the central bank are given by the volume of lending times the risk mark-up that should be imposed to cover expected losses (grey area in figure 3). This redistribution is partly a redistribution of "producer" surplus to "consumers" (lighter grey areas) and partly an overall loss of welfare (darker grey area in figure 3). It resembles a loss of consumer surplus which is not compensated for by increasing consumer surplus. The redistribution depends on how the central bank finances its losses. However, if the central bank's targeted interest rate is below its optimum (i_B^{K*}) the central bank subsidises its lending operations and its borrowers by means of other sources of revenue, whatever these may be. As a result everyone who has access to the central banks discount window has an advantage.

Figure 3: Welfare effects of non-optimal currency supply

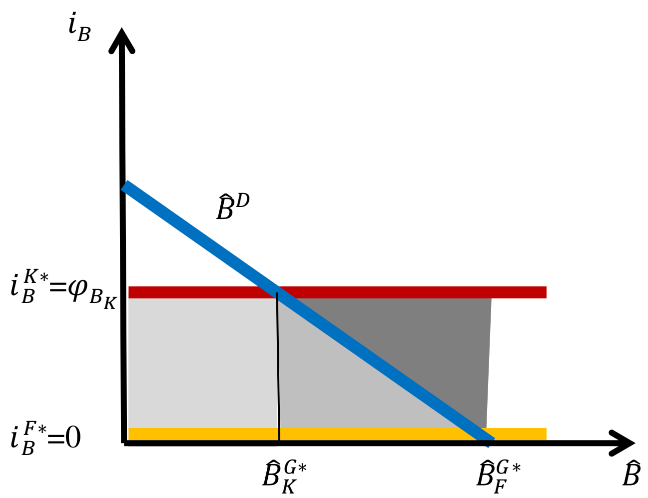

Illustration based on this research

Low refinancing rates have several effects on the economy. Refinancing rates determine the refinancing costs of banks. Hence if refinancing rates are below optimum they subsidise the central banks borrowers by lowered refinancing cost. Banks may realize these advantages and pay out higher dividends or wages. Alternatively competition might force them to pass these advantages to their customers. This may either happen by means of higher deposit rates or by lowering lending rates. By lowering refinancing cost, the central bank potentially distorts interest rates and hence interest spreads and the yield curve.

The advantage of the low rates is distributed among bank owners, bank employees, banks' borrowers or banks' debtors. The distribution of the benefits depends on the degree of competition. In any case, however, the beneficiaries of the low interest rates are most likely not those who bear the cost of the central bank losses or the lowered central bank returns. In standard economic theory such redistributions or subsidies are judged as not welfare optimal because of the distortions they create. The redistribution is judged as externalities which creates a total welfare loss.

Externalities are well known from the economic environment literature. If pollution of the environment is not paid for by producers and customers, i.e. if market prices are below the total cost of production, the community which suffers from the pollution bears cost which the originators of the pollution should initially pay for. Market prices, it is sometimes said, are below their social price, e.g. the prices (or costs) which would have to be paid if the pollution were priced in (see Feess and Seelinger 2013). In the Palgrave dictionary of external effects are defined as:

> "positive (negative) external effects in production are unpaid side effects of one producer's output or inputs on other producers. […] External economies in this modern sense imply as a rule that market prices in a competitive market economy will not reflect marginal social costs of production. Hence, a 'market failure' arises, meaning that the market economy cannot attain a state of efficiency on its own" (Bohm 2008).

These ideas can be traced back to Marshall, Pigou or Vinor. This approach to externalities can be applied to understand the welfare effect of non-optimal central bank rates. If central banks pursue the original Friedman-rule they risk pushing the risk free rate below zero. The private costs of acquiring currency by means of lending differ from the social costs.

The externality from a non-optimal inflation target differs from the one usually presented in textbooks. A standard approach to explain external effects is to refer to air pollution of cars. In the case of cars, it is argued, that drivers of cars pay for fuel but not for polluting the air. The external effect which arises in this example is a direct and continuous damage to the environment which arises while driving. The externality is visible, "proportional" to using the product, and incurs directly when driving. Such external effects shall be called d i r e c t e x t e r n a l e f f e c t s, as they are directly connected to the use of the resource (air). One can see, measure, and smell the pollution caused by every single car while it is being driven.

The external effect from non-optimal inflation targets is not directly or continuously observable. It creates a gap between risks taken and risk compensation. Until these risks materialize the burden is not obvious. Such external effects, which built up as risk until they materialize and which – until realized – appear invisible will be called i n d i r e c t e x t e r n a l e f f e c t s. Air pollution of cars does not fit as an example for indirect external effects. An example for indirect effects requires that the externality is caused by a risk. Nuclear plants may be used as such an example. Nuclear plants have to be insured against the risk of a nuclear catastrophe.

The costs of a nuclear catastrophe, thus its probability times the expected cost, have to be incorporated into the price of electricity. At this point it is abstracted from the impossibility to determine such costs precisely. The attention shall be directed to another point. Assuming the costs could be known, they could be insured by an insurance company. A company insuring the nuclear power plant would, in theory, have to charge an insurance fee which covers, in the long run, the costs connected to a nuclear catastrophe. This fee is a cost element to the producer of electricity and it will be added to the cost of production of electricity and therefore to its price. The consumers of electricity therefore pay for the private costs of producing the electricity and on top of that, at least in principle, for the additional costs which might be created in the unlikely event of a nuclear catastrophe. If the nuclear power plant would instead not be insured there would be an externality. Imagine the power plant operates without insurance. As long as there is no catastrophe, electricity will be cheaper as there is no insurance fee to be paid. The consumers of electricity and/or the owner of the plant will benefit. As long as there is no catastrophe it seems as if there would be no cost connected to the cheap supply of electricity. The cheap electricity seems like a "free lunch". Once the ground is shaken by an earthquake or tsunami, there are not enough retained funds to cover the costs of the nuclear catastrophe. The reason is that the "cost advantage" has been distributed among the consumers of electricity (or the owners of the nuclear plant). After the catastrophe the owners of the power plant cannot demand consumers to return the distributed advantages and they will not return their former dividends. They cannot rewrite or increase their bills for electricity ex post. In case of the energy companies' insolvency, the costs of the nuclear catastrophe have to be burdened on the tax payer. It is highly unlikely that those who benefited from cheap electricity will pay the cost via taxation in proportion to their consumption of electricity.

To summarize: if the insurance of nuclear power plants covers only part of the risk, e.g. because the true cost are unknown or because of regulatory caps on the necessary amount to insure, the expected losses of nuclear catastrophes are not completely born by plant owners and their customers.[11] Underinsured nuclear plants supply cheap electricity to consumers or high profits to owners. The distribution of the benefits again depends on the degree of competition. Hence, there will be an external effect causing a redistribution of welfare and reducing the social welfare in general.

In either case the external effect caused is not directly observable. With cars it is clear that those who do not drive cars share the burden of the air pollution without having the benefit of cheap car transportation. The burden shouldered by those not using cheap nuclear electricity appears invisible as long as there is no nuclear disaster. This is the biggest difference between a direct and an indirect external effect. The latter can easily be overlooked. Ignoring indirect external effects, it seems that requiring full insurance for the event of a nuclear worst case scenario only increases costs and causes disadvantages. Nonetheless, little attention is paid to the fact that by covering the external effect the true costs of nuclear electricity production are paid by those using nuclear electricity. In the tradition of welfare theory following Pigou and Ramsey, taxes should be applied to bring about external effects. There is no difference between direct and indirect external effects. It was important to Ramsey (1927) that external costs are incorporated into private prices. This should be done without altering usual patterns of consumption, an idea later taken up by Phelps (1973). Hence, with respect to direct or indirect external effects the very same logic applies. The cost should be borne by those who benefit from "consumption".

The externalities which arise due to a non-optimal inflation target and non-optimal interest rate target are indirect external effects. Interest rate targets are not optimal in the sense that they do not cover expected losses. As in the example of the nuclear plant, it seems as if there were no costs connected to the cheap supply of money. However, it is, after all, still true that "there is no free lunch". The costs of cheap money are the distributive effects of losses from a central bank's lending operations. The earnings and the charged lending rate do not cover the risk connected to the granted credit. The central bank subsidises the banking sector and/or its customers receiving cheap credit. Until the advent of the financial worst-case scenario for the economy this indirect external effect is not apparent. Risks are slowly piled up and the true costs are not realized until the risks materialize. The subsidy to the financial sector is hidden as long as there is no catastrophic incident. The exact costs are, similar as in the case of a nuclear catastrophe, difficult or even impossible to specify, ex ante and even in retrospect. The distributive effects, however, can be outlined. The losses to the central bank reduce the seigniorage payments to the ministry of finance. The subsidy to the financial sector is hence to the disadvantage of general taxpayers and recipients of public services.

[11] In Germany, for example, owners of nuclear plants benefit from a cap that limits their insurance premium in case of a nuclear worst case scenario. If the true costs exceed this cap, which is set at 500 Million €, there is an external effect.

Competition in the banking sector determines the beneficiaries of the subsidy. Low refinancing costs are a cost advantage to private banks. If competition between banks is low, the advantages can be realized by bank owners or be used to finance representative buildings. In case of high competition for bank employees the advantage might be distributed among employees in the form of high salaries. If competition between banks is high the advantage might be distributed among customers. Depositors may be exempt from deposit fees or borrowers may be granted lower lending rates.

It may be argued that central banks can make up for losses by raising interest rates above their optimum, after losses have been incurred. However, this must be inefficient. Instead of approaching the optimal interest and inflation targets the central bank would continue to deviate from both optima. Initially it supplies a quantity of money that is too large and after losses have been incurred it turns into the opposite and supplies a quantity of money that is too low. This can be avoided if central banks incorporate a mark-up for expected losses in their interest rate policy and inflation target. If they do so they establish the "first-best" solution, internalizing externalities.

This is a key difference to Pigou taxes under profit maximizing monopolies. Under profit maximizing monopolies the optimal Pigou tax (which internalizes the externality) yield only a second best solution. Profit maximizing monopolist reacts to an optimal Pigou tax by shortening their supply to maximize profits (see Fees and Seeliger 2013, p. 113). A central bank which is not profit maximizing, however, ensures the first best solution.

Independent of the precise redistribution, the beneficiaries of the subsidy and those who bear the burden are different subgroups of the society. Hence non-optimal interest rate and inflation policy creates an externality. As with examples drawn from environmental economics, a non-optimal central bank rate brings about the overuse of resources: with the case of the nuclear plant, an overuse of electricity; and in the case of the credit currency system, an overuse of central bank loans.

5 Conclusion

Economists criticize central banks for their inflation targets. In respect to economic theory the perused targets are judged as to high. Interpreting high inflation targets with high seigniorage income this suggests that central banks support the treasury and the government's budget. It was argued however that the economic theory which is used for this comparison assumes a specific currency supply mechanism. It assumes that fiat currency is issued by printing and spending on behalf of the treasury. In such a supply mechanism there is no risk. In contrast to this assumption the modern currency supply is largely organized by means of lending currency. Currency is lent to private entities, in particular banks. Banks receive the full amount of currency, but the central bank does not receive equivalent real resources. Instead it realizes its seigniorage over time by means of interest payments. Thus, while the banks may spend the full amount borrowed right away the central bank needs to await its receipts from interest payments. In the worst case the central bank acquires losses if banks cannot repay their loans. While these loans are usually secured by means of government bonds, central banks might still incur losses if a bank defaults and if the government defaults on its security. Hence there is a small risk, identified with the default risk on government bonds, that a central bank may incur losses from its currency supply.

Acknowledging the fact that currency is issued by means of lending requires revising the Friedman-rule. Instead of a nominal zero rate of interest (in a riskless environment), the revised Friedman-rule requires a nominal rate of interest such that expected losses can be covered. Hence if the interest rate is decomposed into two a risk-free component and a risk component, the revised Friedman-rule deems the interest rate as optimal if the risk-component is such that it suffices to cover expected losses. Hence after interest payments and expected losses are netted, the risk-free component of the optimal interest rate is zero. In this respect the Friedman-rule is unchanged and solely adapted to a risky environment. It was furthermore shown that the perceived gap between central bank's target rates and corrected optima is considerably smaller.

Lastly, the welfare effects of a non-optimal inflation and interest rate policy were laid out. Hence, the welfare effect of pursuing interest and inflation targets following the Friedman-rule in a risky environment are explored. In a risky environment, nominal interest targets of zero push risk free rates below zero. Such a non-optimal interest and inflation policy creates an indirect externality. In good times, borrowers, i.e. the banking system and its customers, enjoy cheap lending rates. In bad times, when defaults occur central banks have to handle losses. This may be achieved by reducing seigniorage transfers to the Ministry of Finance or even by transfers from the Ministry of Finance to the Central Bank. Changes in the interest rate policy of central banks to make up for losses by increasing interest and inflation target above optimal rates were not considered. Such measures replace one suboptimal policy by another.

It is argued that such a subsidy creates an externality, similar to those in the environment literature. The low refinancing rates in goods time and the burden to general tax payers in bad times are understood as a subsidy to the banking industry and its customers. The peculiarity of this external effect is its indirect nature. While external effects in the environment literature usually apply constantly while exploiting natural resources, the indirect external effect piles up throughout the system until risk materialize.

This result is typical for the literature on environmental economics. A net welfare gain is possible if the external effect is priced in, hence if central banks set their interest and inflation targets according to the revised Friedman-rule.

The non-optimal pricing of credit currency may even create further risks in the financial system. If the interest rate and inflation policy are not optimal according to the revised Friedman-rule the central bank and the government provide an indirect or hidden subsidy to the financial industry and its debtors. In case the overuse of credit currency leads to a general overuse of credit in the financial system, the risks from low interest rates may amplify. Credit and risk intermediation becomes risk creation. In this case the welfare effects of adopting the revised Friedman-rule are even larger than in a narrow perspective on the money market.

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