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International financial transmission of the Fed's monetary policy

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Abstract

This paper proposes a way to study the transmission mechanism of the US monetary policy to foreign yield curves. It elaborates the high-frequency identification of monetary policy shocks from (Piazzesi, 2005) in an international setting. The shocks are extracted from a two-country term structure model and the procedure is illustrated on the US-UK daily data.

Keywords: term premia, Fed, policy actions

JEL Classification: E43, E52, G12

1. Introduction

Increasingly integrated financial markets are one of the key transmission channels of international macroeconomic and monetary shocks[2]. The transmission mechanism of the US monetary policy is particularly researched, where usually a vector autoregression (VAR) - type analysis is used to enhance our understanding of how monetary policy affects equity markets[3], interest rates[4] or both[5].

Yet, as pointed out in (Cochrane and Piazzesi, 2002), the VARs may not be sufficiently flexible to accommodate the time-varying preferences of the Fed, nor able to provide a solid identification of the Fed's reaction to the interest rates from the interest-rate reactions to the Fed. Consequently, a high-frequency identification strategy from (Piazzesi, 2005), together with monetary policy shocks extracted from the state variables' residuals around policy action days, can be used to analyse the impact of the US monetary policy decisions on foreign interest rates and term premia. The Fed decisions in the sample are split into two different groups, depending on the direction of the policy rate move and whether the move

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[2] See (Canova, 2005; Cooley and Quadrini, 2001; Ehrmann and Fratzscher, 2006).

[3] See (Bernanke and Kuttner, 2005; Ehrmann and Fratzscher, 2004).

[4] See (Taylor, 1995; Evans and Marshall, 1998; Canova, 2005).

[5] See (Rigobon and Sack, 2004).

was anticipated[6]. Different "types" of policy shocks are then used to assess the reaction of foreign yield curve to different policy actions, therefore allowing for an asymmetrical response of interest rates to policy rate decisions discussed in (Bernanke and Kuttner, 2005).

The model used in the assessment is a two-country Gaussian term structure model with observable risk factors from (Joslin, Singleton and Zhu, 2011) (henceforth JSZ)[7]. Given the reduced-form nature of the model, the two economies are "connected" through the exchange rate between them. Following (Backus, Foresi and Telmer, 2001) and (Dong, 2006), both pricing kernels are defined and the implied depreciation rate is used to confirm that the model satisfies the widely acknowledged empirical finding[8], according to which high interest rate currencies tend to appreciate, oppositely to what the Uncovered Interest Rate Parity (UIRP) would suggest. (Fama, 1984) attributes such behaviour of exchange rates to the time-varying risk premium and imposes two necessary conditions, which the proposed model satisfies.

The idea of estimating the effect of US monetary policy shocks to foreign yield curves is illustrated on the UK term structure of interest rates. The two countries are close trading partners[9] and their financial markets are arguably highly integrated[10]. The US and the UK yield curves are jointly fitted and the estimated model residuals from the days of the FOMC statements are considered as monetary policy shocks in a dynamic response of the UK yields to policy rate decisions in the US. In addition, every instantaneous change in the UK yield curve is decomposed to expected future short-rate change and the term premia change.

Dynamic response of the UK yield curve to the Fed funds rate decisions is estimated to be negative, independently of weather the Fed delivered an interest rate hike or cut. The puzzling result is contrasted to the reaction of the US yields and to instantaneous changes of the UK short-rate expectations and term premia. Interestingly, both countries' yield curves seem to steepen after expansionary policy shocks, which is broadly in line with (Evans and Marshall, 1998). On the other side, instantaneous responses of the UK yields to hikes show that the medium and long-term UK yields decline, because the implicit term premia fall[11]. Finally, the average estimated reaction of the UK short- and medium term premia to

[6] Following the ideas in (Kuttner, 2001) and looking at the Fed funds futures market.

[7] The previous studies that modelled the JSZ canonical form in a multi-country setting are (Graveline and Joslin, 2011; Jotikasthira, Le and Lundblad, 2010; Bauer and de los Rios, 2011).

[8] See (Hansen and Hodrick, 1983; Fama, 1984; Cumby and Obstfeld, 1985; Hodrick, 1987; Engel, 1996; Bansal, 1997; Dong, 2006; Graveline, 2006) among others.

[9] Source: U.S. Census Bureau, Foreign Trade Statistics.

[10] See for example (Fraser and Oyefeso, 2005).

[11] This result is very much in line with (Favero and Giavazzi, 2008), who estimate a negative response of the interest rates in the Euro area to monetary policy tightening in the US. In contrast to this, (Canova, 2005) estimates that a contractionary US monetary shock induces an instantaneous increase in Latin American interest rates.

"surprise" decisions of the Fed seem to be positive and again independent of the direction of the policy rate move.

The rest of the paper is organised as follows. The next Section illustrates the dataset and explains how the Fed decisions are split. Section 3 introduces the model and the (Fama, 1984) conditions, while the estimation details could be found in Section 4. Finally, Section 5 discusses the results and Section 6 concludes.

2. Dataset

2.1 Yields

The dataset covers the period from January 1994 to the end of December 2008 and contains 3912 daily observations of the 6-month U.S. Dollar and G.B. Pound Libor rates, and plain vanilla fixed-for-floating interest rate swap rates from the two countries with maturities of 2, 3, 5, 7 and 10 years[12]. All the yields are converted to continuously compounded assuming semi-annual compounding[13]. The two curves are illustrated in Figure 1.

On the short end, the 6-month Libor rates are corrected for the consequences of the credit disruption initiated in August 2007 and lasted until the end of the sample. For this time period, I simply use the 6-month Overnight Indexed Swap (OIS) rates in two currencies plus the average OIS - Libor spread for the entire sample[14]. In such a way, the short rate in the sample reflects the average credit conditions throughout the sample and excludes the spike in the Libor rates after the Lehman Brothers bankruptcy. During the considered time period, there were indeed several other episodes with particularly tight credit conditions in both the U.S. and the U.K., most notably the "Asian crisis" in July 1997, the "Russian crisis" in August 1998 and the "Dot-com bubble" burst in early 2000. Yet, on all these occasions there was no significant divergence of the Libor rates from the respective OIS rates in the two countries, nor from the respective Treasuries securities' yields.

Regarding the mid- and longer-term maturities, the swap rates are used mainly for two reasons. First, they are often regarded as "true" constant maturity yield data[15] and thus not a subject to approximation error of bootstrapping and interpolation techniques. In addition, the swap rates imply a limited credit risk premium, as in most cases only the intermediate cash-flows are exchanged. The preliminary data inspection shows that the spread, as much

[12] The Libor rates are obtained from daily fixings by the British Bankers Association while the swap rates are indicative mid-quotes averaged across many data providers. Both series are available on Bloomberg and the fixing time for the swap rates is set to 17:00 hours New York time.

[13] See (Hull, 2008).

[14] The OIS rates are also available on Bloomberg from beginning of 2001. The average OIS - Libor spread in the U.S. case was 11 basis points, and in the U.K. case 29 basis points.

[15] See (Dai and Singleton, 2000).

as the change in the spread, between the swap rates and off-the-run treasuries (in the U.S.) and the gilts (in the U.K.) of the corresponding maturity is minor, also around the Lehman Brothers bankruptcy and the subsequent credit disruption in October 2008.

2.2 Fed policy actions

The dataset includes 125 policy meetings of the Federal Open Market Committee (FOMC) that resulted in an interest rate decision[16]. The starting policy action was an interest rate hike delivered on the 4th of February 1994. With this particular decision, the Fed started communicating the policy rate at the end of each meeting and the procedure has not been changed ever since[17]. The last decision in the sample was made on the 16th December 2008 in the midst of the recent financial crisis, when the Fed decided to cut the reference rate by 75 basis points to the target range 0 - 1/4 percent.

Out of 125 FOMC meetings, 15 decisions are identified as "surprise changes" of the Federal Funds target rate. Following (Kuttner, 2001)[18], I first construct a measure of the "surprise element" in Federal Funds target changes using the Federal Funds futures data from Chicago Mercantile Exchange. Secondly, different policy actions are characterised as expected or unexpected.

In the construction of the policy surprise indicator, the change in the Fed target rate implied by the current-month futures contract on (monthly) average Federal Funds rate is considered. For a Fed decision that took place at day *d* of the month *m*, the unexpected change in the policy rate, scaled up by the factor that takes into account the number of days in the month affected by the change is calculated as:

$$\Delta i^{unexpected} = \frac{D}{D-d}(F_{m,d} - F_{m,d-1}) \tag{1}$$

where *D* is the number of days in the current month and $F_{m,d}$ is the Fed Funds rate implied by the current-month futures contract value. If a policy decision was widely expected, the above change should be close to zero. In order to minimise the effect of month-end noise, I calculate an unscaled change for any decisions that came in place in the last 10 calendar days of any month[19]. Results are shown in Table 1 in the Appendix.

Once constructed the surprise index, a "surprise change" is considered to be any

[16] During the period, the FOMC delivered 126 policy rate decisions, out of which the interest rate cut delivered on the 8th of October 2008 was coordinated with, among others, the Bank of England (BoE). Consequently, this particular decision is excluded from the set.

[17] See (Piazzesi, 2005; Gurkaynak, Sack and Swanson, 2005). The starting date in the sample has been chosen accordingly.

[18] See also (Bernanke and Kuttner, 2005; Gurkaynak et al., 2005).

[19] Kuttner (2001) proposes 3 days for the same purpose. 10 days are chosen to bring the measure closer to what previous studies using the tick-by-tick data produced, most notably (Fleming and Piazzesi, 2005).

difference calculated in (1) that exceeds a two thirds of the usual 25 basis points move in any direction, namely under -16 and above +16 basis points. The two-thirds threshold was chosen as an arguably reasonable portion of the usual policy move, above which the move might be considered as a surprise one[20]. Out of 125 policy actions, 15 decisions are classified as "surprise moves" of the Fed.

Specifically, out of 31 decisions opting for an interest rate hike, four seem to have surprised the markets. The three of them were brought in 1994 and one was delivered on 22nd of March 2005, in a series of rate hikes lasting from June 2004 to June 2006. Two decisions are considered as unexpected holds, namely the one delivered on the 19th of March 2002 and the one on the 18th of September 2008. The remaining 9 policy actions are considered as surprise target rate cuts and are equally spaced between the dot-com crisis at the beginning of 2000's and the sub-prime crisis. Roughly half of these are delivered after an unscheduled meeting of the Fed[21]. There were overall 28 Fed decisions to cut the target rate.

To illustrate the splits, Figure 2 reports the histograms of the size of policy rate changes for single "types" of policy decisions. It shows that the moves larger than 25 basis points tend to be classified as surprise moves, especially for the interest rate cuts. Also to notice is that expansionary policy decisions seem more likely to come at a surprise and that those decisions in the sample were on average higher in magnitude than the hiking decisions. Figure 3 illustrates the distributions of the surprise indicator, again conditional on different policy actions. The magnitude of the indicator seem to be again much higher around the policy rate cuts. This might not be surprising, as the decisions to cut the policy rate are usually delivered in times of elevated uncertainty and sometimes after an unscheduled meeting[22].

Finally, a brief comment regarding the FOMC decision on the 16th of December 2008, when the policy rate reached the target range 0 - 25 basis points, is warranted. It seems that the futures market was actually "surprised" only by the magnitude of this final rate cut, where the scaled one day changed of the Fed futures was 35 basis points. Considering the size of the reserve balances of depository institutions at Federal Reserve banks at that time, the amount of monetary easing seem to have front-run the effective Federal funds rate[23]. For this reason, I do not consider this last Fed decision in the sample as a "surprise move" and re-classifying it to "anticipated" does not change the results.

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[20] Altering the threshold to 13 bp (assuming a "more-than-a-half" rule) makes the Fed funds cuts from 2nd October 2001 and 6th November 2001 become surprise cuts. Changing the cut-off around 16bp also does not alter the split significantly. The key results remain in both cases. Finally, increasing the cut-off to one entire move (25bp) would classify only few decisions as surprise.

[21] Namely, on the 15th of October 1998, 3rd of January 2001, the 18th of April 2001, the 17th of September 2001, and the 22nd of January 2008.

[22] The highest reading of the indicator of minus 68 basis points followed from the unscheduled meeting of the Federal Open Market Committee (FOMC) on the 22nd of January 2008, the details are reported in Table 1.

[23] See (Taylor, 2010).

3 Model

The following Section presents the two-country model where the home country (e.g. the United States) market prices of risk are priced into foreign bond markets (e.g. the United Kingdom). The key assumption is that the financial markets are perfectly integrated[24] and complete[25].

3.1 General Pricing Equation

Let $B_{n,t}^{F}$ be the price of an n-days-to-maturity bond denominated in foreign currency (e.g. British Pounds) at time t. The general pricing formula reads:

$$B_{n,t}^{F} = E_t \left[M_{t+1}^{F} B_{n-1,t+1}^{F} \right] \tag{2}$$

where M_{t+1}^{F} is a strictly positive stochastic discount factor (SDF), such that all traded assets in the foreign country satisfy the general pricing relation in (2). In a risk-neutral world where investors request no risk compensation, the price of the bond $B_{n,t}^{F}$ equals:

$$B_{n,t}^{F} = E_t^{Q} \left[exp(-y_{1,t}^{F}) B_{n-1,t+1}^{F} \right] \tag{3}$$

and $y_{1,t}^{F}$ is the one-period interest rate. If the bond market in the foreign country is opened to home investors, the same bond denominated in domestic currency (e.g. US Dollars) follows:

$$B_{n,t}^{F} S_t = E_t \left[M_{t+1}^{H} B_{n-1,t+1}^{F} S_{t+1} \right]$$

where S_t is the exchange rate (e.g. the amount of US dollars for one British pound) and M_{t+1}^{H} is the unique home country SDF. We can rearrange the above equation as:

$$B_{n,t}^{F} = E_t \left[M_{t+1}^{H} \frac{S_{t+1}}{S_t} B_{n-1,t+1}^{F} \right] \tag{4}$$

Intuitively, the home country risk factors, together with the adequate depreciation rate S_{t+1}/S_t, are priced in foreign bonds, as long as all the bonds and currencies can be traded. To preclude arbitrage opportunities in the international markets, the bond prices in (2) and (4) need to be equal, i.e. it must be that[26]:

[24] See (Brennan and Xia, 2006; Dong, 2006).

[25] See (Brandt and Santa-Clara, 2002) for implications of the incomplete-markets assumption.

[26] Backus et al. (2001) derive this relation under the complete market assumption. See (Brandt and Santa-Clara, 2002) for the case when markets are incomplete.

$$\frac{M_{t+1}^F}{M_{t+1}^H} = \frac{S_t}{S_{t+1}}$$

or expressed in logs:

$$\Delta s_{t+1} = m_{t+1}^H - m_{t+1}^F \tag{5}$$

The relation in (5) basically states that, if strictly positive and unique SDFs in the two countries exist and if the no-arbitrage assumption holds, the implied expected depreciation rate can be derived from the two SDFs. Exchange rate dynamics are completely driven by the factors which determine the SDFs' dynamics. Put differently, one out of three random variables, $m_{t+1}{}^H$, $m_{t+1}{}^F$ and Δs_{t+1} is redundant and can be constructed from the other two.

Following (Backus et al., 2001) and (Dong, 2006), I define the two pricing kernels and use the implied depreciation rate to perform a sort of "model consistency" check, namely weather the time-varying forward risk premium (implicit in the model-generated depreciation rate) satisfies the (Fama, 1984) conditions. Details are reported in Section A of the Appendix.

3.2 Mechanics

3.2.1 Setting

Following (Duffie and Kan, 1996) and (Graveline and Joslin, 2011), the short interest rates in two countries are affine functions of Z-dimensional risk factors X_t^H and $X_t{}^F$[27]:

$$\begin{bmatrix} y_{1,t}^H \\ y_{1,t}^F \end{bmatrix} = \begin{bmatrix} \rho_{0X}^H \\ \rho_{0X}^F \end{bmatrix} + \begin{bmatrix} \rho_{1X}^H & 0 \\ 0 & \rho_{1X}^F \end{bmatrix} \begin{bmatrix} X_t^H \\ X_t^F \end{bmatrix} \tag{6}$$

where $\rho_{0X}{}^C$, $C = \{H,F\}$ is a scalar proportional to the average long-run one-period yield, $\rho_{1X}{}^C$ is a $1 \times Z$ vector of loadings of state variables on $y_{1,t}{}^C$, and 0 is a $1 \times Z$ vector of zeros. The state variables follow an AR(1) process under the risk neutral measure Q:

$$\begin{bmatrix} X_{t+1}^H \\ X_{t+1}^F \end{bmatrix} = \begin{bmatrix} K_{0X}^{H,Q} \\ K_{0X}^{F,Q} \end{bmatrix} + \begin{bmatrix} K_{1X}^{H,Q} & 0 \\ 0 & K_{1X}^{F,Q} \end{bmatrix} \begin{bmatrix} X_t^H \\ X_t^F \end{bmatrix} + \begin{bmatrix} \Sigma_X^H & 0 \\ 0 & \Sigma_X^F \end{bmatrix} \begin{bmatrix} \varepsilon_t^{H,Q} \\ \varepsilon_t^{F,Q} \end{bmatrix} \tag{7}$$

[27] Naturaly, the ideas also apply to a model with different number of state variables in single countries. Most of the notation is taken from (Joslin et al., 2011).

where $K_{1X}^{C,Q}$ is the feedback matrix, Σ_X^C is the variance-covariance matrix of the normally distributed error term $\varepsilon_t^{C,Q} \sim N(0, 1)$. The zero restrictions in equations (6) and (7) have two important implications. First, the state variables in single countries under Q drive one-period yields in those countries only. As the short-rate is closely related to the monetary policy rate instrument, the zero restrictions on the one-period loadings intuitively imply, that the respective monetary policy makers mostly regard domestic variables of interest, when delivering a policy rate decision.

Secondly, the co-movement between the risk factors in two countries is not allowed under the Q measure. Both implications result in single countries cross-sections of yields being driven by the domestic state-variables only. An obvious disadvantage of it is that the model cannot accommodate common risk factors for the two countries yield curves[28]. Yet the zero restrictions prove to be useful in the analysis presented here, as the model assigns a minor role of the US factors in explaining the UK yields and term premia. Since one would expect that the US yields (and not the UK yields) are particularly responsive to the Fed decisions, minimising their role in the model might offer more "conservative" results in assessing the reaction of the UK yield curve to policy rate decisions in the US.

Combining the two equations and assuming joint log-normality of the stochastic discount factor and the bond prices in the general pricing equation (2), it can be shown that the n-days to maturity zero-coupon yields in the two countries are functions of the respective state variables:

$$\begin{bmatrix} y_{n,t}^H \\ y_{n,t}^F \end{bmatrix} = \begin{bmatrix} A_{n,X}^{H,Q} \\ A_{n,X}^{F,Q} \end{bmatrix} + \begin{bmatrix} B_{n,X}^{H,Q} & 0 \\ 0 & B_{n,X}^{F,Q} \end{bmatrix} \begin{bmatrix} X_t^H \\ X_t^F \end{bmatrix} \tag{8}$$

where:

$$B_{n,X}^{C,Q} = K_{1X}^{C,Q} B_{n-1,X}^{C,Q} - \rho_{1X}^C$$

$$A_{n,X}^{C,Q} = K_{0X}^{C,Q} B_{n-1,X}^{C,Q} + \frac{1}{2}(B_{n-1,X}^{C,Q})' \Sigma_X^C B_{n-1,X}^{C,Q} + A_{n-1,X}^{C,Q} - \rho_{0X}^C$$

Differently from Q dynamics, the pricing factors' under physical measure P are allowed to co-move. Once more, the state variables follow the AR(1) process:

$$\begin{bmatrix} X_{t+1}^H \\ X_{t+1}^F \end{bmatrix} = K_{0X}^P + K_{1X}^P \begin{bmatrix} X_t^H \\ X_t^F \end{bmatrix} + \Sigma_X^P \begin{bmatrix} \varepsilon_t^{H,P} \\ \varepsilon_t^{F,P} \end{bmatrix} \tag{9}$$

where the upper-left and the lower-right blocks of the matrix Σ_X^P are equal to the matrices Σ

[28] Diebold and Li (2006) for example find a strong empirical support of a common level factor in international bond markets. See also (Leippold and Wu, 2002; Dong, 2006).

$_X^H$ and Σ_X^F, respectively. Yet the off-diagonal blocks of K_{1X}^P and Σ_X^P matrices are no more zero matrices[29]. Allowing for co-movement between the pricing factors from two countries under *P* implies that the risk factors in one country affect the shape of market prices of risk[30] in the other:

$$\Lambda_t^X = \left(K_{0X}^P - \begin{bmatrix} K_{0X}^{H,Q} \\ K_{0X}^{F,Q} \end{bmatrix}\right) + \left(K_{1X}^P - \begin{bmatrix} K_{1X}^{H,Q} & 0 \\ 0 & K_{1X}^{F,Q} \end{bmatrix}\right) \begin{bmatrix} X_t^H \\ X_t^F \end{bmatrix} \tag{10}$$

As we will see in Section 3.2.3, the forward term premia in the foreign country will be consequently driven by the domestic risk factors also. Explicitly accounting for "shared risks" in international term premia is arguably in line with what previous studies have estimated[31].

Finally, the market prices of risk process in (10) can be constrained to allow for a small number of "priced" risk factors. Specifically, (Cochrane and Piazzesi, 2008) show that the level shock only is priced in yields, while (Joslin et al., 2010) argue that both level and slope factors are responsible for driving excess returns in bond yields.

3.2.2 JSZ Rotation

This section describes how the JSZ rotation is implemented in a two-country setting to obtain a canonical term structure model with *observed* yield factors. The rotation proves to be especially useful in estimation, where even standard maximum likelihood algorithms converge to the global optimum almost instantaneously[32]. Let R_t^H and R_t^F be the vectors of rotated cross sections of domestic and foreign yields Y_t^H and Y_t^F in time *t* as:

$$\begin{bmatrix} R_t^H \\ R_t^F \end{bmatrix} = \begin{bmatrix} W_{N\times N}^H & 0_{N\times N} \\ 0_{N\times N} & W_{N\times N}^F \end{bmatrix} \begin{bmatrix} Y_t^H \\ Y_t^F \end{bmatrix}$$

where *N* is the number of maturities in the term structures and $W_{N\times N}^C$, $C = \{H,F\}$ is a full-rank matrix of loadings obtained from an eigenvalue decomposition of the variance-covariance matrix of yields[33]. Assume that the first *Z* principal components explain the most of the variation in the cross-section of the yields in the domestic and the foreign country, respectively:

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[29] As in (Graveline and Joslin, 2011).

[30] See (Joslin, Priebsch and Singleton, 2010).

[31] See for instance (Sutton, 2000; Kose, Otrok and Whiteman, 2003).

[32] See JSZ and (Joslin et al., 2010).

[33] Alternatively, one could think of extracting the pricing factors from international cross-section of yields, as illustrated in (Leippold and Wu, 2002).

$$\begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} = \mathbf{W} \begin{bmatrix} Y_t^H \\ Y_t^F \end{bmatrix}$$

with:

$$\mathbf{W} = \begin{bmatrix} W_{Z\times N}^H & 0_{Z\times N} \\ 0_{Z\times N} & W_{Z\times N}^F \end{bmatrix}$$

Pre-multiply the equation (8) for the entire cross-section of yields with the rotation matrix **W**:

$$\begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} = \mathbf{W} \begin{bmatrix} A_X^{H,Q} \\ A_X^{F,Q} \end{bmatrix} + \mathbf{W} \begin{bmatrix} B_X^{H,Q} & 0 \\ 0 & B_X^{F,Q} \end{bmatrix} \begin{bmatrix} X_t^H \\ X_t^F \end{bmatrix} \tag{11}$$

and express the latent factors in terms of the observable factors and the parameters. Plugging it back into equation (8) yields the rotated measurement equation:

$$\begin{bmatrix} Y_t^H \\ Y_t^F \end{bmatrix} = A_P + B_P \begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} \tag{12}$$

where:

$$A_P = \left(\mathbf{I} - \begin{bmatrix} B_X^{H,Q} & 0 \\ 0 & B_X^{F,Q} \end{bmatrix} \left(\mathbf{W} \begin{bmatrix} B_X^{H,Q} & 0 \\ 0 & B_X^{F,Q} \end{bmatrix} \right)^{-1} \mathbf{W} \right) \begin{bmatrix} A_X^{H,Q} \\ A_X^{F,Q} \end{bmatrix}$$

and

$$B_P = \begin{bmatrix} B_X^{H,Q} & 0 \\ 0 & B_X^{F,Q} \end{bmatrix} \left(\mathbf{W} \begin{bmatrix} B_X^{H,Q} & 0 \\ 0 & B_X^{F,Q} \end{bmatrix} \right)^{-1}$$

Applying the same idea to the short rates in (6), to the state variables dynamics under the risk neutral measure (7) and under the physical measure (9) yields the JSZ canonical Gaussian dynamic term structure model:

$$\begin{bmatrix} y_{1,t}^H \\ y_{1,t}^F \end{bmatrix} = \begin{bmatrix} \rho_{0P}^H \\ \rho_{0P}^F \end{bmatrix} + \begin{bmatrix} \rho_{1P}^H & 0 \\ 0 & \rho_{1P}^F \end{bmatrix} \begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} \tag{13}$$

$$\begin{bmatrix} P_{t+1}^H \\ P_{t+1}^F \end{bmatrix} = \begin{bmatrix} K_{0P}^{H,Q} \\ K_{0P}^{F,Q} \end{bmatrix} + \begin{bmatrix} K_{1P}^{H,Q} & 0 \\ 0 & K_{1P}^{F,Q} \end{bmatrix} \begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} + \begin{bmatrix} \Sigma_P^H & 0 \\ 0 & \Sigma_P^F \end{bmatrix} \begin{bmatrix} \varepsilon_t^{H,Q} \\ \varepsilon_t^{F,Q} \end{bmatrix} \tag{14}$$

$$\begin{bmatrix} P^H_{t+1} \\ P^F_{t+1} \end{bmatrix} = K^P_{0P} + K^P_{1P} \begin{bmatrix} P^H_t \\ P^F_t \end{bmatrix} + \Sigma^P_P \begin{bmatrix} \varepsilon^{H,Q}_t \\ \varepsilon^{F,P}_t \end{bmatrix} \tag{15}$$

Given the rotation matrix **W**, the invariant transformations of the single parameters of the model are equivalent to those in a single-country setting and thus can be found in JSZ[34]. In addition, note that the dynamics under *P* is entirely driven by the parameters from the *P* distribution, i.e. $K_{0P}{}^P$ and $K_{1P}{}^P$. This is the so called "separation property" of the JSZ normalisation and it proves to be very helpful in estimation, because if the pricing factors P_t^C are observed, the $K_{1P}{}^P$ matrix can be estimated with the ordinary least squares.

Finally, the matrix $K_{1P}{}^P$ as already mentioned shapes the market prices of risk process, which in the rotated form reads:

$$\Lambda^P_t = \Lambda_{0t} + \Lambda^P_{1t} \begin{bmatrix} P^H_t \\ P^F_t \end{bmatrix} \tag{16}$$

where:

$$\Lambda^P_{0t} = \left(K^P_{0P} - \begin{bmatrix} K^{H,Q}_{0P} \\ K^{F,Q}_{0P} \end{bmatrix} \right) \text{ and } \Lambda^P_1 = \left(K^P_{1P} - \begin{bmatrix} K^{H,Q}_{1P} & 0 \\ 0 & K^{F,Q}_{1P} \end{bmatrix} \right)$$

Constraining the number of priced risks amounts to constraining the rank of the matrix $\begin{bmatrix} \Lambda^P_0 & \Lambda^P_1 \end{bmatrix}$[35]. The next section defines the likelihood function and explains how the market prices of risk can be constrained.

3.2.3 Forward Term Premia

In this section, the model-implied forward term premia are derived. The reason for focusing on this particular definition of the risk premium[36] is that most of the studies of the U.S. term premia report the forward term premia[37]. According to the expectation theory of the term structure[38], an "*n* - *m* period" forward rate *n* periods ahead is equal to the expected

[34] See Appendix B of the article.

[35] A less restrictive constraint would be to impose the number of ranks on the $\Lambda_1{}^P$ matrix alone, yet this would constrain the number of time varying market prices of risk. See (Joslin et al., 2011).

[36] The term premium or the risk premium can be equivalently defined as a yield risk premium, a forward risk premium and a return risk premium. For a detailed discussion see (Cochrane and Piazzesi, 2008).

[37] See (Kim and Wright, 2005; Cochrane and Piazzesi, 2008; Joslin et al., 2010) among others.

[38] See (Campbell and Shiller, 1991) for an insightful discussion of the expectation theory of the term structure.

future short rate plus the term premium:

$$\begin{bmatrix} fwd^H_{mn,t} \\ fwd^F_{mn,t} \end{bmatrix} = E^P_t \begin{bmatrix} y^H_{1,t+n-1} \\ y^F_{1,t+n-1} \end{bmatrix} + \begin{bmatrix} FTP^H_{1,n} \\ FTP^F_{1,n} \end{bmatrix} \tag{17}$$

where the continuously compounded $fwd^C_{mn,t}$, $C = \{H, F\}$ equals:

$$fwd^C_{mn,t} = ny^C_{n,t} - my^C_{m,t} \tag{18}$$

The corresponding expected one-period rate *n* periods in advance is:

$$\begin{aligned} & E^P_t \begin{bmatrix} y^H_{1,t+n-1} \\ y^F_{1,t+n-1} \end{bmatrix} \\ = & \begin{bmatrix} \rho^H_{0P} \\ \rho^F_{0P} \end{bmatrix} + \begin{bmatrix} \rho^H_{1P} & 0 \\ 0 & \rho^F_{1P} \end{bmatrix} E^P_t \begin{bmatrix} P^H_{t+n-1} \\ P^F_{t+n-1} \end{bmatrix} \\ = & \begin{bmatrix} \rho^H_{0P} \\ \rho^F_{0P} \end{bmatrix} + \begin{bmatrix} \rho^H_{1P} & 0 \\ 0 & \rho^F_{1P} \end{bmatrix} \left(\left(I + K^P_{1P} + ... + (K^P_{1P})^{n-1} \right) K^P_{0P} + (K^P_{1P})^{n-1} \begin{bmatrix} P^H_t \\ P^F_t \end{bmatrix} \right) \end{aligned}$$

I subtract the obtained expectation part from the forward rates to get the forward term premia. As it can be noticed, the home country risk factors do not affect the yields, but do impact the decomposition of the yields and most importantly the term premia in the foreign country[39].

4. Econometric Identification and Estimation

4.1 Parameter Identification

Solid identification of parameters is an essential part of dynamic term structure models estimation. Before defining the likelihood function and providing estimation details, this section explains the identification strategy used, which is mostly based on ideas from JSZ work.

Following (Hamilton and Wu, 2010; Calvet, Fisher and Wu, 2010; Bauer and de los Rios, 2011), the $K_{1X}^{C,Q}$ matrix, $C = \{H,F\}$ is set to be a power law structure, with zero non-diagonal elements and the following power relation on the matrix' diagonal:

$$\lambda^{C,Q}_{zz} = \lambda^{C,Q}_{11} \alpha^{C,z-1}$$

[39] Yet when the market prices of risk are constrained, the parameters in K_{1P}^P exercise some impact on the cross-section of yields as well, see the last paragraph of Section 4.2.

where $\lambda_{11}^{C,Q}$ is the largest eigenvalue of the matrix $K_{1X}^{C,Q}$, α^C is a scaling parameter controlling the distance between the eigenvalues, and finally $z = 2,...Z$. Given the pricing factors' dynamics under the risk neutral measure Q in (14), the pricing factors might not be necessarily stationary under Q, i.e. the eigenvalues of $K_{1P}^{C,Q}$ might be equal or larger than one. As noted in Joslin et al. (2011), the long-run means[40] of the one-period rates in such case are not well-defined or negative, respectively. Consequently, the authors propose the following identification tactic. The $\rho_{0P}{}^{C}$ is set to zero and the drift of the most persistent factor $P_{1,t}^{C}$ is set to be a constant:

$$K_{0X}^{C,Q} = \begin{pmatrix} k_{\infty}^{C,Q} \\ 0 \\ \vdots \\ 0 \end{pmatrix}$$

where $k_{\infty}^{C,Q}$ is a derived parameter[41]. Finally, the scale of the pricing factors $\rho_{1P}{}^{C}$ is set to be a unit vector and the $\Sigma_{P}{}^{P}$ is Cholesky-decomposed to a lower triangular matrix $L_{\Sigma P}{}^{P}$ with *2Z(2Z + 1)/2* parameters to estimate.

That said, the parameters $\lambda_{11}^{C,Q}$, α^C and the two blocks on the diagonal of $\Sigma_{P}{}^{P}$ entirely characterise the Q distribution of yields. The physical dynamics P, on the other side, is determined by the $(K_{0P}{}^{P}, K_{1P}{}^{P}, \Sigma_{P}{}^{P})$ parameter set. The complete parameters' vector is:

$$\Theta = \left\{ \lambda_{11}^{H,Q}, \lambda_{11}^{F,Q}, \alpha^H, \alpha^F, K_{0P}^{P}, K_{1P}^{P}, \Sigma_{P}^{P} \right\}$$

4.2 Estimation

Let us now define the likelihood function. Following (Chen and Scott, 1993) and JSZ, it is assumed that the first Z principal components P_t^C, $C = \{H,F\}$ are observed without error and the remaining $(N\text{-}Z)$ components $P_t^{C,u}$ are measured with error:

$$\begin{bmatrix} P_t^{H,u} \\ P_t^{F,u} \end{bmatrix} = \mathbf{W}^u A_P + \mathbf{W}^u B_P \begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} + \mathbf{\Sigma}_{\xi} \begin{bmatrix} \xi_t^H \\ \xi_t^F \end{bmatrix} \tag{19}$$

where:

$$\mathbf{W}^u = \begin{bmatrix} W_{(N-Z)\times N}^{H} & 0_{(N-Z)\times N} \\ 0_{(N-Z)\times N} & W_{(N-Z)\times N}^{F} \end{bmatrix} \text{ and } \mathbf{\Sigma}_{\xi} = \begin{bmatrix} \Sigma_{\xi}^{H} & 0_{(N-Z)\times N} \\ 0_{(N-Z)\times N} & \Sigma_{\xi}^{F} \end{bmatrix}$$

[40] The intercept term in the equation (13).

[41] Calculated in such a way that, a particular value of $k_{\infty}^{C,Q}$ corresponds to the zero vector $\rho_{0P}^{C,}$ given $K_{1P}^{C,Q}$, see the appendix of JSZ.

and the variance-covariance matrix of the pricing errors Σ_{ξ} is diagonal, while the error term is a multivariate normal $\xi_t \sim N(0, 1)$. The conditional joint density of the state vector and the P_t^u unobserved components is:

$$\begin{aligned} pdf\left(P_t^H, P_t^F, P_t^{H,u}, P_t^{F,u} | P_{t-1}^H, P_{t-1}^F, \Theta\right) &= \\ & pdf\left(P_t^H, P_t^F | P_{t-1}^H, P_{t-1}^F, K_{0P}^P, K_{1P}^P, \Sigma_P^P\right) \\ &\times \; pdf\left(P_t^{H,u} | P_t^H, \lambda_{11}^{H,Q}, \alpha^H, \Sigma_P^H\right) \\ &\times \; pdf\left(P_t^{F,u} | P_t^F, \lambda_{11}^{F,Q}, \alpha^F, \Sigma_P^F\right) \end{aligned} \tag{20}$$

The Q parameters, $\left\{\lambda_{11}^{H,Q}, \lambda_{11}^{F,Q}, \alpha^H, \alpha^F\right\}$, are estimated using the maximum likelihood (ML) estimation. In a constrained optimisation[42], a standard line-search algorithm is used where the descent direction is calculated with Quasi-Newton method. The starting values for the covariance matrix are taken from the unconstrained VAR(1) estimation of the pricing factors. Departing from randomly chosen values of parameters $\left\{\lambda_{11}^{H,Q}, \lambda_{11}^{F,Q}, \alpha^H, \alpha^F\right\}$, the algorithm converges almost instantaneously to the same solution to the 6th decimal.

The parameters of the physical distribution, $\left\{K_{0P}^P, K_{1P}^P\right\}$, are estimated using the OLS. Yet, as already mentioned in the previous section, the market prices of risk can be also constrained by reducing the rank of the matrix $\begin{bmatrix} \Lambda_{0t}^P & \Lambda_{1t}^P \end{bmatrix}$ in equation (16). In that case, the parameters of the *P* distribution are computed as if they were ML estimates in the following way. The idea is to first perform the following reduced-rank regression:

$$\begin{bmatrix} P_{t+1}^H \\ P_{t+1}^F \end{bmatrix} - \left(\begin{bmatrix} K_{0P}^{H,Q} \\ K_{0P}^{F,Q} \end{bmatrix} + \begin{bmatrix} K_{1P}^{H,Q} & 0 \\ 0 & K_{1P}^{F,Q} \end{bmatrix} \begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} \right) = \beta_0 + \beta_1 \begin{bmatrix} P_t^H \\ P_t^F \end{bmatrix} + \epsilon_t^P$$

where β_1 is restricted to have a rank lower than the number of pricing factors[43].

Given the parameters $\left\{\lambda_{11}^{H,Q}, \lambda_{11}^{F,Q}, \alpha^H, \alpha^F, \Sigma_P^P\right\}$, the ML estimates of the *P* parameters are then given by:

$$K_{0P}^P = \begin{bmatrix} K_{0P}^{H,Q} \\ K_{0P}^{F,Q} \end{bmatrix} + \widehat{\beta_0} \quad \text{and} \quad K_{1P}^P = \begin{bmatrix} K_{1P}^{H,Q} & 0 \\ 0 & K_{1P}^{F,Q} \end{bmatrix} + \widehat{\beta_1}$$

[42] Only the non-negativity constraint on the diagonal elements of the covariance matrix is imposed.

[43] As it is shown in JSZ, the solution for is singular value decomposition of β_1, namely, = $UD_r^{*V'}$, where the matrix D_r^* is obtained by setting to zero all the singular values of D with index n > r.

As it can be noticed, the ML estimates of the P parameters, when the rank of the β_1 is reduced will be no longer given by their OLS counterparts. In other words, the assumptions on the parameters from the P measure directly affect the estimates of the P and the "separation property" of the JSZ normalisation does not hold anymore. In addition, the reduced rank idea allows us to understand the nature (and the number) of priced factors in a two-country setting.

Finally, the base-case market price of risk specification in this study is considered to be the one, where the rank of the β_1 is set to 4, i.e. where "level" and "slope" risks in the two countries are priced in yields[44].

5. Results

5.1 Parameters

The estimated parameters are reported in the Table 2 together with asymptotic and bootstrapped[45] standard errors. As it can be noticed, the values of standard errors are comparable for most of the parameters[46]. The 3 × 3 matrices on the diagonal of $L_{\Sigma P}{}^{P}$ are covariance matrices of single countries' pricing factors, while the remaining parameters are covariances of state variables across the two countries. Few of the residuals seem to significantly co-move. On the other side, the estimates of the $K_{1P}{}^{P}$ matrix point to a statistically significant relation among the international pricing factors.

As expected, the UK level factor has no predictive power on the US level factor, but the US level factor in one period does explain a portion of the UK level factor in the next period. What is more, all the US factors can help explain the UK level factor, where the US curvature factor seem to have the strongest predictive power. One percentage point increase in the US curvature factor in t is on average followed by a 2.6 basis points increase in UK level factor in $t + 1$.

Finally, the lower-left non-zero block of $K_{1P}{}^{P}$ matrix allows for the US risk factors to affect the term premia in the UK. The Figure 4 illustrates the decomposition of the 10-year UK term premia to the parts driven by the UK factors and the US factors. By construction, the most of the variation in premia is produced by the UK factors, whereas the US factors capture the variation in the UK premia not contained in the shape of the UK yield curve[47].

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[44] As in (Duffee, 2010; Joslin et al., 2010).

[45] Bootstrapped standard errors are calculated as follows. A starting value for pricing factors is randomly chosen from the dataset. The estimated parameters are then used to simulate a time series of pricing factors with 3,000 observations. The parameters and the simulated path of pricing factors produce a simulated path of two yield curves. The model is estimated on such simulated paths for 1,000 times.

[46] Bigger differences between the asymptotic and the standard errors are estimated for the variance parameters of the slope and curvature factors in the two countries.

[47] Similarly to (Joslin et al., 2010).

5.2 Forward premium conditions

As discussed in the Section 3.1 and Appendix A, the two-country model needs to generate the foreign exchange risk premium in line with (Fama, 1984): it should be negatively correlated with the interest rate differential and its variance should be higher than the variance of the interest rate differential. The upper panel of the Figure 5 plots the model-implied depreciation rate, together with its two components. Most of the variation in the depreciation rate indeed comes from the variation in the foreign exchange risk premium and the standard deviations of the two are 15.13 and 16.17 percent, respectively. Nonetheless, there is a negative correlation of -.83 between the foreign exchange premium and the interest rate differential.

Finally, the lower panel of the Figure 5 plots the model-generated foreign exchange premium against the one from the data. As it can be noticed, the model explains some variation in the observed depreciation rate, where the correlation of the two series is 0.21 and the standard deviations of the modelled and the observed depreciation rates are 15.13 and 10.71 percent, respectively. A rather poor fit, yet correctly estimated moments of the single elements of model-implied depreciation rate, might be enough to confirm the validity of the two-country model.

5.3 Pricing performance

The upper panel of the Table 3 reports the mean absolute pricing errors of the single- and the two-country model. The single-country models for the UK and for the US are estimated under the full-rank $\begin{bmatrix} \Lambda_{0t}^{P} & \Lambda_{1t}^{P} \end{bmatrix}$ matrix. The two-country model, with the market price of risk matrix having the rank of 2, corresponds to the notion that only the level risks are priced in the yield curve[48]. If the matrix has the rank of 4, both level and slope risks are priced in yields[49]. As it can be noticed, the performance of the two-country model is comparable to the single-country model, whereas the two-country model marginally improves the fit of the US yield curve.

The Table 3 in the lower panel reports the means and the standard deviations of the 1-day-ahead forecasting errors of the two-country model on different policy action days and for the selected yields. The independent two-sample means t-test shows that some of the forecasting errors' means are statistically different from zero. Specifically, the yields on the short-end of the US yield curve and around the Fed funds rate cuts are systematically over-priced by 4.4 basis points. This is also the case for the longer-end of the UK yield curve and around anticipated Fed funds hikes, where the yields are on average over-priced by 2.2 basis points.

Finally, one can also notice that the magnitude and the volatility of the US forecasting errors is much higher around interest rate cuts, than around interest rate hikes. The lower

[48] As in (Cochrane and Piazzesi, 2008).

[49] Similarly to (Duffee, 2010; Joslin et al., 2010).

forecasting performance might be due to elevated macroeconomic uncertainty during the circumstances in which the decisions to cut the Fed funds rate are usually delivered. The model is thus more likely to be "wrong" around those decisions. The same pattern does not seem to hold for the UK yields.

5.4 Reactions to the Fed decisions

As already mentioned, different policy rate decisions of the Fed are classified across two dimensions and used to analyse the reaction of yields to those decisions. As there might be no particular reason to assume that yields respond symmetrically to contractionary and expansionary monetary policy shocks, the splitting should provide a sort of generalisation of policy shock notion and flexibility in estimating the response. This section reports both dynamic and instantaneous reaction of the UK yield curve to the Fed policy actions.

5.4.1 Impulse response functions

In a VAR- or term structure model analysis, general impulse response function of (Pesaran and Shin, 1998) is usually used to describe the reaction of state variables or yields to one standard deviation shock in another state variable[50]. In such a case, the dynamic reaction of yields to a monetary policy shock could be analysed by considering the one-period interest rate in the sample as the monetary policy instrument and then using it as one of the state variables[51]. In this study, the one-period US interest rate is the 6-month USD Libor. Even though the short-term Libor rates closely co-move with the Fed funds rate, the spread between the funds rate and the Libor rates might not be necessarily constant, because the latter include credit risk premium[52].

Alternatively, the idea here would be to extract the shocks from the models' residuals around policy action days. From every realisation of the state variable vector $\boldsymbol{P}_d$ on a policy action day d, its ex-ante expectation $E[\boldsymbol{P}_d \mid \boldsymbol{I}_{d-1}]$ is subtracted. The residuals obtained in this way are then grouped to classes (e.g. hikes) and used to calculate impulse response functions. The Appendix B illustrates the idea and the Figure 6 reports the average response functions of the 6-month and the 10-year yields in the two countries together with 90 percent confidence intervals.

To begin with, the UK short rate reacts negatively to both hikes and cuts of the Federal funds rate. On the other side, the sign of the US short rate response is analogous to direction of the policy rate move and both UK and US short rates react more strongly to interest rate cuts. Section 5.4.2 shows that the negative reaction of the UK short rate

[50] See for instance (Evans and Marshall, 1998; Söderlind, 2010) or (Kaminska, 2008).

[51] In the JSZ framework, this can be done by setting the element (1,1) of the rotation matrix $W_{Z\times N}$ in (11) to 1 and other elements of the first row of the matrix to 0.

[52] An insightful way of including the Fed policy rate to the model estimation is proposed in (Piazzesi, 2005), who uses the effective Fed funds rate as the state variable.

to contractionary policy shocks in the US might be explained by a fall in estimated term premia.

Moving to the longer-end of the curve, the yields reaction seem to be much lower, which is in line with (Evans and Marshall, 1998). Interestingly, the yield curves in both countries seem to shift in a parallel fashion around Fed funds rate hikes and steepen around rate cuts. The letter result is also in line with (Evans and Marshall, 1998), whereas the magnitude of the short rate reaction is estimated to be lower. Specifically, the authors estimate that a one-standard deviation monetary policy shock, corresponding to circa 50bp increase/decrease in the Federal funds rate, produces a 20 basis points rise/fall in a 1-month interest rate. The analogous estimate in this paper is approximately 7 basis points fall in the 6-month USD Libor.

Finally, it might be important to notice that the estimated state variables are substantially persistent, given that the data frequency is daily. Consequently, the reported lengths of shocks' persistence should be considered as indicative and one possible remedy would be to estimate the state variable process on monthly data and then use the extracted residuals to "shock" the system, as previously explained[53].

5.4.2 Instantaneous reactions

Table 4 reports one-day average change in the UK yields followed by different policy rate decisions of the Fed. The changes are expressed in basis points and compared with the average one-day changes on non-policy days in an independent two-sample t-test of means[54]. The values in brackets are corresponding p-values of the test statistic. As it can be noticed, there is a statistically significant decrease in the UK yields on the long-end of the curve, as an average change after anticipated decisions to hike the Fed funds rate.

This might not sound intuitive, because the "anticipated" decisions should be priced in yields. Yet, if the Fed funds futures market correctly anticipated a policy decision, it does not necessarily mean that the rates market followed suit. The decisions are classified into expected or surprise policy actions by only looking at the Fed funds futures quotes and the corresponding implicit Fed funds rate "expectation". In addition to this, (Bernanke and Kuttner, 2005) notice that asset prices need not to respond only to surprise moves of the Fed, but also to revisions in expectation about future policy, which may also result from a policy decision[55].

Why do the long-term UK yields fall after an anticipated hike of the Federal funds rate? As the Table 5 reports, the fall in yields seem to be given mostly by the decrease in the

[53] A similar idea was used in (Bauer and Rudebusch, 2011) to estimate future short-rate expectations when decomposing the US yield curve.

[54] As the fixings for the Libor rates take place around 13:00 hours London time, so before the FOMC statement is released on a given day d, the one-day changes of Libor rates are calculated by using d + 1 and d observations.

[55] Every policy rate decision is announced together with a brief communiqué on the general economic assessment, in the form of so called Federal Open Market Committee (FOMC) Statement.

term premia. If the estimated time-varying premia can be regarded as uncertainty around future short-rate expectation i.e. a "deviation" from expectation hypothesis[56], then the anticipated hike decision of the Fed seem to reduce that uncertainty. The negative reaction of the premia is almost equal in magnitude across the maturity spectrum. Since the future short-rate expectations for maturities under 5Y slightly rise[57], only the yields on the longer-end seem to be affected by the shift. The average increase of the Fed funds rate by 29bp (on 27 anticipated hike decisions) is estimated to cause on average a 2bp fall in 5 to 10Y maturities yields. Almost entire reaction is estimated to be driven by the fall in longer term premia by approximately the same amount.

If anticipated rate decisions provoke a decrease in the premia, a surprise policy actions should have an opposite effect. Indeed, the Table 5 reports statistically significant and positive 1-day change of the premia after both unexpected policy rate hikes and cuts of the Fed funds rate. There is on average a 4.5 bp increase in the premia around short- and medium term maturities after an unexpected interest rate cut. As only 4 decisions to increase the Fed funds rate are labelled as unexpected, the reaction of the premia around those days is not statistically significant. Still, the average change of the premia after all surprises are statistically different from the average change on a non-policy day. The Table 6 confirms these conclusions for the single-country model for the UK yield curve and the results do not change when the market prices of risk are constrained.

5.4.3 Robustness check: Post-2007 period

On the 9th of August 2007, the interbank markets of the United States and the euro area came under unexpected and severe strains[58], after months of falling house prices and adverse events in the US sub-prime mortgage market. The US policy-maker, concerned about the tightening of credit conditions, lowered the Federal funds rate by 50 basis points on the 18th of September 2007 and embarked on a stream of interest rate cuts. In the UK, the Bank of England started to decrease the reference rate in December 2007 and continued to do so on several occasions until the end of the sample[59].

Highly correlated policy paths during this period, together with globally deteriorating growth prospects and dire credit conditions, might be excessively driving the results presented above. For this reason, I re-estimate the two-country model on the sub-sample excluding the period from the beginning of August 2007 until the end of the sample. The estimated term-premia average changes are reported in the Table 7. As it can be noticed, the main result remains. The one-day average change in the term premia, after an anticipated

[56] See (Kim and Orphanides, 2007).

[57] Unfortunately, the changes in future short-rate expectations are not statistically significant and thus not reported.

[58] See (Borio, 2008).

[59] The bank rate was reduced on 7th of February, 10th of April, 8th of October, 6th of November and 4th of December 2008. The details about the decisions can be found here.

hike of the Federal funds rate, is statistically different from zero. Nonetheless, there seem to be an increase in premia on short- and medium-term maturities, after the surprise policy actions of the Fed.

5.4.4 Robustness check: Weighted average response

Another important check would be to control for the size heterogeneity of policy moves across and within different groups of policy actions. As we have seen in the Section 2.2, larger changes of the Fed funds rate are usually communicated after expansionary decisions. In addition, most of the surprise decisions are changes in the policy rate of more than 25 basis points, see Figure 3. Accordingly, the results might be driven by several extreme cases of substantial change in the policy rate and the subsequent reaction in the yields.

To control for such effects, I calculate a weighted average reaction of the UK premia to different policy actions in the following way. All the one-day changes are multiplied by the inverse of the corresponding policy rate move times 25 (e.g. for a 50 basis points hike, the "weight" would be 25/50). The re-scaled changes are then summed up within a group of policy actions and divided by the number of decisions in the group. The outcome is an estimated one-day average change of the term premia, as a result of *25 basis points change* in the policy rate and it is reported in Table 8. As expected, the magnitude of changes is somewhat lower, especially after the interest rate cuts. Still, the reaction of the premia to surprise policy moves is still statistically different from zero and independent of the direction of the policy move and there is a decrease in the premia at the medium and long-end of the curve as a result of anticipated hikes of the Fed funds rate.

6. Conclusion

International financial transmission of the US Federal Reserve can be studied by extracting monetary policy shocks from daily interest rate movements around the FOMC decisions. This study illustrates it by estimating a two-country term structure model on the US-UK data.

There are several ways to go from here. One could use a latent-factor framework to allow the home country risk factors to explain movements in foreign term premia. The estimated factor loadings on one-period rates could provide insight into the nature of information used by the central banks in respective countries. Furthermore, it might be interesting to explore the extent to which a highly correlated or even common level and slope factors can be connected to the convergence in medium-term inflation expectations in the two countries, or to similar business cycles or policy instruments paths.

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Appendix

A. Fama conditions

The depreciation rate generated by the two-countries model needs to be in line with the so-called "forward premium anomaly", i.e. the widely acknowledged empirical finding[60] according to which the high interest rate currencies tend to appreciate. (Fama, 1984) imposes two necessary conditions on the time-varying forward risk premium. First, it must be negatively correlated with its expected rate of depreciation. Secondly, it must have greater variance than the expected depreciation rate. The conditions are tested as follows.

First, define the log-pricing kernel from equation (5) as:

$$m_{t+1}^{C} = -y_{1,t}^{C} - \tfrac{1}{2}(\Lambda_t^C)'\Lambda_t^C - (\Lambda_t^C)'\varepsilon_{t+1} \tag{A1}$$

where $C = \{H,F\}$ and Λ_t^c is a time-varying market price of risk defined in the following sub-section. Given (5) and (A1), the *expected* depreciation rate consists of the interest rate differential in the two countries and the foreign exchange risk premium:

$$\Delta s_{t+1} = ird_t + frp_t$$

$$ird_t = y_{1,t}^{F} - y_{1,t}^{H}$$

and

$$frp_t = \frac{1}{2}\left((\Lambda_t^F)'\Lambda_t^F - (\Lambda_t^H)'\Lambda_t^H\right)$$

Under the risk neutral measure Q, the depreciation rate equals the interest rate differential:

$$\Delta s_{t+1} = y_{1,t}^{F} - y_{1,t}^{H} \tag{A2}$$

or, in other words, the uncovered interest rate parity (UIRP) should hold. To test for the "forward premium anomaly", regress the ex-post depreciation rate against the rate differential:

$$\Delta s_{t+1} = a + b(y_{1,t}^{F} - y_{1,t}^{H}) + \varepsilon_{t+1} \tag{A3}$$

[60] See (Hansen and Hodrick, 1983; Fama, 1984; Cumby and Obstfeld, 1985; Hodrick, 1987; Engel, 1996; Bansal, 1997; Dong, 2006; Graveline, 2006) among others.

where the slope coefficient of the regression is broadly found to be negative, instead of being 1, as the UIRP would suggest. According to (Fama,1984), the deviations from the UIRP can be expressed as two conditions on the forward premium anomaly. First, there is a negative correlation between the forward risk premium and the interest rate differential:

$$\begin{aligned} b &= \frac{cov\left(\Delta s_{t+1}, ird_t\right)}{var(ird_t)} \\ &=> \quad cov(frp_t, ird_t) + var(ird_t) < 0 \\ &\qquad\qquad - \qquad\qquad + \end{aligned} \tag{A4}$$

and, secondly, the variance of the foreign exchange risk premium should be higher than the variance of the interest rate differential. Specifically, (Fama, 1984) performs the two following regressions:

$$F_t - S_{t+1} = a1 + b1(F_t - S_t) + \varepsilon_{1,t+1}$$

and

$$S_{t+1} - S_t = a2 + b2(F_t - S_t) + \varepsilon_{1,t+1}$$

where F_t and S_t are the forward- and the spot exchange rate, respectively. He estimates the distance between the coefficients $b1$ and $b2$:

$$b1 - b2 = \frac{var(frp_t) - var(E[S_{t+1} - S_t])}{var(F_t - S_t)}$$

to be positive for all the considered currency pairs, from where he concludes that the *var*(*frp*$_t$) is larger than *var*(*E*(S_{t+1} -S_t)). Consequently, it follows that *var*(*frp*$_t$) is larger than *var*(*ird*$_t$) as well[61]. In other words, most of the variation in the depreciation rate should come from variation in the foreign exchange risk premium. As it is shown in the Section Results, the model satisfies both conditions.

[61] See (Fama, 1984) for details.

B. Impulse response functions

Let us re-write the transition equation (15) as:

$$\mathbf{P}_d = E\left[\mathbf{P}_d | I_{d-1}\right] + \Sigma_P^P \begin{bmatrix} \varepsilon_d^{H,P} \\ \varepsilon_d^{F,P} \end{bmatrix} \tag{A5}$$

where d is the day of a Fed decision, I_{d-1} is the information set in d - 1 and:

$$\mathbf{P}_d = \begin{bmatrix} P_d^H \\ P_d^F \end{bmatrix}$$

$$E\left[\mathbf{P}_d | I_{d-1}\right] = K_{0P}^P + K_{1P}^P \begin{bmatrix} P_{d-1}^H \\ P_{d-1}^F \end{bmatrix}$$

Iterating (A5) forward, it can be shown that:

$$\mathbf{P}_{d+n} - E\left[\mathbf{P}_{d+n} | I_{d-1}\right] = \left(K_{1P}^P\right)^{n-1} \Sigma_P^P \begin{bmatrix} \varepsilon_d^{H,P} \\ \varepsilon_d^{F,P} \end{bmatrix} \tag{A6}$$

Pre-multiplying the right-hand side of the above equation with the factor loadings matrix B_P gets the impulse response function of single yields to the shock $\boldsymbol{P}_d$ - $E[\boldsymbol{P}_d \mid \boldsymbol{I}_{d-1}]$. For every class of the Fed decisions (e.g. surprise cuts), an average value of residuals is calculated:

$$\frac{1}{N_d} \sum_{n_d=1}^{N_d} \left(\mathbf{P}_d^{(n_d)} - E\left[\mathbf{P}_d^{(n_d)} | I_{d-1}\right]\right)$$

and used to calculate the average impulse response function. N_d is the number of certain decisions (e.g. there are in total 8 interest rate cuts, sorted as surprise cuts) in the sample.

C. Tables and Graphs

Table 1: The reported FOMC meetings that resulted in an interest rate decision include both scheduled and unscheduled meetings. The sample covers 31 decisions to hike the policy rate, 29 cut and 66 hold decisions. Column Surprise (bp) reports the unexpected element of every decision extracted from the Fed futures market and following (Kuttner, 2001)

Day	Month	Year	Decision (bp)	Surprise (bp)	Surprise Hike	Surprise Cut
4	Feb	1994	25	16	*	
22	Mar	1994	25	11		
18	Apr	1994	25	25	*	
17	May	1994	50	12		
6	Jul	1994	0	-2		
16	Aug	1994	50	21	*	
27	Sep	1994	0	0		
15	Nov	1994	75	0		
20	Dec	1994	0	-23		
1	Feb	1995	50	2		
28	Mar	1995	0	2		
23	May	1995	0	-1		
6	Jul	1995	-25	-9		
22	Aug	1995	0	-4		
26	Sep	1995	0	4		
15	Nov	1995	0	2		
19	Dec	1995	-25	-7		
31	Jan	1996	-25	3		
26	Mar	1996	0	1		
21	May	1996	0	1		
3	Jul	1996	0	-6		
20	Aug	1996	0	-1		
24	Sep	1996	0	-12		
13	Nov	1996	0	2		

Day	Month	Year	Decision (bp)	Surprise (bp)	Surprise Hike	Surprise Cut
17	Dec	1996	0	0		
5	Feb	1997	0	-2		
25	Mar	1997	25	2		
20	May	1997	0	-9		
2	Jul	1997	0	-1		
19	Aug	1997	0	3		
30	Sep	1997	0	0		
12	Nov	1997	0	-3		
16	Dec	1997	0	-2		
4	Feb	1998	0	0		
31	Mar	1998	0	0		
19	May	1998	0	-5		
1	Jul	1998	0	-2		
18	Aug	1998	0	3		
29	Sep	1998	-25	4		
15	Oct	1998	-25	-24		*
17	Nov	1998	-25	-12		
22	Dec	1998	0	-4		
3	Feb	1999	0	1		
30	Mar	1999	0	-1		
18	May	1999	0	10		
30	Jun	1999	25	-8		
24	Aug	1999	25	2		
5	Oct	1999	0	6		
16	Nov	1999	25	11		
21	Dec	1999	0	12		
2	Feb	2000	25	2		
21	Mar	2000	25	-1		
16	May	2000	50	8		
28	Jun	2000	0	-2		
22	Aug	2000	0	3		
3	Oct	2000	0	2		
15	Nov	2000	0	0		
19	Dec	2000	0	3		
3	Jan	2001	-50	-24		*
31	Jan	2001	-50	-5		
20	Mar	2001	-50	-7		
18	Apr	2001	-50	-79		*
15	May	2001	-50	-22		*

Day	Month	Year	Decision (bp)	Surprise (bp)	Surprise Hike	Surprise Cut
27	Jun	2001	-25	9		
21	Aug	2001	-25	-3		
17	Sep	2001	-50	-28		*
2	Oct	2001	-50	-14		
6	Nov	2001	-50	-16		
11	Dec	2001	-25	-7		
30	Jan	2002	0	3		
19	Mar	2002	0	53		
7	May	2002	0	-4		
26	Jun	2002	0	-9		
13	Aug	2002	0	-7		
24	Sep	2002	0	-2		
6	Nov	2002	-50	-12		
10	Dec	2002	0	0		
29	Jan	2003	0	2		
18	Mar	2003	0	4		
6	May	2003	0	-7		
25	Jun	2003	-25	11		
12	Aug	2003	0	0		
16	Sep	2003	0	0		
28	Oct	2003	0	-1		
9	Dec	2003	0	1		
28	Jan	2004	0	3		
16	Mar	2004	0	0		
4	May	2004	0	1		
30	Jun	2004	25	-8		
10	Aug	2004	25	7		
21	Sep	2004	25	8		
10	Nov	2004	25	1		
14	Dec	2004	25	0		
2	Feb	2005	25	1		
22	Mar	2005	25	29	*	
3	May	2005	25	2		
30	Jun	2005	25	2		
9	Aug	2005	25	0		
20	Sep	2005	25	7		
1	Nov	2005	25	1		
13	Dec	2005	25	0		
31	Jan	2006	25	1		

Day	Month	Year	Decision (bp)	Surprise (bp)	Surprise Hike	Surprise Cut
28	Mar	2006	25	6		
10	May	2006	25	1		
29	Jun	2006	25	-7		
8	Aug	2006	0	-5		
20	Sep	2006	0	0		
25	Oct	2006	0	-2		
12	Dec	2006	0	-1		
31	Jan	2007	0	0		
9	May	2007	0	1		
28	Jun	2007	0	2		
7	Aug	2007	0	8		
18	Sep	2007	-50	-44		*
31	Oct	2007	-25	9		
11	Dec	2007	-25	0		
22	Jan	2008	-75	-63		*
30	Jan	2008	-50	-10		
18	Mar	2008	-75	49		*
30	Apr	2008	-25	-7		
25	Jun	2008	0	-4		
5	Aug	2008	0	-3		
16	Sep	2008	0	21		
8	Oct	2008	-50	-17		coordinated cut
29	Oct	2008	-50	-10		
16	Dec	2008	-75	-35		*as anticipated

Table 2: The table reports the estimated parameters. The standard errors for $K_{1P}{}^{P}$ are calculated from the output of an unconstrained VAR(1). The standard errors of the Q parameters are asymptotic standard errors in (·) brackets and bootstrapped standard errors in {·} brackets

$K_{1P}{}^{P}$							
US level		0.998	0.004	0.006	0.001	-0.007	0.004
		(0.002)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
US slope		0.001	0.998	-0.018	-0.001	0.001	-0.003
		(0.003)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
US curvature		0.001	0.000	0.985	-0.001	0.001	-0.005
		(0.012)	(0.004)	(0.003)	(0.010)	(0.004)	(0.002)
UK level		0.004	-0.006	0.026	0.997	-0.004	0.002
		(0.002)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
UK slope		-0.001	0.001	0.009	0.002	0.997	0.018
		(0.003)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)
UK curvature		0.001	-0.001	-0.006	-0.001	0.000	0.988
		(0.011)	(0.004)	(0.003)	(0.009)	(0.004)	(0.002)
		$L_{\Sigma P}{}^{P}$					
		US (Home Country)					
		0.131					
$\lambda_{11}{}^{F,Q}$		(0.082)					
0.991		{0.089}					
(0.005)		-0.030	0.035				
{0.014}		(0.053)	(0.022)				
α^{F}		{0.017}	{0.005}				
0.748		-0.025	0.005	0.026			
(0.014)		(0.029)	(0.025)	(0.016)			
{0.018}		{0.035}	{0.012}	{0.002}	UK (Foreign Country)		
$\lambda_{11}{}^{Q}$		0.059	0.002	-0.002	0.090		
0.997		(0.156)	(0.072)	(0.065)	(0.056)		
(0.003)		{0.059}	{0.021}	{0.072}	{0.020}		
{0.003}		-0.014	0.010	0.002	-0.016	0.037	
α		(0.059)	(0.033)	(0.034)	(0.032)	(0.022)	
0.813		{0.010}	{0.068}	{0.018}	{0.091}	{0.005}	
(0.011)		0.007	0.002	-0.004	0.010	0.004	0.025
{0.007}		(0.035)	(0.024)	(0.025)	(0.020)	(0.024)	(0.016)
		{0.028}	{0.016}	{0.041}	{0.016}	{0.061}	{0.007}

Table 3: The upper panel of the table reports in-sample mean absolute pricing errors calculated on the entire sample and expressed in basis points. The lower panel reports the means and the standard deviations of 1-day ahead forecasting errors on different policy days and for the selected 6-month US and the 10Y UK yields. The p-values reported in brackets come from an independent two-sample means t-test and the levels of significance of .10, .05 and .01 are denoted with *, ** and *, respectively**

Single-country Model						
	6m	2Y	3Y	5Y	7Y	10Y
UK	0.5	2.4	1.3	2.3	1.2	2.0
US	0.4	2.4	1.7	1.7	1.0	1.4
Two-country Model						
UK						
Rank	6m	2Y	3Y	5Y	7Y	10Y
2	0.5	2.5	1.4	2.3	1.2	2.1
4	0.7	3.1	2.0	2.9	1.6	2.7
US						
Rank	6m	2Y	3Y	5Y	7Y	10Y
2	0.3	1.8	1.1	1.5	0.8	1.2
4	0.3	1.6	1.0	1.4	0.8	1.2

Decisions	6m US		10Y UK	
	mean	std	mean	std
Hikes (31)	0.4	2.2	-1.4	5.2
	(0.15)		(0.31)	
- Anticipated Hikes (27)	0.4	2.1	-2.2***	3.3
	(0.24)		(0.01)	
- Surprise Hikes (4)	1.1	3.1	3.6	11.9
	(0.49)		(0.53)	
Cuts (28)	-4.4**	11.4	0.1	4.6
	(0.05)		(0.44)	
- Anticipated Cuts (20)	-2.3*	4.8	-0.7	4.0
	(0.06)		(0.77)	
- Surprise Cuts (8)	-8.1	19.3	2.2	5.5
	(0.24)		(0.18)	

Table 4: One-day average changes in the UK yields after different policy actions. The p-values reported in brackets come from an independent two-sample means t-test

	6M	1Y	3Y	5Y	7Y	10Y
All Decisions (125)	-0.4	0.3	0.4	-0.1	0.1	0.0
	(0.16)	(0.35)	(0.22)	(0.92)	(0.58)	(0.82)
All Surprises (15)	-2.1	0.7	1.6	1.7	2.1	2.4
	(0.14)	(0.54)	(0.20)	(0.30)	(0.18)	(0.15)
Hikes (31)						
- Anticipated Hikes (27)	-0.1	-1.1	-1.3**	-1.9***	-1.7**	-1.8***
	(0.98)	(0.11)	(0.05)	(0.01)	(0.02)	(0.01)
- Surprise Hikes (4)	-5.1	0.9	1.2	2.9	3.1	4.6
	(0.16)	(0.73)	(0.65)	(0.63)	(0.60)	(0.49)
Cuts (28)						
- Anticipated Cuts (20)	-0.7	-0.4	-0.1	-0.6	-0.3	-0.2
	(0.22)	(0.68)	(0.99)	(0.55)	(0.83)	(0.90)
- Surprise Cuts (8)	-1.9	0.9	2.1	1.8	2.2	2.6
	(0.32)	(0.65)	(0.28)	(0.32)	(0.18)	(0.14)

Table 5: One-Day average change in the UK forward term premia in basis points. The estimated premia comes from the two-country model. The p-values reported in brackets come from an independent two-sample means t-test

	6M - 2Y	2Y - 3Y	3Y - 5Y	5Y - 7Y	7Y - 10Y
All Decisions (125)	0.9**	0.8	0.4	0.1	-0.1
	(0.04)	(0.12)	(0.44)	(0.93)	(0.82)
All Surprises (15)	4.2**	5.0**	4.5*	4.0	3.6
	(0.03)	(0.05)	(0.09)	(0.15)	(0.20)
Hikes (31)					
- Anticipated Hikes (27)	-1.4**	-1.9***	-1.9***	-1.9**	-1.9**
	(0.03)	(0.01)	(0.01)	(0.03)	(0.05)
- Surprise Hikes (4)	6.8	9.3	9.7	9.5	9.2
	(0.30)	(0.33)	(0.36)	(0.38)	(0.39)
Cuts (28)					
- Anticipated Cuts (20)	0.4	0.4	0.4	0.3	0.2
	(0.70)	(0.71)	(0.74)	(0.79)	(0.83)
- Surprise Cuts (8)	4.7**	5.3**	4.4**	3.5	3.0
	(0.03)	(0.02)	(0.05)	(0.16)	(0.26)

Table 6: One-Day average change in the UK forward term premia in basis points. The estimated premia comes from the single-country model for the UK. The p-values reported in brackets come from an independent two-sample means t-test

	6M - 2Y	2Y - 3Y	3Y - 5Y	5Y - 7Y	7Y - 10Y
All Decisions (125)	0.9**	0.8	0.4	0.1	-0.1
	(0.04)	(0.12)	(0.44)	(0.92)	(0.83)
All Surprises (15)	4.2**	5.0**	4.5*	4.0	3.6
	(0.03)	(0.05)	(0.09)	(0.15)	(0.20)
Hikes (31)					
- Anticipated Hikes (27)	-1.4**	-1.9***	-1.9***	-1.9**	-1.8*
	(0.03)	(0.01)	(0.01)	(0.03)	(0.06)
- Surprise Hikes (4)	6.8	9.4	9.8	9.7	9.4
	(0.30)	(0.33)	(0.35)	(0.37)	(0.38)
Cuts (28)					
- Anticipated Cuts (20)	0.4	0.5	0.4	0.3	0.3
	(0.70)	(0.70)	(0.72)	(0.75)	(0.78)
- Surprise Cuts (8)	4.7**	5.3**	4.4*	3.4	2.9
	(0.03)	(0.02)	(0.06)	(0.17)	(0.28)

Table 7: One-Day average change in the UK forward term premia in basis points. The premia reaction is estimated on the sub-sample from the beginning of January 1994 until the end of July 2007 and using the two-countries model. The p-values reported in brackets come from an independent two-sample means t-test

	6M - 2Y	2Y - 3Y	3Y - 5Y	5Y - 7Y	7Y - 10Y
All Decisions (115)	0.7**	0.7	0.4	0.0	-0.2
	(0.05)	(0.11)	(0.39)	(0.91)	(0.78)
All Surprises (12)	3.8**	4.81*	4.5	3.9	3.5
	(0.05)	(0.08)	(0.15)	(0.27)	(0.35)
Hikes					
- Anticipated Hikes (27)	-1.3*	-1.7***	-1.8***	-1.7*	-1.7
	(0.06)	(0.01)	(0.01)	(0.07)	(0.15)
- Surprise Hikes (4)	6.2	9.3	10.4	10.8	10.9
	(0.24)	(0.26)	(0.29)	(0.32)	(0.34)
Cuts (21)					
- Anticipated Cuts (15)	0.3	0.3	0.3	0.2	0.1
	(0.79)	(0.79)	(0.80)	(0.83)	(0.86)
- Surprise Cuts (6)	2.9	3.4*	2.7	1.9	1.4
	(0.14)	(0.10)	(0.16)	(0.40)	(0.60)

Table 8: One-Day *weighted* average change in the UK forward term premia in basis points. The single reactions are weighted with the inverse of the size of policy rate move multiplied by 25, e.g. the reaction to a 75 basis point move is weighted by 25/75. The p-values reported in brackets come from an independent two-sample means t-test

	6M - 2Y	2Y - 3Y	3Y - 5Y	5Y - 7Y	7Y - 10Y
All Decisions (125)	0.1	0.2	0.2	0.2	0.2
	(0.67)	(0.58)	(0.54)	(0.54)	(0.54)
All Surprises (17)	2.5**	3.6*	3.8*	3.9	3.9
	(0.05)	(0.07)	(0.10)	(0.14)	(0.16)
Hikes (31)					
- Anticipated Hikes (27)	-1.1*	-1.5***	-1.5**	-1.4*	-1.4
	(0.07)	(0.01)	(0.02)	(0.10)	(0.20)
- Surprise Hikes (4)	5.6	8.99	10.5	11.4	11.8
	(0.29)	(0.30)	(0.31)	(0.31)	(0.32)
Cuts (28)					
- Anticipated Cuts (20)	0.5	0.7	0.6	0.6	0.6
	(0.53)	(0.47)	(0.46)	(0.48)	(0.51)
- Surprise Cuts (8)	2.0**	2.4***	2.1**	1.8	1.6
	(0.02)	(0.01)	(0.04)	(0.13)	(0.23)

Figure 1: The US (Upper panel) and the UK (right panel) yield curves are plotted with the FOMC policy rate decisions to hike (solid lines) or cut (dashed lines) the Federal funds rate. The grey areas are NBER recessions in the US

Figure 2: The Figure reports the histograms of sizes of the Fed funds rate increases/ decreases for different policy actions. The x-axis is expressed in basis points and the y-axis shows the number of corresponding decisions

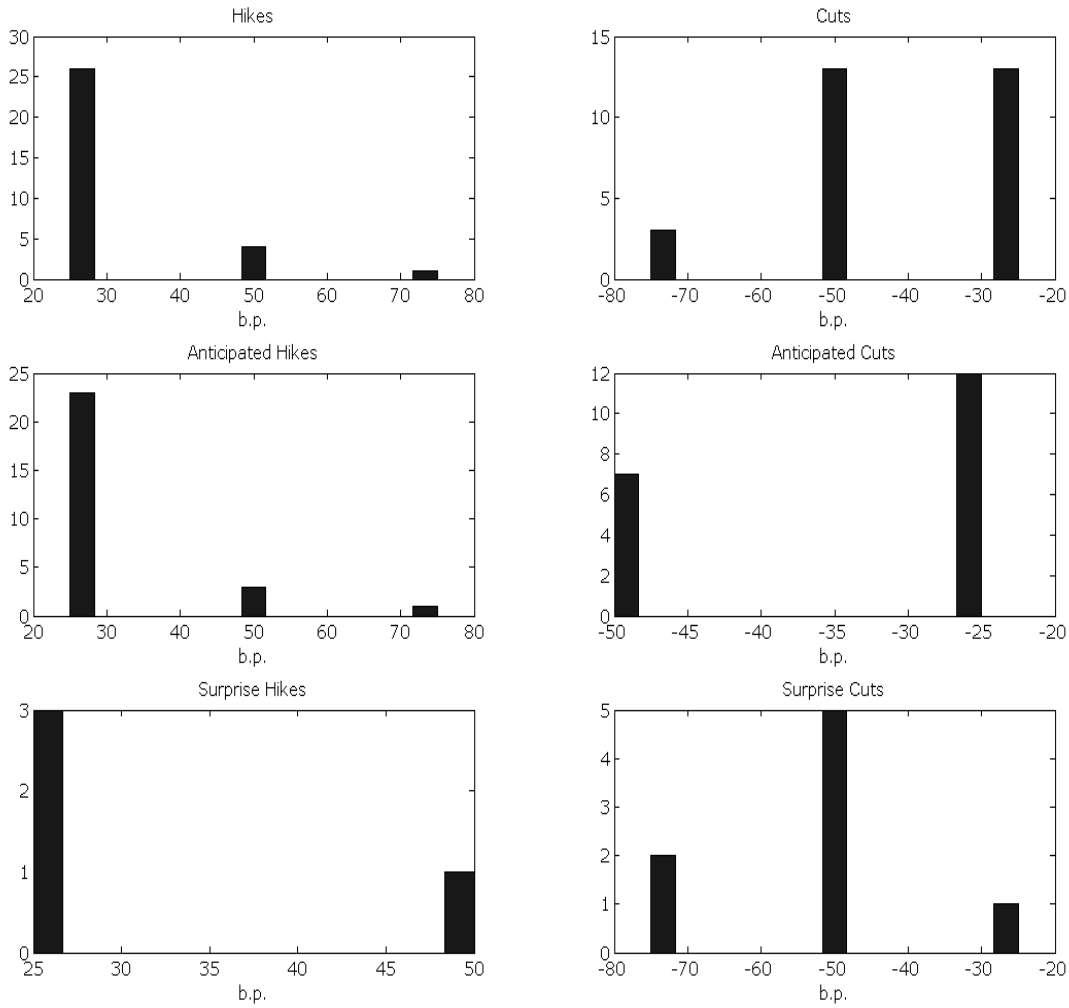


Figure 3: The Figure reports the histograms of surprise indicator calculated in equation (1) for different policy actions. The x-axis is expressed in basis points and the y-axis shows the number of corresponding decisions

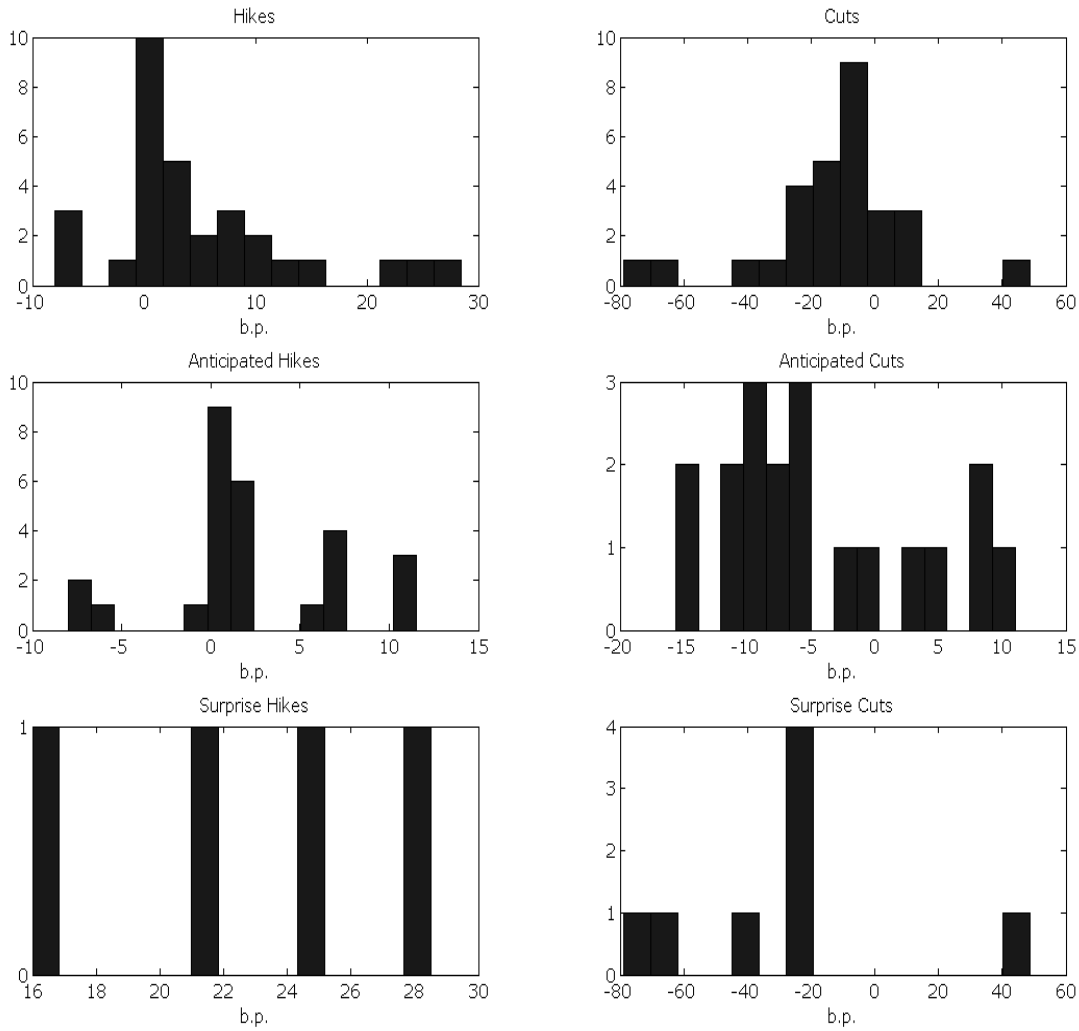


Figure 4: The Figure reports the decomposition of the UK term premia (solid thick line) to the part driven by the three UK factors (dashed) and US factors (solid thin)

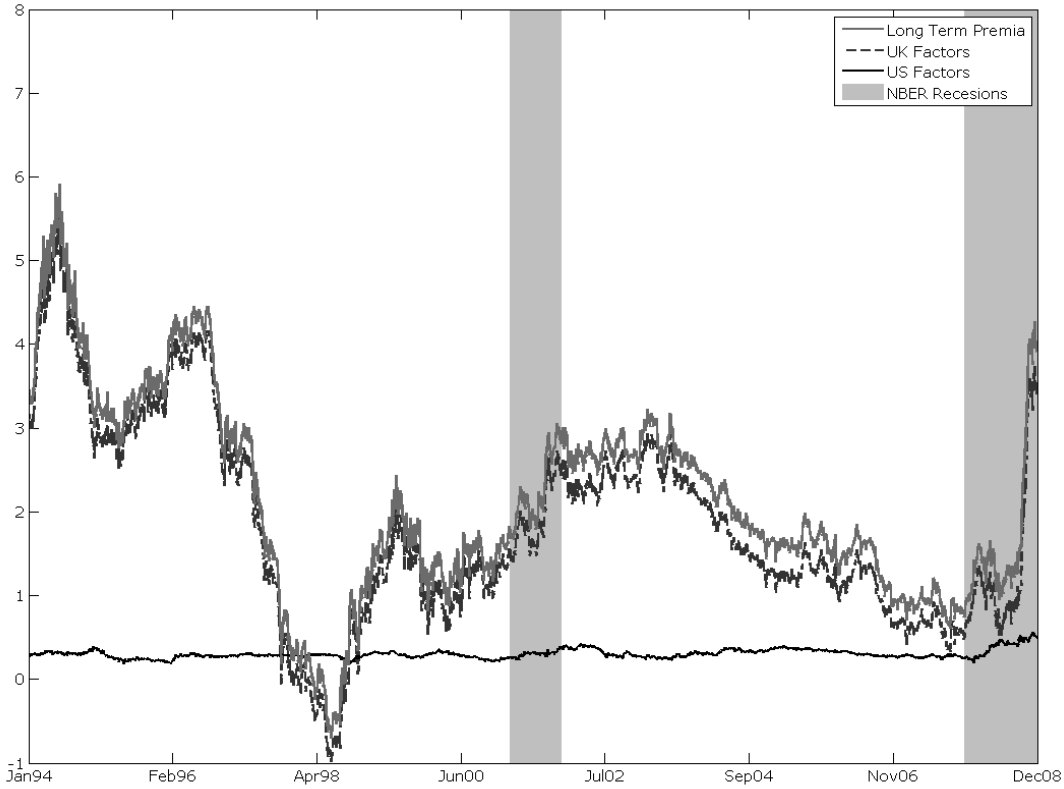


Figure 5: The upper panel illustrates the decomposition of the model-implied depreciation rate (solid thick line) to interest rate differential (solid thin line) and foreign exchange risk premium (dashed line). The lower panel plots the modelled depreciation rate (solid line) against the data (dashed line). The data depreciation rate is annualised and expressed in percentages

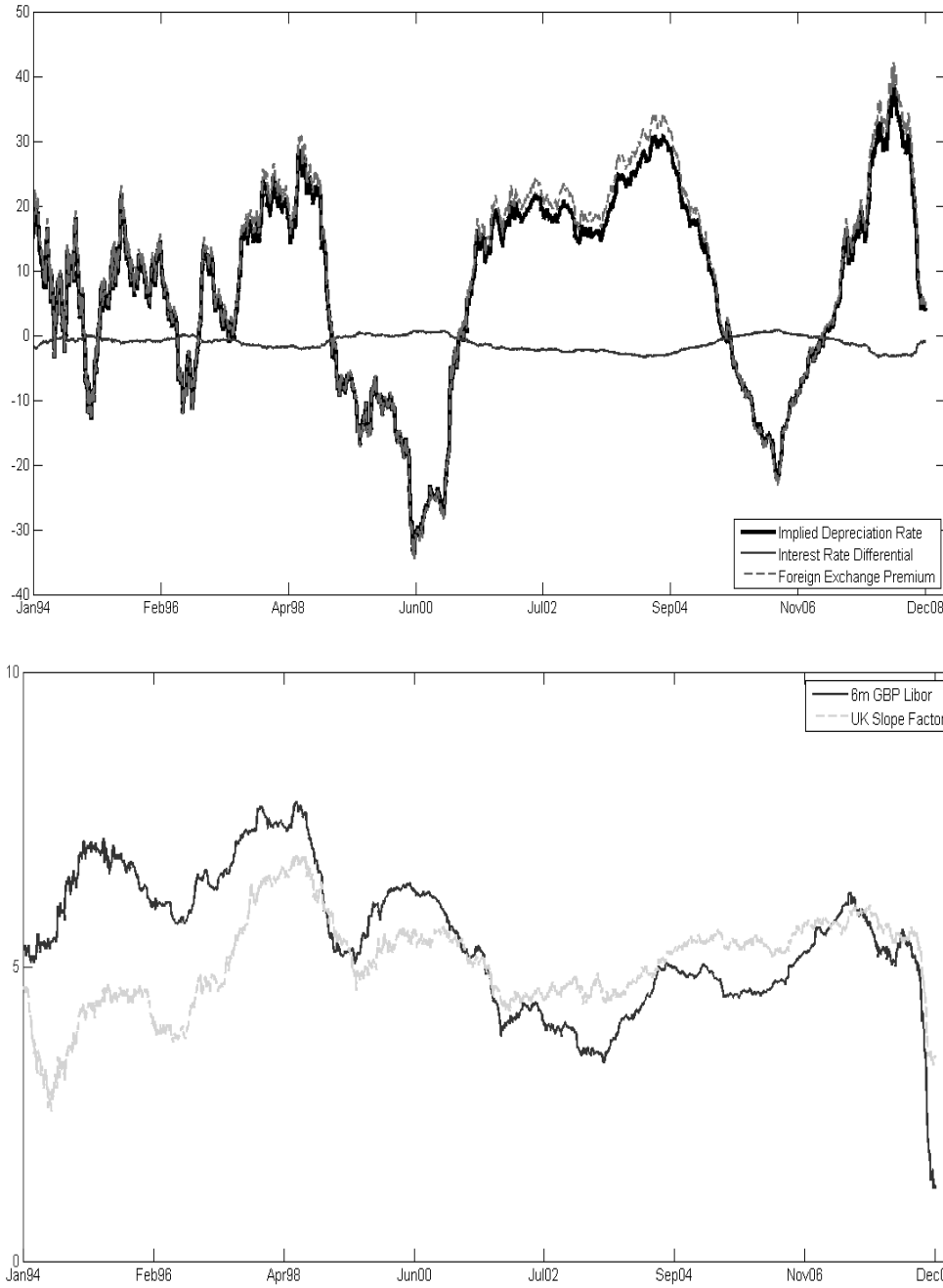
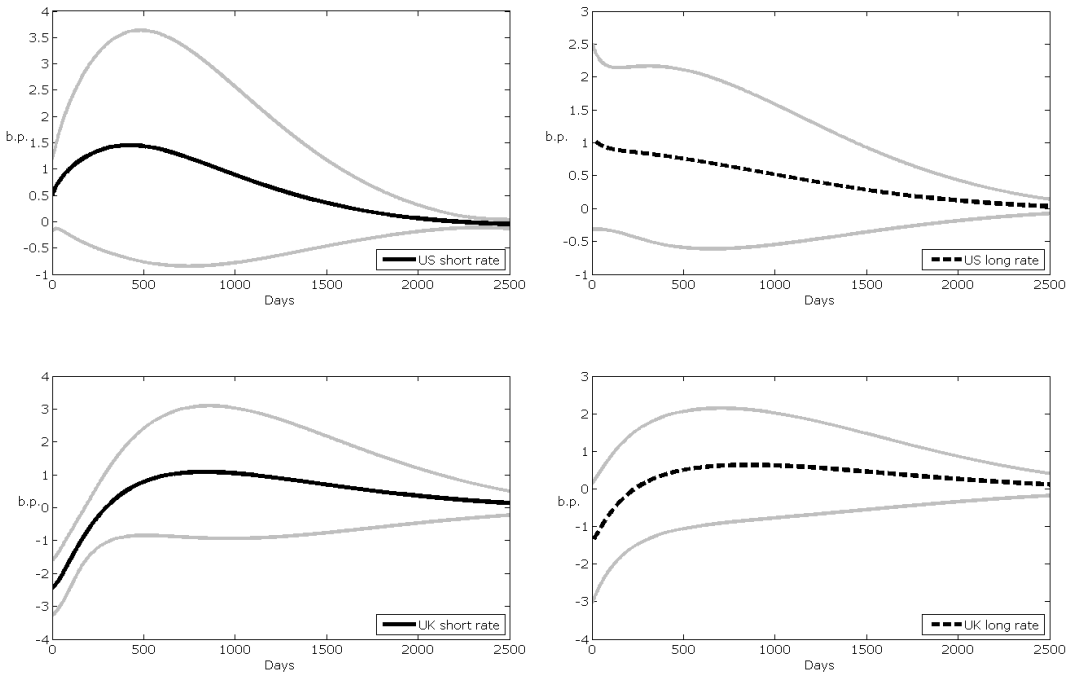
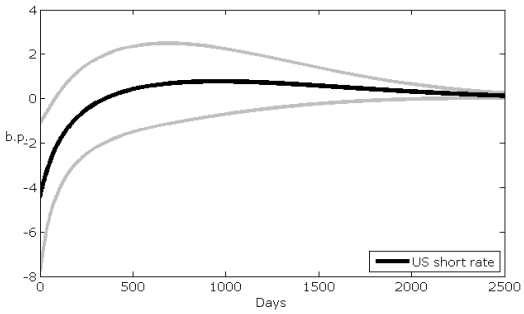


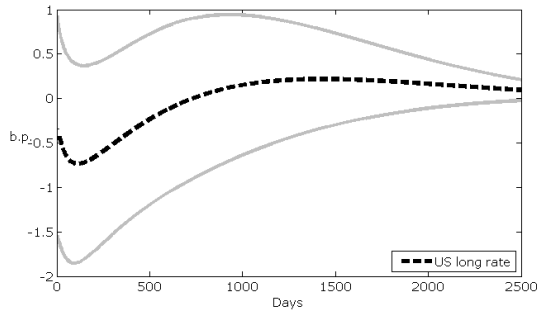
Figure 6: The figure reports average impulse response functions of the 6-month (solid line) and the 10-year (dashed line) UK and US yields to a contractionary (upper panel) and expansionary (lower panel) US monetary policy shocks, together with 90 percent confidence intervals. The confidence intervals are calculated as +/- 1.64 standard deviations of impulse response functions in a group of policy actions (e.g. hikes)

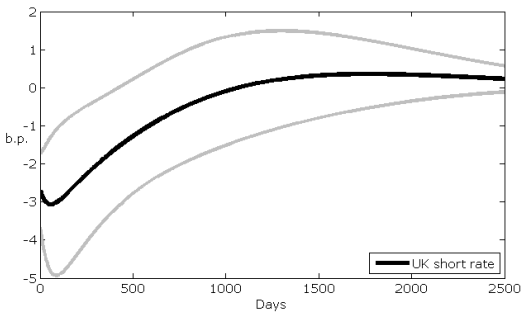
Hikes

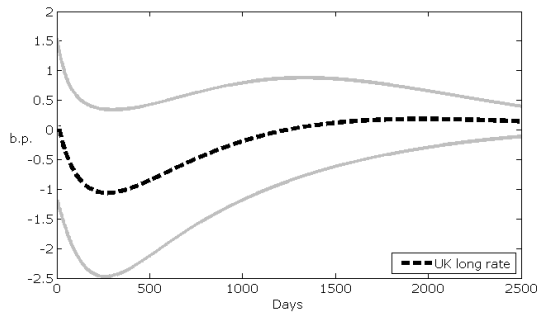


Cuts


b.p.
Days
US short rate


b.p.
Days
US long rate


b.p.
Days
UK short rate


b.p.
Days
UK long rate

The impact of the recent global crisis on the prioritization of central banks final objectives. A structural approach in the context of Central and Eastern European states

Iulian Vasile Popescu[1]

Abstract

This paper aims to identify the actual objectives of monetary authorities in Central and Eastern Europe (CEE) that promote an independent monetary policy. In this sense we consider the study of central banks (CBs) behavior in the Czech Republic, Poland, Romania and Hungary in establishing short-term nominal interest rate by estimating a Taylor-type monetary policy rule, with new features in terms of elements aimed at exploring the interactions between the monetary policy and financial stability. We estimate the monetary policy rule based on a dynamic stochastic general equilibrium model (DSGE). The main results revealed the strong stance of the selected monetary authorities towards their fundamental objective of price stability, but in parallel, towards stabilizing the exchange rate and real economic activity and the existence of specific elements indicating a leaning against the wind orientation of the monetary policy in countries under analysis. Following the emergence of international turmoil our analysis has identified the maintaining of a strong orientation towards the primary objective of monetary policy, a similar relative stance of monetary policy relative to the stabilization of the real activity alongside a decrease in the focus of stabilizing the exchange rate, while the accentuated focus on financial stability does not appear to be achieved through monetary policy.

Keywords: DSGE models, Taylor rules, monetary policy, Bayesian methods, Central and Eastern Europe

JEL Classification: C11, E52, F41

1. Introduction

Identifying the behavior of central banks in setting interest rates may provide a conclusive picture on both their objectives and on their attached importance. A standard approach in this respect is the estimation of the CBs reaction function as a Taylor rule.

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Since the formulation of its original version, the Taylor-type monetary policy rule has undergone a number of changes and extensions designed to better reflect the central bank's monetary policy decisions. Given the current specific of CEE countries, all small and open economies, a first extension is to include the exchange rate in the Taylor-type monetary policy rule.

In addition, we introduce into the rule specific to these states additional variables financial stability-related in order to investigate how monetary authorities subject to analysis have approached the asset prices in the conduct of their monetary policy. All these appear as an objective necessity, due to the extensive discussions on the optimality of 'cleaning' or 'mopping-up' approach versus 'leaning against the wind' (cleaning effects after asset price bubble burst or intervention in an early stage to avoid their creation) amid the recent financial crisis consequences.

The estimation of the Taylor-type monetary policy rule including exchange rate changes, private credit and property prices fluctuations is supported by a Neo-Keynesian model for a small open economy in which the central bank reaction function is one of the model equations (along with those of aggregate demand, aggregate supply and exchange rate dynamics). The model is a dynamic stochastic general equilibrium-type (DSGE), following the general lines developed by Lubik and Schorfheide (2007). The mentioned model has been chosen as reference due to the fact that it has been previously used to estimate monetary policy rules with different specifications, including for the states subject to our analysis (Caraiani, 2011a; 2013), so that a comparative study is relevant.

The model estimation for CEE countries following a direct inflation targeting strategy (the Czech Republic, Poland, Romania and Hungary) is based on Bayesian techniques that offer the advantage of robust results in the context of small samples sizes. Estimation is performed using Matlab and Dynare, a widely used program both by central banks and academia arena to solve, simulate and estimate DSGE models.

The remainder of the paper presents as follows. The first part consists of an overview of the literature, the second part describes the model, the third is focused on methodology and data sources, while the estimation results are summarized in the fourth part. The fifth section concludes.

2. Literature review

While existing evidence reveal that CBs monetary policy in the major developed countries can be described by a reaction function (Clarida et al., 1998), the studies for emerging countries, including Central and Eastern Europe members are much narrower. A number of estimates of Taylor-type monetary policy rules in different specifications and using different methods (usually GMM) can be found in the works of: María Dolores (2005), Angeloni et al. (2007), Frömmel and Schobert (2006; 2011), Vašíček (2008), Orlowski (2008; 2010).

As for exploring interactions between monetary policy and financial stability, a first representative paper that takes into account a number of emerging economies (the Czech

Republic, Poland and Hungary) is the one of Munoz and Schmidt-Hebbel (2012). The authors analyze the monetary policy decisions on a group of 28 emerging and developed countries, between 1994 and 2011 by inserting into the Taylor rule alongside the exchange rate of two financial variables, namely the development of private credit and stock prices, following their actions towards the avoidance of asset prices bubbles formation. Munoz and Schmidt-Hebbel (2012) identified specific items that indicate a 'leaning against the wind' orientation of monetary policy in CEE countries.

From a structural perspective, of the dynamic stochastic general equilibrium models, existing evidence of Taylor-type monetary policy rules estimates in the case of CEE is even more limited. Of course, over time, central banks in the region have developed complex structural DSGE models including estimates of monetary authority's reaction function, as shown by a number of recent examples: Andrle et al. (2009) in the case of the Czech Republic; Grabek et al. (2011) for Poland; Copaciu (2013) on Romania and Szilágyi et al. (2013) for Hungary.

To compare, a common estimate of a Taylor-type monetary policy rule within a DSGE model is to be found in Caraiani (2013) for the Czech Republic, Poland, and Hungary and by using the same model in Caraiani (2011a) in the case of Romania. The author' model is close to Lubik and Schorfheide (2007) framework. The results retuned by the Bayesian estimation have illustrated that central banks subject to analysis reacted to exchange rate changes, which have generally led to a similar monetary policy, characterized by a high level of conservatism and a moderate or low gradualism.

Eschenhof (2009) used a comparable model to determine the role of the exchange rate in monetary policy of the euro area. The Taylor-type monetary policy rule specifications in three different forms, taking into account the GDP, the output gap and inflation expectations simultaneously with the output gap, allowed the identification of clear evidence regarding the ECB's reaction to exchange rate fluctuations. The monetary policy rule that includes the output gap and inflation expectations proved to fit best with the ECB conduct.

The estimation of the model is based on Bayesian techniques, which are considered the most appropriate for estimating DSGE models (An and Schorfheide, 2007), in Dynare, an array of programs that allow to solve, simulate and estimate models including rational expectations. The algorithm supporting Dynare can be found in Juillard (1996), a description of it in Juillard (2004) and an initiation into its use in Griffoli (2008).

3. The Model

The model broadly follows the framework developed by Lubik and Schorfheide (2007), which, in turn, is an improved version of the DSGE model built by Gali and Monacelli (2005). The Neo-Keynesian context underlying the model includes four equations. The first equation is the aggregate demand curve described by an IS curve for an open economy that comprises forward-looking items. The second equation is the aggregate supply as a Phillips curve for an open economy with forward-looking components. Monetary policy is introduced by setting the interest rate according to a Taylor-type rule and the exchange

rate is indirectly inserted by assuming uncovered interest rate parity (PPP). In addition, the terms of trade, private credit and real estate prices are introduced into the model by specifying certain development laws of motion on their dynamics as exogenous AR (1) processes. Due to the fact that the model is outlined for an open economy, foreign output, foreign inflation and technology are modeled as exogenous AR (1) processes.

The model is presented in log-linearized form. Solving the problem of maximizing the utility of households expressed by the Euler consumption equation leads to the IS curve with forward-looking elements as described in relation (1).

$$y_t = E_t y_{t+1} - \left[\tau + \alpha(2-\alpha)(1-\tau)\right](r_t - E_t\pi_{t+1}) - \rho_z z_t - \alpha\left[\pi + \alpha(2-\alpha)(1-\tau)\right]E_t\Delta q_{t+1} - \\ -\alpha(2-\alpha)\frac{1-\tau}{\tau}E_t\Delta y^*_{t+1} \quad (1)$$

where: y_t is domestic production, π_t domestic inflation expressed by the consumer price index (CPI), r_t short-term nominal interest rate, E_t expectations operator and Δ is the difference operator. All other variables in equation (1) are considered to be exogenous: z_t is the technology growth rate internationally, Δq_t changes in the terms of trade (relative prices difference of exports and imports at time t and t-1), the differentiation operator being the result of the fact that inflation is affected only by changes in relative prices and not by the relative price itself, and y^*_t the foreign output. In the context of an open economy α ($0 < \alpha < 1$) is the share of imports, while τ is the inter-temporal substitution elasticity.

The price setting by domestic producers is described by a Phillips curve for an open economy with forward-looking components in the form of relation (2):

$$\pi_t = \beta E_t\pi_{t+1} + \alpha\beta E_t\Delta q_{t+1} - \alpha\Delta q_t + \frac{\kappa}{\tau + \alpha(2-\alpha)(1-\tau)}(y_t - \bar{y}_t) \quad (2)$$

where: $\bar{y}_t = \left[-\alpha(2-\alpha)(1-\tau)/\tau\right]y^*_t$ is potential GDP assuming the absence of nominal rigidities and the κ parameter (Phillips curve slope coefficient, with $\kappa > 0$) is a structural parameters function depending on the model specification.

To introduce changes in the nominal exchange rate Δe_t consumer price inflation (CPI) is defined according to the relation (3):

$$\pi_t = \Delta e_t + (1-\alpha)\Delta q_t + \pi^*_t \quad (3)$$

where: π^*_t is the foreign inflation. Relation (3) implies uncovered interest rate parity functionality (PPP), with inflation depending on changes in the nominal exchange rate, terms of trade and foreign inflation.

The model is closed by specifying a monetary policy rule as a Taylor-type rule that takes into account both the deviation of GDP (real GDP - potential GDP) and inflation expectations. Besides, as a novelty in the Taylor rule we considered the insertion of private credit and real estate market prices changes to capture the behavior of selected monetary

authorities geared towards financial stability, pursuing, in fact, the extent to which they include asset price developments in their monetary policy decision. Relation (4) presents the Taylor rule:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left[\psi_1 E_t \pi_{t+1} + \psi_2 (y_t + \frac{\alpha(2-\alpha)(1-\tau)}{\tau} y_t^*) + \right.$$
$$\left. + \psi_3 \Delta e_t + \psi_4 \Delta pc_t + \psi_5 \Delta pp_t \right] + \varepsilon_t^r \quad (4)$$

where: ρ_r is the coefficient of interest rate inertia, Δpc_t private credit variation and Δpp_t the housing market price changes. According to Lubik and Schorfheide (2007) the output gap in equation (4) is modeled as a combination of domestic and foreign production.

The model is complemented by a series of equations that describe the behavior of exogenous variables, i.e. the terms of trade, the technology growth rate international, inflation and foreign output and the changes in the private credit and property prices. All variables are modeled as AR (1) processes according to relations (5) - (10).

Terms of trade shocks:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \varepsilon_t^q \quad (5)$$

Technology shocks:

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \quad (6)$$

Shocks of foreign inflation:

$$\pi_t^* = \rho_\pi \pi_{t-1}^* + \varepsilon_t^{\pi^*} \quad (7)$$

Shocks in foreign production:

$$y_t^* = \rho_y y_{t-1}^* + \varepsilon_t^{y^*} \quad (8)$$

Private credit shocks:

$$\Delta pc_t = \rho_{pc} \Delta pc_{t-1} + \varepsilon_t^{pc} \quad (9)$$

Shocks in the prices of real estate assets:

$$\Delta pp_t = \rho_{pp} \Delta pp_{t-1} + \varepsilon_t^{pp} \quad (10)$$

The model is solved and estimated by Bayesian techniques using Matlab and Dynare.

4. Methodology and data

The model is estimated with quarterly frequency data for the four CEE countries in the process of convergence towards the euro area that apply an inflation targeting strategy: the Czech Republic, Poland, Hungary and Romania. The intention of an analysis for a time horizon that starts with the date of adopting inflation targeting strategy by the four countries has been heavily restricted by the availability of data series on the development of real estate prices. Therefore, data samples cover the following ranges: the Czech Republic - 2004q1:2013q1; Poland - 2002q4:2013q1; Romania - 2005q3:2013q1; Hungary - 2001q4:2013q1. Estimates for the period subsequent to the global financial crisis cover the interval 2008q4:2013q1. All data is provided by Eurostat database, except for private credit and the price of real estate, where the data comes from the database of the Bank for International Settlements.

The data series include the quarterly national GDP in constant prices (2005) expressed as volume of national currency; quarterly domestic inflation measured as the difference between national consumer price indices as monthly quarterly average and multiplied by 400 to obtain annualized inflation interest rate; quarterly interest rate as short-term nominal interest rates set by central banks; quarterly exchange rate given by the average quarterly nominal exchange rate against EUR; foreign quarterly GDP as quarterly GDP in the euro area in constant prices (2005) expressed as volume in the European single currency, foreign quarterly inflation as the Eurozone inflation for the same time horizon, similar to national inflation; quarterly internal private credit as a fixed base index (2005 = 100) and quarterly properties price in real estate markets as fixed base index (2005 = 100). All series except for the interest rates were logarithmic. Subsequently, all series have been seasonally adjusted and filtered through a Hoddrik-Prescott filter.

The study of the literature reveals two main methods of evaluating DSGE models: calibration and econometric estimation. The calibration method was widely used until a few years ago, when its popularity positioned on a downward trend. However, calibration should be considered a fundamental aspect in the model construction and estimation, contributing essentially, for example, in the learning of model properties (Tovar, 2008). Regarding the econometric estimates, this can be achieved by various methods such as the estimation of equilibrium relationships based on the generalized method of moments (GMM), the maximum likelihood method and Bayesian methods (see Canova (2007), An and Shorfheide (2007), Ruge-Murcia (2007) and Favero (2001) for details of the various approaches).

The Bayesian techniques are presently considered the best way of estimating such models and consist in adding to the probability function of early information (priors).

Bayesian estimates are actually a bridge between the calibration method and maximum likelihood method. Tradition of calibration models is included in the Bayesian estimates by specifying a priori information (priors). Maximum likelihood approach is the result of the estimation based on the model-data comparison. Priors can be seen as weights

within the probability function in order to give greater importance to certain areas of the parameter subspace. These two blocks, priors and maximum likelihood, are linked together by Bayes's theorem.

Given the vector ψ (6 x 1) of the monetary policy rule parameters:

$$\psi = \left[\rho_r, \psi_1, \psi_2, \psi_3, \psi_4, \psi_5\right] \tag{11}$$

vector θ (17 x 1) containing the other parameters and standard deviations of the shocks:

$$\theta = \left[\alpha, r, \kappa, \tau, \rho_q, \rho_z, \rho_{pc}, \rho_{pp}, \rho_{y^*}, \rho_{\pi^*}, \sigma_R, \sigma_q, \sigma_z, \sigma_{pc}, \sigma_{pp}, \sigma_{y^*}, \sigma_{\pi^*}\right] \tag{12}$$

vector Y^T (7 x 1) of observable variables:

$$Y^T = \left[4R_t, 4\pi_t, \Delta y_t + z_t, \Delta e_t, \Delta q_t, \Delta pc_t, \Delta pp_t\right] \tag{13}$$

a random distribution with density $p(\psi,\theta) = p(\psi)p(\theta)$ and a probable distribution function of data $L_D(\psi,\theta/Y^T)$ with $Y^T = \{Y_1,...,Y_7\}$ then the posterior density $p_D(\psi,\theta/Y^T)$ of the model parameters is given by Bayes' theorem:

$$p_D(\psi,\theta/Y^T) = \frac{L_D(\psi,\theta/Y^T)p(\psi)p(\theta)}{\int L_D(\psi,\theta/Y^T)p(\psi)p(\theta)d(\psi,\theta)} \tag{14}$$

Distribution type is based on the allowable ranges for the parameter values and random information on mean and standard deviation as in Lubik and Schorfheide (2007), Eschenhof (2009), Caraiani (2011a; 2013). Posterior distribution of the parameters is determined by the Metropolis-Hastings algorithm.

Before the Bayesian approach, a number of coefficients are calibrated using results from the literature. β discount factor is calibrated at 0.99, its reference value in the literature ($\beta = \exp(-r/400)$), ρ_{π^*} at 0.69, ρ_{y^*} at 0.92 with standard deviations of 0.5 and respectively 0.3 (Caraiani 2008; 2011b). $\rho_z, \rho_{pc}, \rho_{pp}$ parameters and shocks standard deviations are calibrated similar to external variables coefficients given that they are considered AR (1) processes. Parameters estimates, as in fact the Dynare code we used (mod. file) and Matlab files (m. files) can be obtained on request from the author.

The final set of parameters to be estimated is reflected by the following array:

$$\{\alpha, \kappa, \tau, \rho_r, \psi_1, \psi_2, \psi_3, \psi_4, \psi_5\} \tag{15}$$

5. Estimation results

5.1 The Czech Republic case

The estimation was based on 2 Metropolis-Hastings chains of 50,000 extractions each, with final acceptance rates of 28.08% and 28.17%, indicating a high quality of the estimation given that the literature recommends an optimal acceptance rate between 20% and 40%.

Results of univariate and multivariate Brooks-Gelman (1998) convergence statistics presented in Annex 1 reveal convergence after a reasonable number of iterations. Priors and posterior distributions are illustrated in Annex 2. The estimation findings in terms posterior distributions can be found in Table 1.

The estimation results indicate a ψ_1 value of 1.9384, which emphasizes a stabilizing monetary policy. A coefficient of inflation gap greater than one shows the viability of the Taylor principle, a stabilizing monetary policy assuming an increase in the nominal interest rate to a greater extent (more than proportionally) than inflation.

However, such a high value returned by the Bayesian estimates for inflation coefficient compared to parameters related to other macroeconomic variables in the monetary policy rule underlines a strong orientation towards maintaining the price stability.

Table 1: Results of the Bayesian estimation - the case of the Czech Republic (2004q1:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1689	0.1419	0.1964	beta	[0,1)	0.1500
α	0.5000	0.6967	0.5972	0.7997	beta	[0,1)	0.1000
κ	0.5000	0.3767	0.2377	0.5129	gamma	R^+	0.1000
ρ_r	0.7000	0.2638	0.1270	0.3997	beta	[0,1)	0.1500
ψ_1	1.5000	1.9384	1.5414	2.3261	gamma	R^+	0.3000
ψ_2	0.2500	0.1381	0.0773	0.1969	gamma	R^+	0.1250
ψ_3	0.2500	1.6436	1.2967	1.9812	gamma	R^+	0.1250
ψ_4	0.2500	0.2510	0.0620	0.4391	gamma	R^+	0.1250
ψ_5	0.2500	0.2496	0.0571	0.4319	gamma	R^+	0.1250
ρ_q	0.4000	0.4767	0.2420	0.7226	beta	[0,1)	0.1500

Source: author's estimation

For the output gap coefficient (ψ_2) the findings point out a value of 0.1381 that shows a rather low orientation of monetary policy towards the stabilization of the real activity.

The importance attached by national monetary authorities to the exchange rate stability is evidenced by the ψ_3 value. The high coefficient value (1.6436) emphasizes a strong orientation of CBs towards the stabilization of the exchange rate through short-term nominal interest rate.

The estimation results for the variables coefficients introduced into the monetary policy rule to identify the behavior towards financial stability through monetary policy, respectively ψ_4, related to changes in private credit and ψ_5, corresponding to real estate price trends, are 0.2510 and 0.2496.

The parameters significant values reveal the presence (though not very strong) of a 'leaning against the wind' monetary policy approach of the national CBs. The analysis of central bank behavior in setting the interest rate in order to ensure financial stability shows that it has taken into account to some extent both private credit developments and the evolution of real estate prices. Besides, the monetary policy stance of ensuring financial stability can be determined even by simply identifying the importance attributed to the exchange rate in the monetary policy rule, believed to be high. Such an approach seems to be justified if we consider the high degree of euroisation and currency mismatch of financial institutions assets and liabilities, a distinctive feature of selected economies, because the depreciation of national currencies severely affects the financial stability.

ρ_r coefficient of inertia (interest rate smoothing) resulting from the estimation returns a value of 0.2638, which indicates a relatively low degree of inertia in adjusting interest rates. The value of the parameter expresses the position of national monetary authority towards the compromise between less aggressive changes in the interest rate not to cause instability in financial markets, on the one hand, and strengthening the credibility of monetary policy (which would automatically imply fast and powerful interest rates reactions, with a lower level of inertia) on the other hand.

The focus on the recent financial crisis subsequent period has led to results that can be identified in Table 2. Given this range, the final acceptance rates for the 2 Metropolis - Hastings chains of 50,000 extractions each retuned values of 33.79% and 33.94% respectively, with a corresponding quality of estimation and Brooks and Gelman convergence univariate and multivariate statistics highlighting convergence achievement after a reasonable number of iterations.

Table 2: Results of the Bayesian estimation - the case of the Czech Republic (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1491	0.1157	0.1830	beta	[0,1)	0.1500
α	0.5000	0.6519	0.5336	0.7698	beta	[0,1)	0.1000
κ	0.5000	0.4009	0.2555	0.5422	gamma	R^+	0.1000
ρ_r	0.7000	0.3816	0.2030	0.5645	beta	[0,1)	0.1500
ψ_1	1.5000	1.8535	1.4744	2.2324	gamma	R^+	0.3000
ψ_2	0.2500	0.1389	0.0515	0.2219	gamma	R^+	0.1250
ψ_3	0.2500	0.8516	0.3577	1.3244	gamma	R^+	0.1250
ψ_4	0.2500	0.2481	0.0592	0.4335	gamma	R^+	0.1250
ψ_5	0.2500	0.2489	0.0554	0.4324	gamma	R^+	0.1250
ρ_q	0.4000	0.4175	0.1673	0.6561	beta	[0,1)	0.1500

Source: author's estimation

The comparative approach of the two intervals has indicated similar values for the ψ_1, ψ_2 coefficients included in the monetary policy rule, which emphasizes the maintaining of monetary policy stance towards the basic objective of price stability and a similar orientation of monetary policy relative to the stabilization of real economic activity in the post-crisis period. Significantly close values for the parameters can also be identified in the case of ψ_4 and ψ_5, which emphasizes that in the aftermath of the international turmoil the increased focus towards financial stability has not been achieved through monetary policy. Instead, the ψ_3 coefficient of exchange rate retuned lower values, reflecting a decrease in the monetary policy stance towards the stabilization of the exchange rate subsequent to the crisis.

5.2 The case of Poland

The model is estimated based on two Metropolis Hastings chains of 50,000 extractions each, with acceptance rates between 27.90% and 27.96%, and appropriate quality estimation. Convergence statistics supported by Brooks-Gelman (1998) approach presented in Annex 1 have highlighted convergence both in univariate and multivariate terms. Annex 2 includes the a priori and posterior distributions and differences between them. The estimation results are illustrated by Table 3.

Table 3: Results of the Bayesian estimation - the case of Poland (2002q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1784	0.1507	0.2052	beta	[0,1)	0.1500
α	0.5000	0.6970	0.5938	0.7993	beta	[0,1)	0.1000
κ	0.5000	0.3587	0.2205	0.4937	gamma	R^+	0.1000
ρ_r	0.7000	0.2374	0.1134	0.3570	beta	[0,1)	0.1500
ψ_1	1.5000	2.8952	2.1544	3.6340	gamma	R^+	0.3000
ψ_2	0.2500	0.3352	0.2584	0.4083	gamma	R^+	0.1250
ψ_3	0.2500	1.5676	1.1375	1.9812	gamma	R^+	0.1250
ψ_4	0.2500	0.2503	0.0579	0.4330	gamma	R^+	0.1250
ψ_5	0.2500	0.2508	0.0596	0.4383	gamma	R^+	0.1250
ρ_q	0.4000	0.4137	0.1610	0.6530	beta	[0,1)	0.1500

Source: author's estimation

Inflation coefficient in the monetary policy rule (ψ_1) is estimated at 2.8952, a high value both per se and compared with the corresponding parameters of the other variables taken into account in deciding the monetary policy rule, which firstly confirms the pursuit of price stability objective in full accordance with the inflation targeting strategy.

Such a monetary policy strategy is not applied under a strict form, leaving room for the stabilization of real activity and the exchange rate. The estimated coefficient for the output gap (ψ_2) is 0.3352, which indicates the stance of monetary policy towards the aggregate output stabilization, while the ψ_3 real exchange rate change parameter returns an estimated value of 1,5676, underlining the high importance attributed to exchange rate stability in the monetary policy decision. This evidence, however, is not likely to jeopardize the inflation target priority, as ψ_2 and ψ_3 values are much smaller than those of ψ_1.

Besides the high importance of exchange rate developments, monetary policy stance geared to financial stability can be identified based on the results for the coefficients of changes in private credit (ψ_4) and changes in real estate prices (ψ_5). The estimated values of 0.2503 and respectively 0.2508 emphasize a not very wide, but constant concern of the CBs monetary policy to prevent excessive credit growth and the formation of asset price bubbles in the housing market.

The estimation results indicate a value of 0.2374 for the interest rate inertia coefficient (ρ_r) showing the absence of a high gradualism in implementing the monetary policy.

The analysis of the period following the emergence of the international financial

crisis has led to the results illustrated in Table 4. From the technical point of view, the quality of estimation in this case appears to be appropriate for the rates of acceptance of the two Metropolis Hastings chains, returning values of 34.09% and 33.97%, respectively. In addition, we found univariate and multivariate convergence after a reasonable number of iterations, according to Brooks-Gelman approach.

Table 4: Results of the Bayesian estimation - the case of Poland (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1517	0.1175	0.1860	beta	[0,1)	0.1500
α	0.5000	0.6398	0.5183	0.7632	beta	[0,1)	0.1000
κ	0.5000	0.4086	0.2625	0.5500	gamma	R^+	0.1000
ρ_r	0.7000	0.3380	0.1699	0.5013	beta	[0,1)	0.1500
ψ_1	1.5000	2.4130	1.7659	3.0390	gamma	R^+	0.3000
ψ_2	0.2500	0.2671	0.1485	0.3827	gamma	R^+	0.1250
ψ_3	0.2500	0.7299	0.2472	1.2051	gamma	R^+	0.1250
ψ_4	0.2500	0.2487	0.0580	0.4329	gamma	R^+	0.1250
ψ_5	0.2500	0.2513	0.0596	0.4361	gamma	R^+	0.1250
ρ_q	0.4000	0.4006	0.1480	0.6381	beta	[0,1)	0.1500

Source: author's estimation

The comparison of the two periods in the case of Poland suggests a slight decrease in the monetary policy stance towards price stability and stabilization of real economic activity. The very similar values obtained for the coefficients of private borrowing and asset prices in the housing market indicates a further disengagement of monetary policy in ensuring financial stability after the crisis. An obvious reduction occurs for the exchange rate associated coefficient indicating a dilution in monetary policy authorities' efforts to stabilize the exchange rate in the aftermath of the financial turmoil.

5.3 The case of Hungary

The Metropolis-Hastings algorithm with two chains of 50,000 extractions on data for Hungary resulted in acceptance rates of 32.78% for the first chain, and 32.84% for the second. Brooks-Gelman univariate and multivariate convergence statistics presented in Annex 1 indicates convergence after a reasonable number of iterations. The differences

between a priori and posterior distributions are shown in Annex 2. Estimation results can be found in Table 5.

Table 5: Results of the Bayesian estimation - the case of Hungary (2001q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1788	0.1520	0.2064	beta	[0,1)	0.1500
α	0.5000	0.6433	0.5307	0.7510	beta	[0,1)	0.1000
κ	0.5000	0.3350	0.1942	0.4678	gamma	R^+	0.1000
ρ_r	0.7000	0.2772	0.1434	0.4115	beta	[0,1)	0.1500
ψ_1	1.5000	2.1531	1.7357	2.5796	gamma	R^+	0.3000
ψ_2	0.2500	0.6947	0.6525	0.7370	gamma	R^+	0.1250
ψ_3	0.2500	1.6186	1.2422	1.9812	gamma	R^+	0.1250
ψ_4	0.2500	0.2557	0.0616	0.4455	gamma	R^+	0.1250
ψ_5	0.2500	0.2535	0.0594	0.4391	gamma	R^+	0.1250
ρ_q	0.4000	0.4761	0.2292	0.7190	beta	[0,1)	0.1500

Source: author's estimation

The estimation result for inflation coefficient within the monetary policy rule (ψ_1) indicates a value of 2.1531, highlighting the strong orientation of the NCB towards its primary objective of maintaining the price stability.

Inflation targeting strategy seems to be applied in a flexible manner, as the stabilization of the real economic activity and exchange rate represents a concern of the monetary authority in setting short-term nominal interest rate, as evidenced by the values of ψ_2 and ψ_3 coefficients (0.6947 and 1.6186 respectively). Comparative values of the three parameters emphasize the efforts of the monetary policy to stabilize aggregate production and exchange without affecting the primary objective of price stability.

The values obtained for parameters corresponding to the variables in the Taylor-type rule to identify the conduct of monetary policy in ensuring financial stability (ψ_4 and ψ_5) reveal a 'leaning against the wind' approach, a monetary policy that reacts to some extent to unsustainable credit growth and the formation of a real estate asset price bubbles.

ρ_r interest rate smoothing coefficient is estimated at 0.2772, which translates into a relatively low level of gradualism in adjusting interest rates, partly explained by the CB intent to increase the credibility of its monetary policy.

The estimation results for the period subsequent to the international financial crisis can

be identified in Table 6. The acceptance rates resulting from the application of Metropolis Hastings algorithm with two chains of 50,000 extractions each are 34.37% and 34.38%, respectively, in the context of a sound estimation quality. Convergence achievement is ensured both in terms of univariate and multivariate statistics.

The comparison of results for the period 2008q4: 2013q1 with those of the 2001q4: 2013q1 time horizon suggests a relative decrease in the orientation of the monetary authority towards the fulfillment of the primary objective and the post-crisis stabilization of aggregate production.

Table 6: Results of the Bayesian estimation - the case of Hungary (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1519	0.1169	0.1867	beta	[0,1)	0.1500
α	0.5000	0.6065	0.4805	0.7332	beta	[0,1)	0.1000
κ	0.5000	0.3920	0.2489	0.5343	gamma	R^+	0.1000
ρ_r	0.7000	0.2900	0.1215	0.4513	beta	[0,1)	0.1500
ψ_1	1.5000	1.8691	1.4890	2.2377	gamma	R^+	0.3000
ψ_2	0.2500	0.5746	0.5014	0.6487	gamma	R^+	0.1250
ψ_3	0.2500	0.7518	0.2888	1.2151	gamma	R^+	0.1250
ψ_4	0.2500	0.2501	0.0571	0.4322	gamma	R^+	0.1250
ψ_5	0.2500	0.2533	0.0598	0.4431	gamma	R^+	0.1250
ρ_q	0.4000	0.4121	0.1672	0.6589	beta	[0,1)	0.1500

Source: author's estimation

A second result identifies the maintaining to a certain extent of the leaning against the wind orientation of monetary policy, while the focus on the exchange rate appears significantly lower after the recent financial crisis.

5.4 The case of Romania

In this case also the Bayesian approach is based on two Metropolis-Hastings chains with 50,000 extractions each, with acceptance rates of 28.08% and 27.75%. Convergence both in terms of univariate and multivariate Brooks-Gelman statistics is present, as illustrated by Appendix 1, while priors and posterior distributions can be found in Appendix 2. Bayesian estimation results are displayed in Table 7.

Inflation coefficient in the monetary policy rule (ψ_1) returned by the estimation model is 2.0117, indicating in this case also the principle of Taylor and the strong orientation of the national monetary authority towards the primary objective of price stability. From this point of view, of inflation stabilization magnitude, the CB's monetary policy appears to be well behind the realities of Poland and Hungary, but superior to the monetary authority measures applied by the Czech Republic.

The output gap coefficient (ψ_2) is at 0.2253, emphasizing efforts, to some extent, of the monetary authorities to stabilize the real economic activity. From the perspective of stabilizing the aggregate production, as objective hierarchically subordinate to the primary aim of ensuring a low and stable inflation, the monetary policy of the Central Bank of Romania appears to over perform the monetary policy of the Czech central bank, but it is less efficient than the one implemented in Poland. Hungary appears to be the CEE country with an inflation targeting strategy involving the NCB focus primarily in the real economic activity.

Table 7: Results of the Bayesian estimation - the case of Romania (2005q3:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1616	0.1303	0.1937	beta	[0,1)	0.1500
α	0.5000	0.5538	0.4247	0.6829	beta	[0,1)	0.1000
κ	0.5000	0.3673	0.2206	0.5061	gamma	R^+	0.1000
ρ_r	0.7000	0.3540	0.1979	0.5072	beta	[0,1)	0.1500
ψ_1	1.5000	2.0117	1.5999	2.4187	gamma	R^+	0.3000
ψ_2	0.2500	0.2253	0.0738	0.3777	gamma	R^+	0.1250
ψ_3	0.2500	1.3344	0.8304	1.8904	gamma	R^+	0.1250
ψ_4	0.2500	0.2516	0.0544	0.4330	gamma	R^+	0.1250
ψ_5	0.2500	0.2505	0.0622	0.4389	gamma	R^+	0.1250
ρ_q	0.4000	0.4086	0.1562	0.6504	beta	[0,1)	0.1500

Source: author's estimation

In Romania, the real exchange rate changes coefficient in the monetary policy rule (ψ_3) indicates a value of 1.3344, which means the strong orientation of the NCB to stabilize the exchange rate through interest rate policy. Moreover, for the real exchange rate parameter estimation results showed high values for all selected states, the Czech Republic and Hungary examples revealing a solid focus of the monetary policy authorities on ensuring the external balance.

For the variables parameters in Taylor-type rule used to test the concerns of central banks to ensure financial stability through monetary policy (ψ_4 and ψ_5), estimates on Romania are similar to those obtained for all other CEE countries subject to analysis, highlighting the same limiting trend (not very strong, but there), through the monetary policy, of uncontrolled private credit expansion and the formation of a real estate price bubble.

For the interest rate inertia degree, the estimated coefficient indicates a higher value compared to the other CEE countries (0.3540), showing a moderate gradualism of monetary policy implemented by the national CBs.

The focus on the post-crisis period has led to estimation results presented in Table 8. The forecasting quality is found to be better for this temporal interval, with acceptance rates of the two Metropolis Hastings chains of 33.84% and 33.97%, respectively. The achievement of convergence after a reasonable number of iterations is evidenced by both univariate and multivariate Brooks-Gelman statistics.

The comparative approach of the two time intervals subject to analysis indicates, similar to Poland and Hungary, a slight decrease of the monetary policy stance towards ensuring price and real economic activity stability. Similar values obtained for the coefficients of variables introduced to test the monetary policy stance relative to financial stability highlight, similar to the other three countries analyzed, additional non-involvement of monetary policy.

Table 8: Results of the Bayesian estimation - the case of Romania (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1647	0.1263	0.2025	beta	[0,1)	0.1500
α	0.5000	0.6055	0.4784	0.7373	beta	[0,1)	0.1000
κ	0.5000	0.3934	0.2441	0.5357	gamma	R^+	0.1000
ρ_r	0.7000	0.3817	0.1959	0.5630	beta	[0,1)	0.1500
ψ_1	1.5000	1.8466	1.4692	2.2252	gamma	R^+	0.3000
ψ_2	0.2500	0.1942	0.0545	0.3310	gamma	R^+	0.1250
ψ_3	0.2500	0.8781	0.3840	1.3733	gamma	R^+	0.1250
ψ_4	0.2500	0.2479	0.0611	0.4323	gamma	R^+	0.1250
ψ_5	0.2500	0.2461	0.0601	0.4288	gamma	R^+	0.1250
ρ_q	0.4000	0.4014	0.1538	0.6457	beta	[0,1)	0.1500

Source: author's estimation

Another result close to the other three selected countries revealed diluted efforts of the monetary policy authorities to stabilize the exchange rate in the aftermath of the international financial turmoil.

6. Conclusion

The estimation of CBs reaction functions as Taylor rules is a useful tool both for identifying the objectives of central banks and for getting a conclusive picture on their importance for monetary authorities.

To accurately identify the factors considered by the monetary authorities in setting short-term nominal interest rate we estimated a Taylor-type monetary policy rule that includes the exchange rate. In addition, amid extensive discussion generated by the recent financial crisis on the optimality of cleaning or mopping-up approach versus leaning against the wind (cleansing effects after asset price bubble burst or intervention in an early stage to avoid their formation), we inserted into the monetary policy rule two variables (private credit developments and property prices) in order to identify the behavior of selected central banks to financial stability through the monetary policy.

We estimated the monetary policy rule based on a dynamic general stochastic equilibrium model (DSGE) through Bayesian techniques, currently believed to be the best estimation tool.

Monetary policy rule estimation results within the model with explicit micro-elements showed the strong orientation of CEE states towards fulfilling their goal of price stability.

Inflation targeting strategy does not appear, however, to be used in its strict version, in parallel leaving room for the stabilization of real economic activity. In addition, the high values of changes in the real exchange rate coefficients point out the significant efforts of national monetary authorities to support the exchange rate through short-term nominal interest rate. Such evidence, however, is not likely to jeopardize the inflation target priority, as the corresponding parameters identified for aggregate production and changes in the real exchange rate are much lower than those related to inflation.

The interest rate inertia (interest rate smoothing) values indicate in all states a relatively low degree of inertia in adjusting interest rates. Such a limited gradualism in modifying short-term nominal interest rate can be attributed to the purpose of increasing the credibility of the central bank's monetary policy.

The stance of CBs monetary policy to ensuring financial stability in the CEE region has been primarily identified on the basis of high importance attributed to the exchange rate in the monetary policy rule, because the national currency depreciation poses major problems for financial stability due to the characteristics of these economies in terms of high degree of euroisation and currency mismatch of financial institutions assets and liabilities.

As for the coefficients of variables explicitly introduced in the monetary policy rule to determine the behavior of central banks efforts to enhance financial stability through monetary policy, the results reveal a diluted, but present trend of limiting uncontrolled private credit expansion and the formation of a real estate price bubble. In other words,

the estimation allowed the identification, to some extent, of a 'leaning against the wind' monetary policy orientation of selected monetary authorities.

Orientation of attention to the period following the emergence of the financial crisis has emphasized a strong stance of monetary policy towards the fundamental objective of ensuring price stability (though slightly decreased compared to the extended time period including Romania, Poland and Hungary). If the Czech Republic was found to maintain a similar orientation of monetary policy towards the real activity in post-crisis period, the other three countries subject to analysis reveal a moderate decrease in the monetary policy efforts to stabilize this sector. However, in the aftermath of the global financial crisis, accentuated orientation towards financial stability has not been achieved through monetary policy.

Additional lack of involvement of monetary policy in ensuring financial stability after the crisis was identified in all four countries considered.

Another common result is the change in the monetary policy orientation relative to the exchange rate following the emergence of the turmoil, highlighting limited efforts to stabilize the exchange rate in the post-crisis period.

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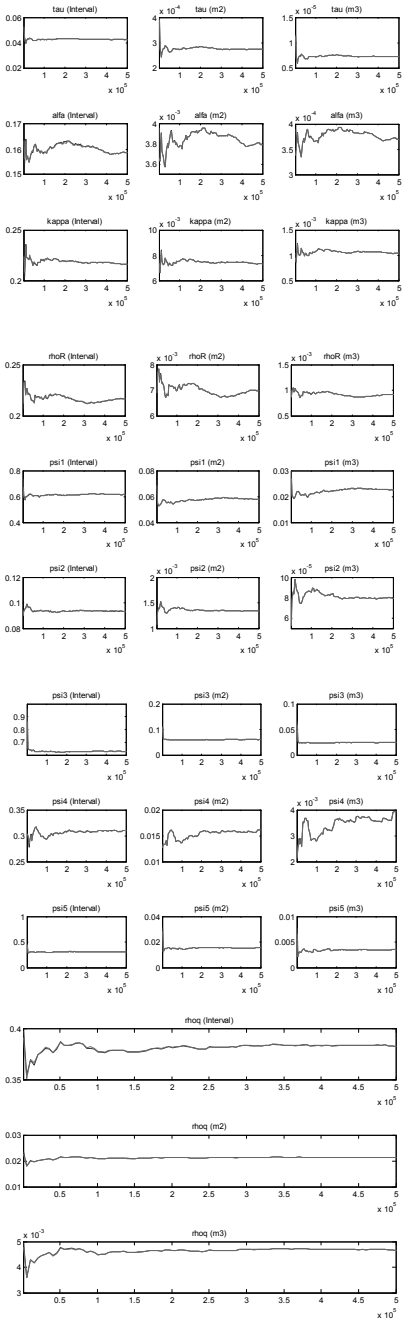
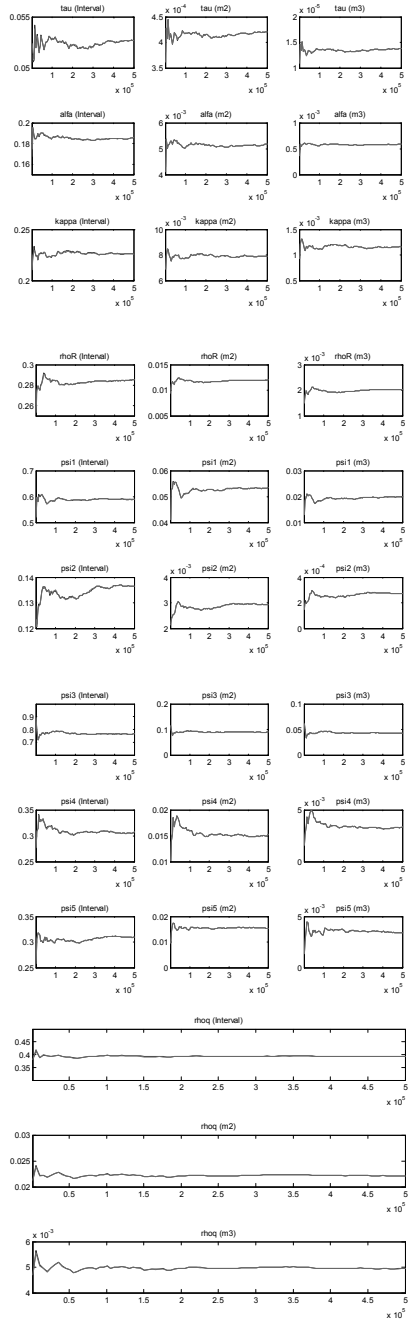
Annex 1

A. Brooks-Gelman (1998) univariate convergence statistics

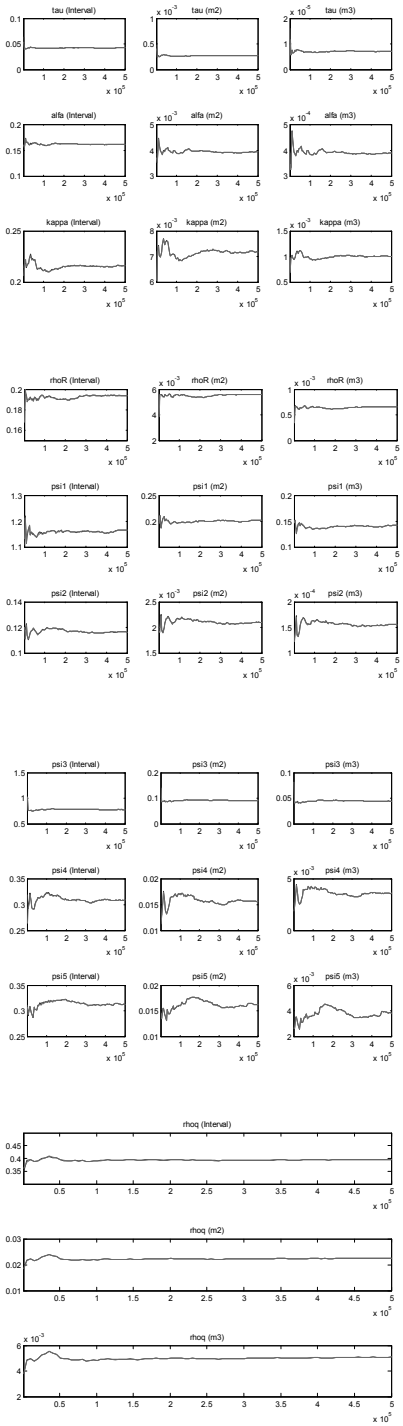
the Czech Republic case (2004q1:2013q1)



the Czech Republic case (2008q4:2013q1)



the case of Poland (2002q4:2013q1)



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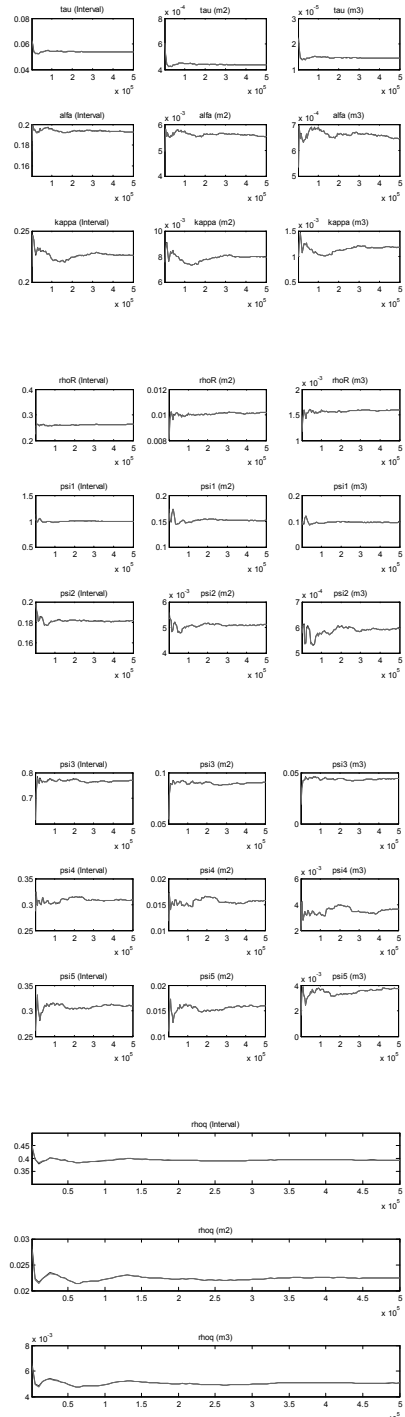
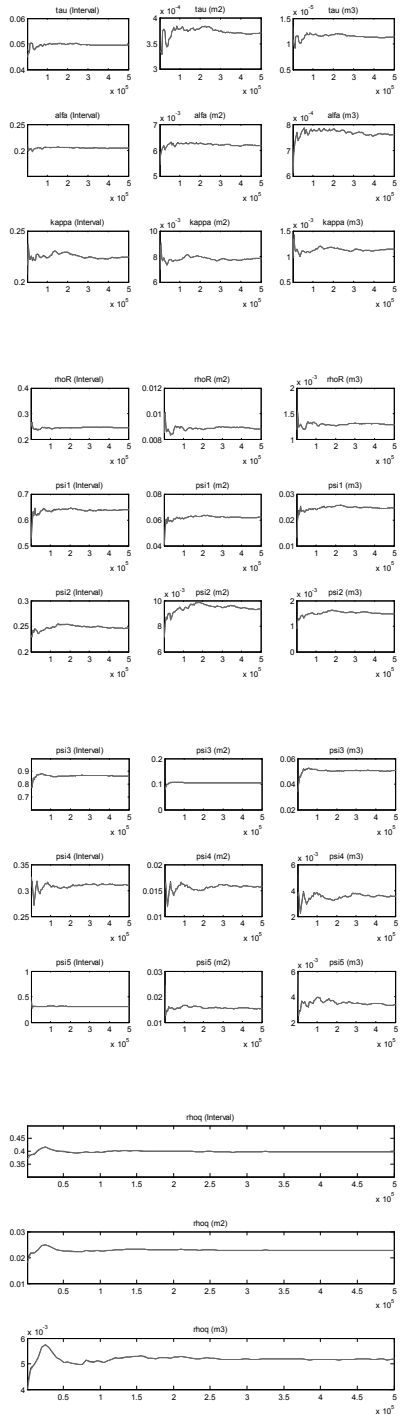
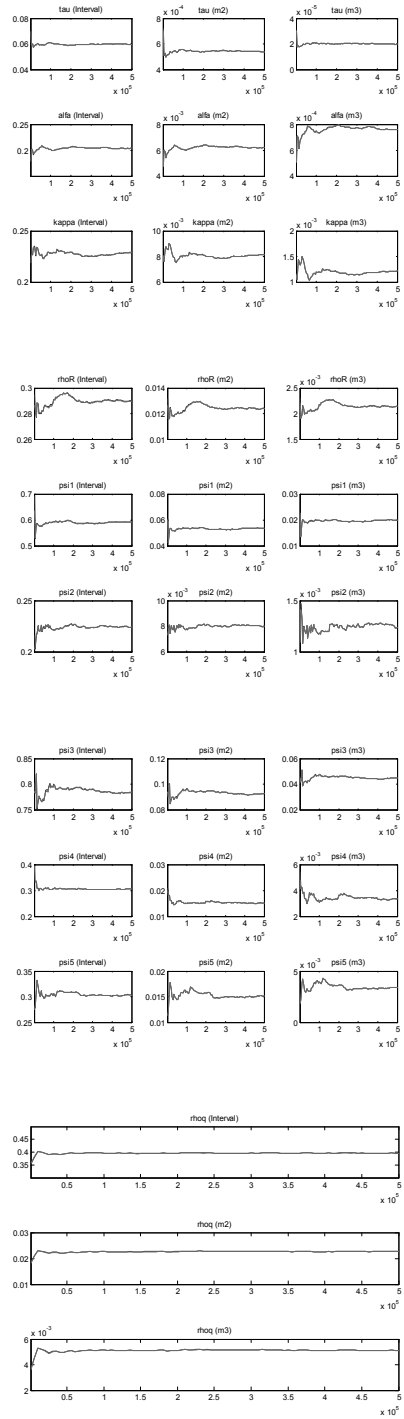


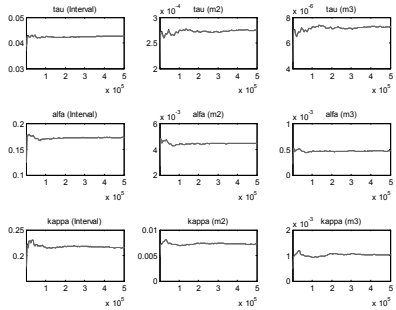
the case of Romania (2005q3:2013q1)

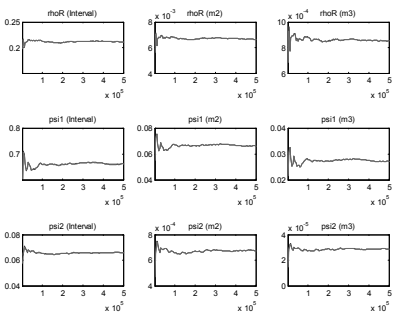


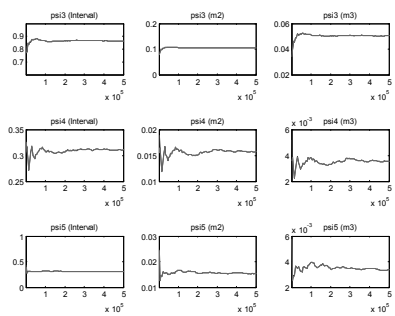
the case of Romania (2008q4:2013q1)

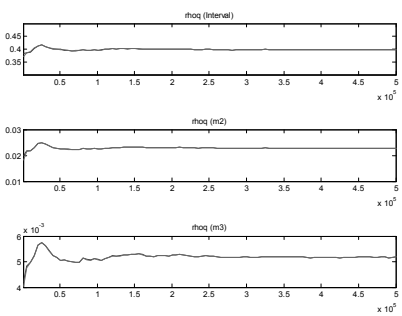


the case of Hungary (2001q4:2013q1)

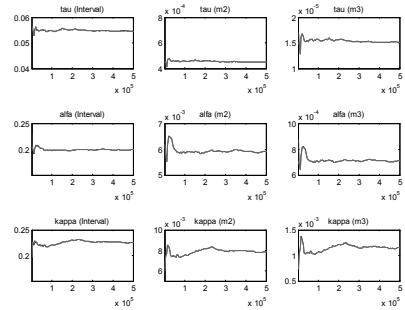


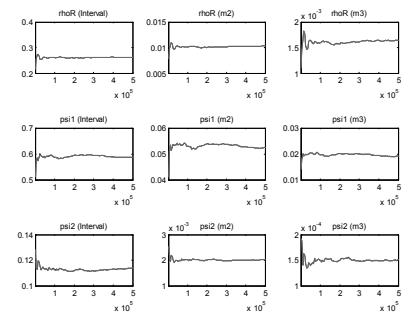


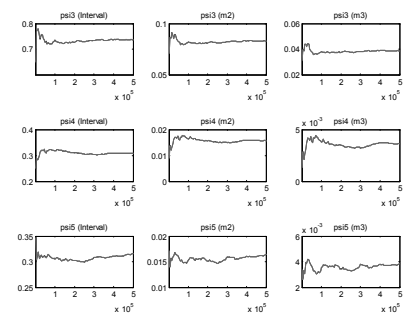


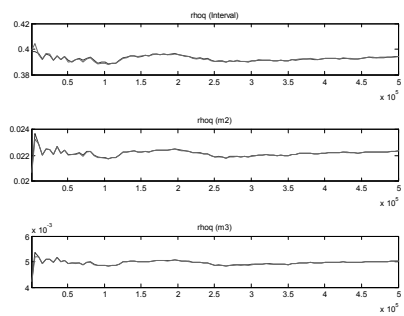


the case of Hungary (2008q4:2013q1)



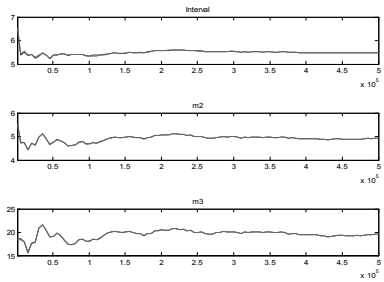




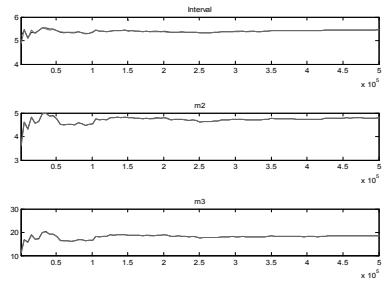


B. Multivatiate convergence statistics

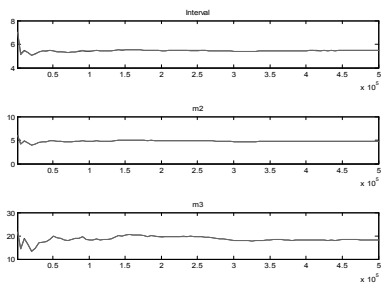
the Czech Republic case (2004q1:2013q1)



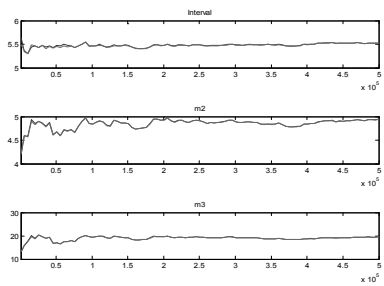
the Czech Republic case (2008q4:2013q1)



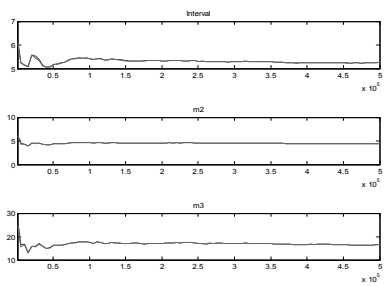
the case of Poland (2002q4:2013q1)



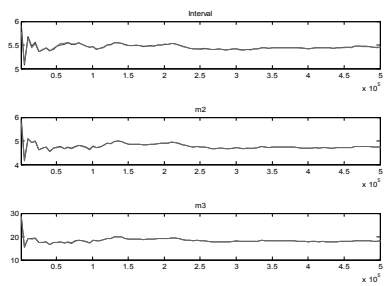
the case of Poland (2008q4:2013q1)



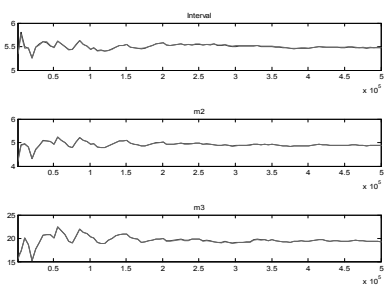
the case of Romania (2005q3:2013q1)



the case of Romania (2008q4:2013q1)



the case of Hungary (2001q4:2013q1)



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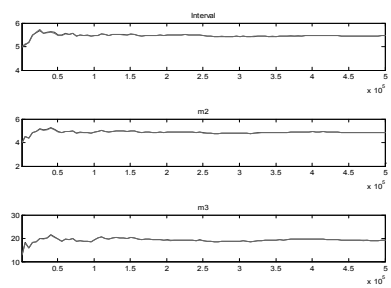
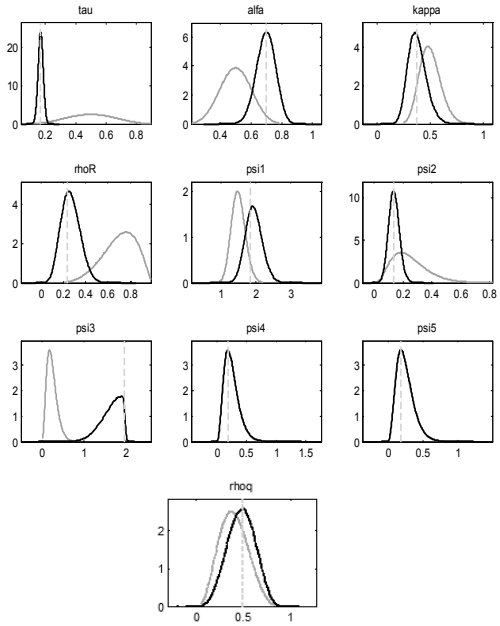


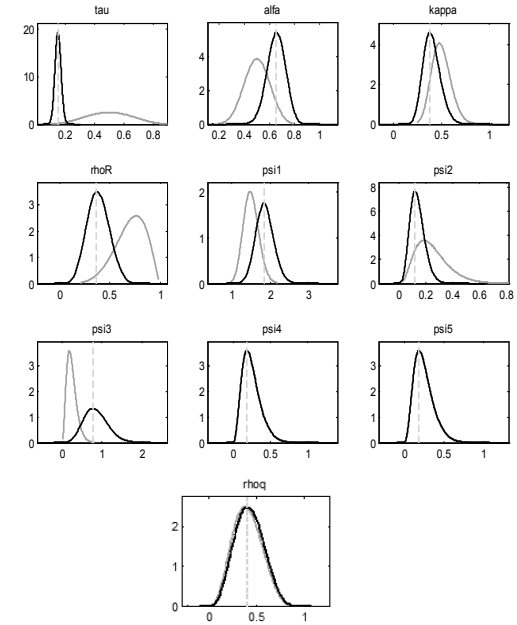
Annex 2

Prior and posterior distributions

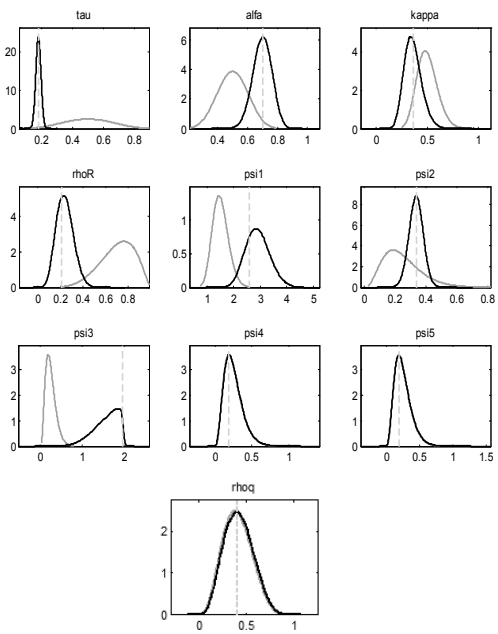
the Czech Republic case (2004q1:2013q1)



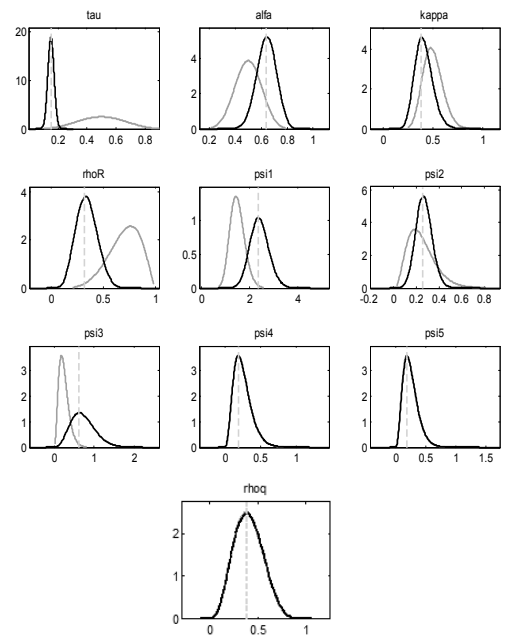
the Czech Republic case (2008q4:2013q1)



the case of Poland (2002q4:2013q1)



the case of Poland (2008q4:2013q1)



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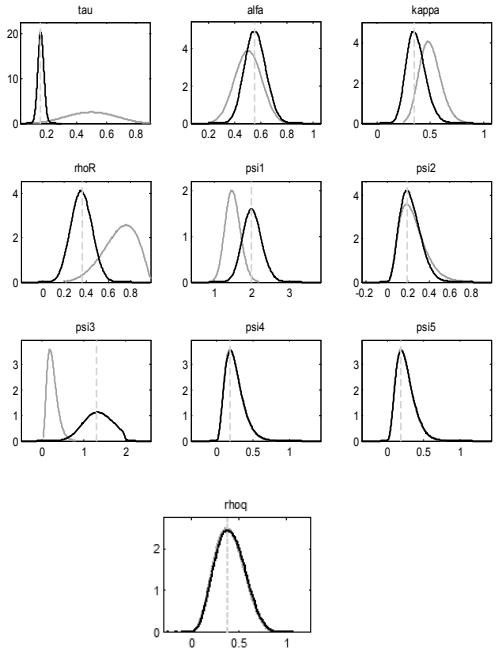

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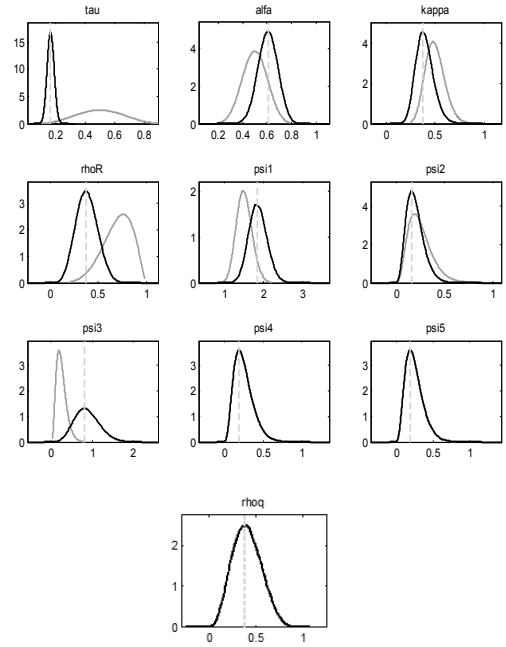

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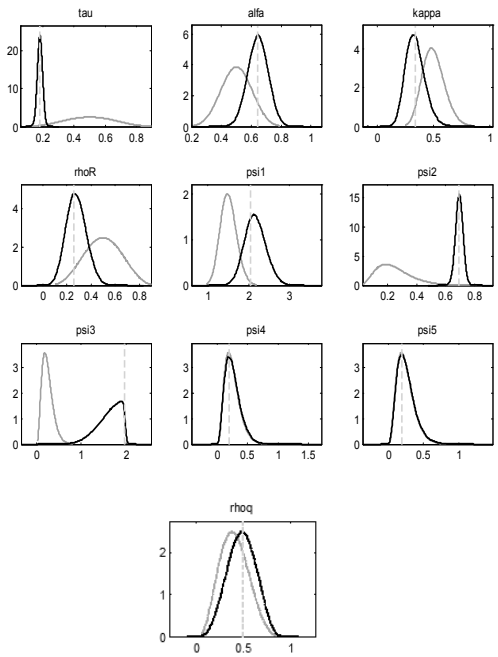
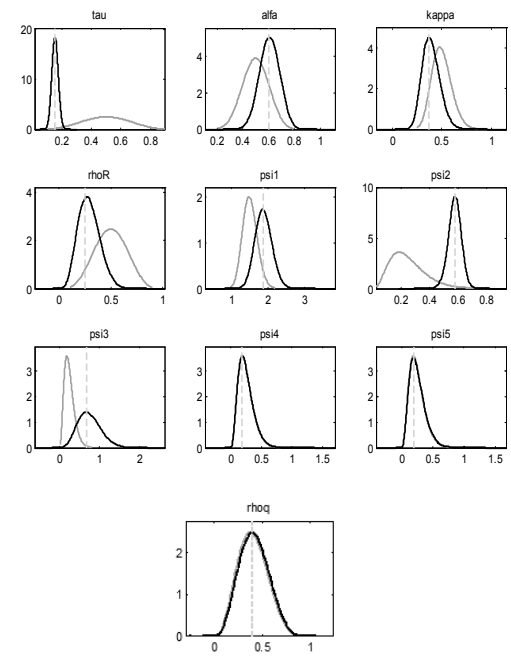


the case of Hungary (2008q4:2013q1)



Growth and project finance in the least developed countries

Lisbeth F. la Cour[1] and Jennifer Müller[2]

Abstract

This article examines the effects of project finance on economic growth in the least developed countries (LDC). Inspired by the neoclassical growth model we set up an econometric model to estimate the effects of project finance for a sample consisting of 38 of the least developed countries using data from the period 1994-2007. The results of our study suggest, that project finance has a significant positive effect on economic growth and therefore constitute an important source of financing in the selected set of countries. Additionally, the project sheds light on other factors of importance for economic growth in LDCs. We find that a higher regulatory quality, lower government consumption and a higher level of education helps increase growth. The significance of these variables are, however, not as consistently robust as the results for project finance.

Keywords: Project Finance, Economic Growth, Least Developed Countries, Foreign Direct Investment

JEL Classification: F43, G15, O16

1. Introduction and Motivation

Worldwide, a growing portion of infrastructure and natural resource projects, are funded by project finance. Even though most of the project finance is invested in developed countries, project finance funds constitute an important and growing portion of foreign investment to developing and even the Least Developed Countries (LDCs). The United Nations (United Nations, 2010) refers to three criteria to identify a country as LDC: low income, human resource weakness and economic vulnerability. To be categorized as a LDC all three criteria have to be fulfilled. With financing being particularly scarce in LDCs, project finance helped to fund major infrastructure and natural resource projects. Many projects were made possible only because of the use of project finance. The potential of project finance as a development tool for developing countries is also recognized by

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development organizations like the World Bank, the International Finance Corporation (IFC), the African Development Bank or the European Investment Bank, which are often key investors and warrantor in project finance deals in the LDCs.

Despite the growing volumes of project finance in LDCs and the commitment of the IFC and other developing banks to project finance as a developing tool, the effect of project finance on economic growth in LDCs or even developing countries in general remains surprisingly under-explored. This paper responds by quantitatively examining the importance of project finance for economic development in LDCs.

On theoretical grounds there are two key reasons why project finance is an especially suitable candidate of long-term capital for LDCs and why it can support economic growth in LDCs.

First, project finance has a very unique financing structure. In contrast to corporate loans, project finance is mostly non-recourse or limited-recourse debt for stand-alone projects. Project financing schemes are characterized by a high level of debt and extensive long-term contracting to guarantee an effective risk distribution. Due to its unique characteristics project finance is often better able to mitigate risk and reduce transaction costs than other forms of foreign direct investment or commercial loans. In addition it is not dependent on local financial markets. Thereby project finance enables investors to enter economically and politically less stables countries like the LDCs. Due to their underdeveloped to basically non-existing local financial markets, LDCs are more dependent on capital from abroad than other countries. Hence, project finance in LDCs can provide the desired capital for investments and helps LDCs to unlock their natural resources.

Second, project finance not only enables economic growth by creating revenue through taxes, jobs and royalties, but it also creates revenues and spill-over effects by setting up strategically important assets like power plants, harbors and other infrastructure ventures. There is a general consensus that infrastructure investments are a strong driver of economic growth and that the lack of infrastructure is a main source of disincentives to invest (Estache, 2005). Despite the substantial inflow of official development assistance (ODA) into LDCs, investment demands for public services and infrastructure in LDCs by far exceed government and donor resources. Therefore, LDCs are dependent on private capital inflows to develop the needed infrastructure. However, infrastructure assets are particularly prone to creeping expropriation by hostile home governments. Consequently, investors are generally reluctant to invest in infrastructure assets in politically unstable countries. Again, due to its unique characteristics, project finance can mitigate these risks and it is therefore suitable for infrastructure investments even in politically unstable countries. To summarize, project finance can provide the desired private capital for infrastructure investment without increasing the debt burden of the LDCs.

On theoretical grounds there are strong arguments that project finance is particularly suitable for LDCs and that there should be a relationship between project finance and economic growth in LDCs. This is supported by case studies and investigations by the World Bank, which generally reveal a positive economic and social effect of project finance in developing countries (Ahmed, 1999). Somewhat surprising tough, the World Bank and

other development banks have not, to the best of our knowledge, empirically investigated the effect of project finance on growth in developing countries. Therefore, we believe that our empirical study can add to the limited research done on project finance in developing countries and can help to shed light on the importance of project finance for LDCs .

In the light of the still ongoing financial crisis, our results are particularly relevant. Due to the financial crisis, project finance volumes dropped considerably in the LDCs. With liquidity drying up, many banks refrain from long-term investments like project finance. Due to the reduced supply of project finance loans, project finance costs increased considerably and risky projects like those in LDCs are affected the most. As a result, more project finance deals in developing countries are seeing delays or even cancellation.

As this study shows, project finance can have a significant positive effect on economic growth in LDCs. Therefore, in case project finance volumes continue to decline or remain low in the aftermath of the financial crisis, this development can pose a new threat to economic growth and recovery in the LDCs (Leigland and Russell, 2009).

In order to substitute for the declining project finance loans issued by commercial banks, the World Bank, the IFC and other development banks have to commit themselves even stronger to project finance by increasing their loan volumes and guarantees in LDCs and by giving assistance and advice in project finance deals.

In section two of the paper we review some of the literature on project finance both theoretically and empirically. In section 3 we present our model and methodology and we discuss our data. Section 4 contains our empirical results and discussions of these results, section 5 reports results of robustness checks while section 6 concludes.

2. Review and Theoretical Extension

This section reviews and extends the theoretical and empirical literature on project finance and economic growth in LDCs.

2.1 Importance of Capital

Investigating the economic growth effect of project finance in LDCs is strongly linked to the finance growth nexus. The interaction between financial markets and growth has been studied extensively in the finance growth literature and the results generally reveal that financial development stimulates growth. By increasing innovation, human capital and physical capital, financial capital triggers and supports economic growth (Kleimeier and Versteeg, 2010). The finance growth nexus thus implies that developing countries and especially LDCs are at a disadvantage. Given their virtually non-existing financial markets, they are particularly dependent on capital from abroad, like foreign direct investment (FDI) and ODA. However the empirical evidence on the growth enhancing effects of FDI and ODA on economic growth in developing countries is rather ambiguous (Alfaro, 2003). Some researchers find that the positive attributes of FDI only materialize if a certain threshold of development, for example in capital (Borensztein et al., 2004), financial institutions

(Durham, 2004) and financial market development (Alfaro et al., 2004) is already reached[1]. Accordingly, Kleimeier and Versteeg (2010) argue that in countries with underdeveloped financial markets not only the quantity of the capital inflow but the quality of the capital inflow matters. They further argue that, given its unique characteristics, project finance can substitute the lack of institutional and financial development.

2.2 Unique Characteristics of Project Finance

In a project finance scheme a so called sponsor, usually a very large multinational company, operating in the relevant sector, sets up a legally independent project company with a limited life (Special Purpose Vehicle). A project finance scheme is further characterized by non- or limited recourse debt, high debt levels and a detailed, long-term contracting.

In the following we address the unique characteristics of project finance and elaborate, why project finance is particularly suitable for the least developing countries.
First, project financing schemes help reduce *transaction costs* arising from asymmetric information and it can increase efficient capital allocation.

Managers might be inclined to undertake projects with negative NPV if these projects yield management perquisites. However, the need to raise substantial bank debt in project financing can reduce the risk of funding negative NPV projects (Esty, 2002). Banks are only willing to invest in a high leveraged asset, if they can be sure that the asset will generate sufficient cash flows to service the debt (Finnerty, 2006).

Furthermore, the concentrated equity ownership in project financing gives a stronger incentive for shareholder to control management behavior (Esty, 2002). At the same time the high leverage induces the participating banks to monitor the project performance carefully. In case more banks are involved in financing the project, one bank, mostly the so called lead arranger, will undertake the general monitoring. Given that most projects are large in size, it is not unusual that more than one bank is involved in the financing. Project financing can therefore generate economies of scale in control and reduces monitoring costs. Additionally, the separation of the project from the sponsor in combination with project financing features like covenants[2], debt service reserve account[3], sinking funds[4] and the finite life of the project makes it easier for shareholder to monitor the investment.

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[1] According to a study by Blomström et al. (1992), FDI does not stimulate growth in low-income developing countries.

[2] Covenants are generally financial ratios that the project entity is not allowed to exceed or resp. to fall short of. A very common covenants in project financing is the Debt Service Coverage Ratio (= CF available for debt service/ debt service). Often covenants in project financing are more extensive than they are in conventional financing. In case a covenant is broken the debt contract will be renegotiated (Finnerty, 2006)

[3] If a project performs better than anticipated, the additional cash is transferred to a sinking fund. The sinking fund can be used as an additional source for debt service financing, in case the projects falls short of cash flows later in the project life and works as a buffer (Navigator, 2010).

[4] Additional cash is set aside to retire back bank debt earlier (Finnerty, 2006).

Generally it is easier to structure a debt contract for a particular project than it is for an entire company (Finnerty, 2006).

Second, project financing can reduce *leverage-induced underinvestment,* arising when a leveraged firm experiences trouble financing attractive projects because of debt overhang at the company level. By using project financing a highly leveraged project structure, with all its advantages, can be achieved, while at the same time a debt overhang problem at the sponsor level can be avoided due to the limited to non-recourse nature of project finance. Project financing can so to say preserve the sponsor's corporate debt capacity as it eradicate all recourse back to the sponsor (Esty, 2002).

Third, project financing enhances *risk allocation and risk management*. The contractual structure of the project entity reduces uncertainty and thereby the cost of capital, by allocating the different risk factors to the project participant that is best able to bear them (Finnerty, 2006). A typical project finance transaction involves 15 parties and on average 40 contractual agreements. Usually there are at least four contracts that manage the supply of input, output, construction and operation. The extensive contracting reduces opportunistic behavior by related parties, like an increase [decrease] in the price of an input [output], once the investment is undertaken. Often crucial off-taker or suppliers are integrated in the ownership group (Esty, 2002).

Also political risks like expropriation can be reduced by using project financing. In developing counties the local government is often part of the project finance agreement, by providing guarantees, own equity and financial or other assurances. Additionally, in developing countries multilateral lending agencies such as the World Bank or the European Bank for Reconstruction are often part of the project company. Their political importance further reduces the risk of expropriation or other political hostile actions against the project. The ability to reducing risk makes project finance an ideal solution for risky projects. Unsurprisingly, a study by Hainz (2002) reveals that project finance is often used for projects with high political risk.

Reducing the risk of expropriation is particularly important for infrastructure investments. Infrastructure investments are tangible and often very capital-intensive investments, which have high location specificity. They cannot easily be moved in case of political or economic distress. Often they require high initial investments and generate a steady cash flow over the project life. Once established the infrastructure asset requires only moderate managerial skills. This makes infrastructure investments especially prone to creeping expropriation and hostile actions by host governments. In his study on project finance and corporate-financed investments in the oil, gas and petrochemical industries, Sawant (2010) only finds limited empirical support that project finance mitigates creeping expropriation. However, he finds empirical evidence that project finance reduces transaction costs arising from concentrated buyer and/or supplier and that project finance reduces the risk arising from large infrastructure investments for multinational enterprises.

2.3 Project Finance in LDCs

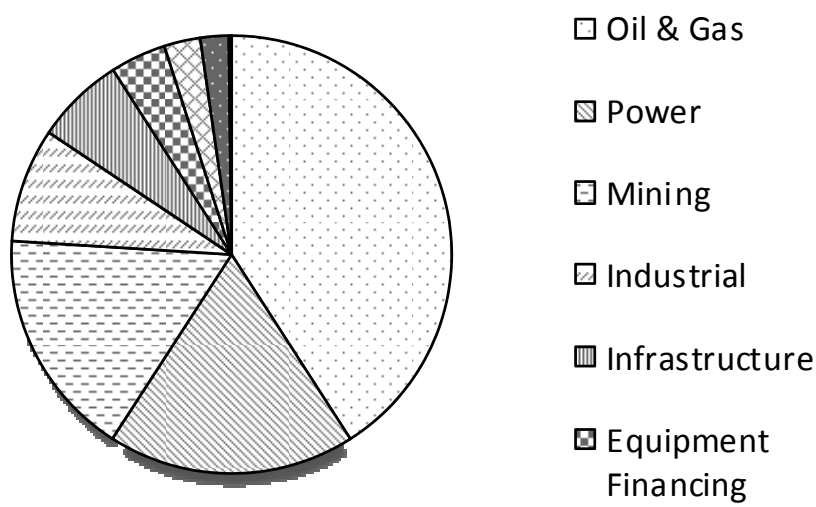
Compared to worldwide project finance volumes, LDCs only attracted comparably little project financing. This is largely due to the fact that LDC exhibit higher country risk and therefore investment risks as compared to developed counties, but also as compared to developing or low income countries[5]. Political unrest, macroeconomic instability, corruption as well as the risk of expropriation are especially prevalent in LDCs. This makes LDCs comparably less attractive for investors. However, compared to other forms of investments, project finance is nevertheless an attractive and especially suitable solution for LDCs, due to its risk mitigation characteristics. As stated earlier, in LDCs local governments are often part of the project finance agreement by providing guarantees or own equity and thereby reduce the political risk and risk of expropriation. Further, according to Dealogic, in nearly half of the project finance projects between 1980 to 2009 multilateral, bilateral and regional agencies, like the IFC or Development Bank of South Africa, were involved in the project finance agreements. The participation of development agencies can reduce political risk and improve the credibility of the project, whereby the project is attractive to commercial lenders even if the project is in a politically unstable LDC. Finally, project finance can reduce the risk of corruption and inefficient capital allocation, which are especially prevalent in LDCs. Due to the high leverage, banks and international companies are only willing to invest in positive NPV projects that will generate sufficient cash to service debt. Therefore, with project financing market mechanisms guide economic activates. Also the involvement of private international companies and banks can effectively reduce corruption ‘within‘ the project. To summarize, because of above average country risks in LDCs, project financing, with its unique risk mitigation characteristics, can be a particularly suitable solution for LDCs.

As displayed in Figure 1, project financing in LDCs is primarily applied in oil & gas, power and the mining sector. Given the severe danger of exchange rate fluctuation in LDCs, these sectors are more suitable as their output is priced in hard currencies. Not surprisingly, project financing is less common in the infrastructure sector. Infrastructure projects only generate revenues in local currencies and with substantial foreign currency financing, currency fluctuation impose a major threat.

But even though project finance in road infrastructure is rare in LDCs, a lot of the project finance deals in natural resources induced the construction of supplementary roads for transport. Take for example the Mozal Project in Mozambique in 1998: for the USD 1.4 billion aluminum smelter, Alusaf, a South African natural resource company, the Mozambican government and Eskom, a South African power utility company teamed up. As the aluminum production is energy-intensive, Eskom rebuild some of Mozambique’s damaged electricity infrastructure and produced inexpensive hydroelectric capacity from

[5] The low income category of countries comes from a classification by the World Bank (2010). There is not a one-to-one correspondence between LDC and low income countries although there is an overlap.

Figure 1: Project finance in our sample by industry



Note: Only the six largest slices are labelled.

the river Zambezi. Today, the Mozal Project provides Mozambique with new electrical and industrial infrastructure. Due to its very successful operation the Mozal Project even saw an expansion in 2001 (Esty, 2004). Another project in Mozambique, the Maputo Port Concession Project Finance deal in 2003, also reveals the spillover effect of project finance. Due to increased freight traffic, which was besides other the result of the Mozal Project, the port was modernized and transport connections by road and rail to neighboring countries were build. The concession improved efficiency and handling volumes doubled (World Bank, 2008).

By helping to unlock LDCs‘ natural resources, project finance further helps to generate government revenues through royalties and income tax, which can be used to promote further economic development. In project finance deals, where road infrastructure investments are necessary for operation, the government is often part of the project finance agreement and guarantees to provide the necessary transport connections. Even if the government is responsible for supplying the required infrastructure and not the project financing investor, this arrangement makes sure that at least some of the royalties the government receives from a mining or oil project finance deal are used for transportation investments and does not land in the pockets of government representatives or is used for military spending.

In a wider meaning the word infrastructure not only entails roads and ports, but also telecommunication, power generation and water supply. In the LDCs four-fifths of the total energy supply is provided by traditional fuels such as wood fuel. Yet the supply of wood fuel in Africa is only limited and its use causes desertification and environmental degradation. Also, about one-quarter of Africa’s hard currency is used to buy petroleum

products from other parts of the world. Given the extensive oil and gas resources of many of the African LDCs, own petroleum production could reduce balance of payments problems and potentially increase electricity supply (Bono, 1992). Another alternative source for energy in Africa is hydro power. From 1980 to 2009 there have been seven hydro power project finance deals worth more than 2.3 billion USD in debt value in the LDCs (Dealogic – Loan Analytic Database).

Hence even though only a small share of the project finance deals of our sample is classified as infrastructure projects there may be hidden infrastructure improvements in many of the other projects as well such that the link from project finance to infrastructure improvements can still be considered a natural channel for ultimate increases in economic growth.

2.4 Project Finance and Economic Growth

As mentioned before, the literature around project finance is still limited. To the best of our knowledge there is only one article so far that quantitatively investigates the effect of project finance on economic growth. In this article by Kleimeier and Versteeg (2010) the authors investigate project finance data from 90 countries. When accounting for the income level of the countries the authors find a significant positive effect of project finance on economic growth in low income countries. For middle and high income countries however, the growth effect is not significant. The authors argue that project finance is especially beneficial to the least developed countries as it "compensates for a lack of domestic financial development". Inspired by Kleimeier and Versteeg (2010) we focus exclusively on a sample of LDC's which we see as a natural extension: 1) In their theoretical section Kleimeier and Versteeg argue strongly for effects of project finance in LDC while they end up estimating effects for low income countries and not LDCs. There is an overlap between the two groups of countries but they are certainly not the same. In fact out of the 90 countries Kleimeier and Versteeg (2010) employ in their analysis, only 16 are from our group of LDCs. 2) The low income countries is the only group of countries in their study where they consistently find significant effects of project finance. Hence extending their study, as we do, by exclusively focusing on LDC seems natural. 3) Kleimeier and Versteeg (2010) incorporate a Sub-Saharan dummy, which has a significant negative coefficient in their study. The negative coefficient implies that the Sub-Saharan countries exhibit, on average, a lower GDP growth than the rest of the sample and that this lower growth cannot be explained by the other variables in the regression[6]. The Sub-Saharan dummy captures 12 out of their LDCs[7]. In our study we do not need a dummy to capture special features of the Sub-Saharan countries, which we see as an indication that our model to a larger extent

[6] The dummy does not imply that the Sub-Saharan countries 'drop out' of the sample. GDP growth in the Sub-Saharan countries is affected to the same extent by changes in project finance as the other countries in the sample.

[7] According to a classification of Sub-Saharan countries by the UNESCO Institute of Statistics (2010).

is able to capture the properties of the countries in our sample. 4) Finally, as our study only looks at LDCs, the coefficients of the control variables can reveal interesting information about the importance of certain variables for growth in LDCs. In the study by Kleimeier and Versteeg's (2010) the control variables' effect apply to a more general context of developing as well as developed countries. It might be that some control variables, which are of importance in a general context of developing and developed countries, end up trivial in a LDC context, and vice versa. Therefore, besides of investigating the growth-effect of project finance in LDCs, our study will also contribute to the limited research that has been done so far on LDCs and growth in general. In our study we employ data for 38 LDC's. For a list of these countries, see Appendix 1. The set of control variables in the study generally follows Kleimeier and Versteeg (2010) and include variables commonly used in the literature. However, due to the focus on LDCs the additional control variable ODA grants was included in the regression, while the control variable 'black market premium' was dropped[8] due to limited data. Contrary to Kleimeier and Versteeg (2010) we also include a war dummy amongst our controls. Further, some variables (education, regulatory quality and FDI) were drawn from different sources than those used by Kleimeier and Versteeg (2010), because of better data coverage. And finally, for this study marginally longer and more recent periods than those studied by Kleimeier and Versteeg (2010) are used[9].

3 Data and Econometric Models

3.1 The Models

As the purpose of the empirical analysis is to examine if project finance contributes to economic growth in LDCs, we base the methodology of this study on Kleimeier and Versteeg (2010) and Alfaro et al. (2004). Following the study by Kleimeier and Versteeg (2010), a neo-classical growth framework[10] is assumed, in which countries converge towards their GDP per capita equilibrium. Therefore, a country's GDP growth is a function of its initial GDP (actually the log of initial GDP), project finance (PF) and a set of control variables:

$$GROWTH_i = \beta_0 + \beta_1 \, INITIAL\ GDP_i + \beta_2 \, PF_i + \Sigma \, \gamma_j \, CONTROL_{ji} + \upsilon_i \qquad (1)$$

Equation (1) will be estimated by OLS and also by IV methods due to the possible endogeneity of project finance. We have also investigated the model using panel data methods (country fixed effects) on the two sub periods. In general we will keep a pragmatic

[8] The data on the black market premium used by Kleimeier and Versteeg (2010) are from the New York University's Global Development Network Growth Database. Unfortunately the database runs just until 1999 and has only limited records for LDCs.

[9] Kleimeier and Versteeg (2010) look at three 5-year periods (1991-1995, 1996-2000, 2001-2005)

[10] The neo-classical framework was first developed in the Swan-Solow and Ramsey-Cass-Koopmans model.

attitude towards model building looking at different models and estimation methods for as long as it is possible to see how this affects our results (Granger, 2009).

The CONTROLS comprise inflation, population growth, regulatory quality, openness, FDI, ODA grants, government consumption and education. A time dummy is incorporated when possible to account for a potential time effect or structural change between the two investigated periods. Finally we include a dummy for war.

In order to reduce the noise of annual data and to mitigate business cycles we use a panel of two 7-year periods from 1994 to 2000 and 2001 to 2007. This procedure is chosen due to the many zeros in the project finance series if analyzed on a yearly basis. The observations start with the year 1994, as for most variables data is available from 1994 onwards. Generally, an observation is included in the regression if at least four out of seven data points are available in the respective period. An observation constitutes the average over the 7-year period. For the period between 1994 and 2000 the source for regulatory quality only provides data for the years 2000, 1998 and 1996. Therefore, an observation is used as long as there are all three data points on regulatory quality available. PF, FDI and ODA are calculated as cumulated shares of the respective variables to GDP. This procedure is quite similar to the procedure used in Kleimeier and Versteeg (2010)[11]. Due to missing data points, the initial GDP, ODA and FDI in 1994 for the Maldives are estimated by linear extrapolation. Finally, FDI data points for Bhutan (1994, 1998) and Eritrea (1994, 1995) were estimated by linear inter- and extrapolation. Contrary to the other control variables, an observation for education is used as long as there is at least one data point available in the 7-year period. A country's education data does not vary considerably over the years and thus, a single data point for education can still be considered a reasonably good estimate for the average over the 7-year period.

For the regressions 72 observations are used. The observations for Haiti (2001-2007), Laos (1994-2000), Tanzania (2001-2007) and Yemen (2001-2007), drop out because of limited data on one or more of the explanatory variables. Even though formally belonging to the list of LCDs we have excluded Equatorial Guinea from our sample. Equatorial Guinea enjoyed a growth rate of on average 20.29% and in the period 1994-2000 the country surprised with an average growth rate of even 24.02%. The dramatic economic growth in Equatorial Guinea is thanks to the discovery and exploitation of large off-shore oil reserves. In the last decade Equatorial Guinea has become Sub-Saharan Africa's third largest exporter, even though by size it is one of the smallest countries in Africa with only around 700,000 inhabitants. According to the United Nations, Equatorial Guinea enjoys the fourth highest per capita income in the world, after Luxembourg, Bermuda and Jersey. Interestingly, despite the economic growth the living standards of the population only increased marginally. Also Equatorial Guinea is plagued by high corruption, with government officials and their families owning most businesses. The World Bank and the IMF even cut their aid programs due to government corruption and mismanagement (United Nations OHRILLS, 2012). As we can find good economic reasons for this country

[11] They, however, use periods of 5 years of duration instead of our 7 years.

and periods to behave differently from the bulk of observations we believe that excluding this country can easily be defended.

3.2 The Data and Descriptive Statistics

The data sources and their definitions are found in Appendix 2. Table 1 displays the descriptive statistics for the dependent and independent variables over the two 7-year periods. The table shows a considerable cross-country variation. Looking at the sample of the OLS regression of equation (1), the mean per capita growth rate over the two 7-year periods is 1.62% with a standard deviation of 2.83. The maximum growth was enjoyed by Sierre Leone (8.07%) in the period 2001-2007, while the Democratic Republic of Congo suffered a growth rate of -5.65% during the first sub period.

Table 1: Descriptive statistics on our variables. Based on the 72 'full sample' observations

Variable	Mean	Std Dev	Minimum	Maximum
Project finance cum. (%)	3.59	9.73	0.00	51.58
FDI cum. (%)	21.67	27.71	-11.59	171.85
ODA cum. (%)	105.87	66.27	9.94	278.41
GDP growth (%)	1.62	2.83	-5.65	8.07
Log og initial GDP p.c.	5.69	0.67	4.39	7.79
Inflation (%)	68.42	487.83	1.01	4149.12
Population Growth (%)	2.55	0.70	0.65	4.23
Openness (% of GDP)	67.40	31.78	21.43	165.86
Regulatory Quality	-0.68	0.52	-2.44	0.61
Gov. Consumption	14.80	8.27	4.48	46.91
Education (%)	24.28	12.45	5.73	72.48
War dummy	0.25	0.44	0.00	1.00

The mean inflation is 68.42% combined with a striking standard deviation of 487.83. The Democratic Republic of Congo has experienced an inflation rate as high as 4149.12% in the period 1994-2000, revealing the macroeconomic problems prevalent in many of the LDCs. Moreover, regulatory quality is low in most of the LDCs, with an average mean of -0.68, implying rather unfavorable business conditions. Cumulative inflow (e.g. stock) of FDI to GDP amount to 21.67%, with a standard deviation of 27.71, revealing that FDI, like project finance, is selective and does not flow to every country equally. The maximum

cumulative FDI inflow was experienced by Chad in the period 2001-2007 with 171.85%. In studies with both developing and developed countries, FDI per annum is generally around 1-2% of GDP[12]. The somewhat higher FDI/GDP ratio in this sample, of on average 3.10% in the two 7-year periods, might be due to the comparably lower GDP of LDCs, combined with FDI inflows for mainly rather costly oil operations. The cumulative inflow of project finance over the two 7-year periods in the baseline regression is 3.59% to GDP, which implies an average of about 0.51% per year. Kleimeier and Versteeg (2010), who investigate both developing and developed countries, find that in most years project finance deals account for no more than 0.01% of GDP. Again, the higher project finance to GDP ratio in our sample might be due to the overall lower level of GDP in LDCs. Similar to FDI, project finance inflows exhibit considerable variation, with a standard deviation of 9.73%. There are a lot of countries that experienced no project finance inflows at all, while others, like Chad had cumulative project finance inflows to GDP of as much as 51.58% during the period 2001-2007. Finally, average cumulative inflow of ODA grants is as much as 105.87% of GDP in the two 7-year periods. ODA appears to be an important source for capital in the LDCs. Especially, as ODA grants only constitute part of the total ODA flows. Given the substantial size of ODA disbursements, it is very surprising that most studies cannot find a significant effect of ODA on economic growth. Similar to project finance and FDI, there is considerable variation in the cumulative ODA inflows to GDP across countries. Bangladesh (cumulative ODA/GDP of 9.94% between 2001-2007) had the lowest cumulative ODA inflows to GDP in the sample. Guinea-Bissau experienced the highest inflow of ODA grants relative to GDP in the two 7-year periods, with 278.41% in 1994-2000 and 273.11% in 2001-2007. Government consumption is on average 14.80% of GDP per year in the LDCs. The findings are in line with the average government consumption (15%) reported by Carkovic and Levine (2003) in their study of developing countries and somewhat lower than the average government consumption (around 24%) reported by Kleimeier and Versteeg (2010) in their study of both developing and developed countries. With 4.48% of GDP in 2001-2007, Cambodia has the lowest government consumption in the sample, while government consumption in Eritrea is as high as 46.91% of GDP in the period 1994-2000. Average enrollment in secondary education relative to the population of the age group that officially corresponds to the level of secondary education in the LDCs is 24.28% in the two 7-year periods. Again, there is considerable cross-country variation. The Maldives have the highest enrollment rate with 72.48% in 2001-2007. The lowest rate of enrollment can be found in Tanzania in the period 1994-2000 (5.73%). But also Burundi, Mozambique and Niger have enrollment rates of less than 7% in the period 1994-2000. However, in all three countries the enrollment rate increased by 2-7 percentage points in the subsequent period 2001-2007. As comparison, the enrollment rate in developed countries like the USA or UK is around 95% to 100%.

[12] Alfaro et al. (2004) have a FDI/GDP of 1% in their sample, Carkovic and Levine (2003) show a FDI/GDP ratio of 1.1% and Kleimeier and Versteeg (2010) suggest that FDI is typically between 1% and 5% of GDP.

The descriptive statistics reveal that, even though all the countries in the sample belong to the group of LDCs, there is considerable variation between the countries in terms of social and macroeconomic conditions.

4. Results

The purpose of the empirical analysis is to examine if project finance has a positive effect on economic development in the LDCs. Table 2 presents the results of the OLS estimation of equation (1) on the pooled data set consisting of the two 7-year periods 2001-2007 and 1994-2000. In Table 2, columns one through 3, a robust standard error is provided below each coefficient estimate. Notice, however, that we find no indication of heteroscedasticity in any of the regressions (results of heteroscedasticity test are available upon request). A limitation of the analysis is that a rather small time frame is investigated. Even though it is common in the literature on ODA and FDI to use 4-year growth regressions, Rajan and Subramanian (2008) advise to use longer term periods. They argue that short-term regressions are prone to cyclical factors and possibly overlook long-run effects. Unfortunately, our sample does not allow for a long-term econometric analysis. First, project finance was not popular until the beginning of the 1990s and especially in the LDCs there were hardly any project finance deals before 1990. Second, as we concentrate only on LDCs the sample size is limited. If we had investigated one 14-year period instead of two 7-year periods, half of the observations would have been lost due to limited data and the degrees of freedom of the model would have severely decreased. In addition to the pooled sample results we also show results for the two sub samples individually. This allows the reader to look for changes from the first sub period to the next. Also the results of the second sub sample will be more comparable to the results of the SUR estimation in Table 2 and the IV and panel estimations in Table 4. Finally, Table 2 contains estimation results based on a SUR approach. This approach is not the classical SUR of a panel data set as that would imply separate regressions for each country taking correlation amongst countries into account. Instead we allow for correlation amongst the two sub periods in our SUR results (a kind of correction for autocorrelation).

The OLS estimation results of equation (1) in column one are used as our starting point. They are in line with prior expectations and match evidence from other studies on economic growth. First, consider the parameter estimates for the control variables. The coefficient of initial GDP is not significant. This might be due to a lower variation in the initial GDP of the LDCs, compared to a sample of both developing and developed countries. Ghosh and Wang (2009) argue that in a sample with countries of similar economic development, country-specific fixed effects might actually be more important for changes in economic growth than the countries' initial conditions. Also, various studies argue that there has been no tendency of low income countries to catch up with developed countries (Sachs and Warner, 1995). Next, inflation exhibits a significant negative impact on growth[13].

[13] Notice however that the significance disappears if data for the democratic republic of Congo is

Table 2: Results of OLS and SUR estimations of growth in LCDs

				SUR	SUR
	Full sample	1994-2000	2001-2007	1994-2000	2001-2007
Intercept	0.014	0.034	-0.034	0.024	-0.033
	(0.031)	(0.036)	(0.056)	(0.051)	(0.063)
Project finance	0.077***	0.161***	0.054**	0.145	0.060
	(0.022)	(0.056)	(0.024)	(0.093)	(0.047)
FDI	-0.005	-0.004	-0.007	-0.007	-0.004
	(0.008)	(0.031)	(0.009)	(0.033)	(0.016)
ODA	-0.002	-0.004	0.001	-0.002	0.004
	(0.004)	(0.004)	(0.008)	(0.007)	(0.007)
Log init. GDP	0.000	-0.006	0.011	-0.005	0.010
	(0.005)	(0.006)	(0.008)	(0.009)	(0.010)
Inflation	-0.001***	-0.002**	-0.038	-0.001*	-0.038
	(0.000)	(0.001)	(0.037)	(0.001)	(0.042)
Population	-0.002	0.332	-0.132	0.439	-0.189
	(0.387)	(0.483)	(0.513)	(0.558)	(0.809)
Openness	0.014	0.006	0.024	0.004	0.020
	(0.013)	(0.017)	(0.020)	(0.024)	(0.020)
Reg. quality	0.027***	0.029***	0.014	0.030***	0.016
	(0.005)	(0.007)	(0.010)	(0.009)	(0.011)
Gov. Consump.	-0.090**	-0.040	-0.165**	-0.043	-0.161**
	(0.037)	(0.047)	(0.063)	(0.059)	(0.065)
Education	0.052**	0.080**	0.034	0.088	0.045
	(0.025)	(0.030)	(0.033)	(0.053)	(0.049)
Period dummy	0.012**	-	-	-	-
	(0.005)				
War dummy	0.031***	0.022***	0.045***	0.023**	0.045***
	(0.007)	(0.007)	(0.009)	(0.010)	(0.011)
Adj R^2	0.52	0.50	0.41	0.62[a]	0.62[a]
No. Obs.	72	37	35	68[a]	68[a]

Notes: Values in parentheses are robust standard errors for the first 3 specifications and standard errors for the SUR equations. Significance: *** at 1% level, ** at 5% level and * at 10% level. The superscript 'a' refers to system values.

Inflation is a proxy for macroeconomic stability, so we would expect a negative coefficient. Kleimeier and Versteeg (2010) also find that inflation has a significant negative effect on growth.

Our estimate of the coefficient of population growth is negative and insignificant. Studies that investigate the effect of population growth on economic development yield only inconclusive results. This might be because population growth has a different impact on economic growth in developing countries vs. developed countries. In developed countries low population growth threatens the supply of (skilled) workers, whereas in developing countries population growth is blamed to trigger economic stagnation with underemployment, low wages and sluggish market demand (Crenshaw et al., 1997). The estimate for population growth in column 1 has a negative sign, but it is far from being significant. Kleimeier and Versteeg (2010) find a significant negative coefficient of population growth, but only in their extended regression. The difference in their results on population growth compared to ours might be because their sample includes both developing and developed countries. Openness to international trade exhibits an insignificant positive effect on economic growth. In theory, openness to international trade increases competition and triggers gains in efficiencies. Countries that specialize according to their comparative advantage ultimately achieve a higher output. Waczjarg (1998) finds that openness triggers economic growth mainly through the increasing accumulation of physical capital. And Sachs and Warner (1995) argue that the lack of trade is the reason for the sluggish convergence of low income countries. In the study by Kleimeier and Versteeg (2010) openness exhibits a positive coefficient, but it is not significant. In line with prior expectations regulatory quality shows a significant positive effect on growth. Regulatory quality has a coefficient estimate of 0.027, implying that an increase in regulatory quality by one unit increases growth by 2.7%. An approximately one unit increase would occur if for example The Democratic Republic of Congo, with an average regulatory quality of -1.58 (2001-1007), moves to the same level of regulatory quality as Nepal or Zambia, with an average regulatory quality of -0.58 (2001-2007). Regulatory quality captures the ability of the country's government to employ sound policies and regulations in order to promote private sector development. In the study by Kleimeier and Versteeg (2010) the law variable has a positive coefficient, but it is not consistently significant. The coefficient of government consumption is negative and significant at the 5% level. Empirical evidence suggests that government consumption generally has a negative effect on growth. Excessive government consumption often causes inflation and an increase in interest rates. This is however not true for public investment expenditures in education or healthcare, which generally trigger a positive effect on economic growth (Saleh, 2003). Kleimeier and Versteeg (2010) find no significant effect of government consumption on growth. Next, secondary education

neutralized. This country experienced a very atypical period of extremely high inflation during our sample period. Due to this sensitivity of our estimation results towards data from one specific country we ask the reader not to put too much emphasis on this coefficient estimate. The estimates of the other coefficients are however barely affected and their significance not at all affected if a dummy for this country is included.

shows a significant positive effect on economic growth, which is again in line with prior expectations and other studies (Haldar and Mallik, 2010, Kleimeier and Versteeg, 2010). However Kleimeier and Versteeg (2010) only find a significant positive effect of education on growth in their baseline regression. Our study suggests, that an increase in the secondary education enrollment rate from 0.25% to 0.5% increase growth by 1.30% (=0.052*0.25). The coefficients of ODA and FDI exhibit negative signs. They are however insignificant. The negative sign possibly indicates that the negative effects of ODA, like inflationary pressure and crowding out of private (foreign) investment, prevail in LDCs. But we have to be careful with our interpretation, as the negative sign could be caused by inverse causality. Countries that experience war and natural disaster receive more ODA, while at the same time their GDP often decreases. The coefficient of the time dummy exhibits a significant positive sign, indicating that the average GDP growth per capita was higher in the period 2001-2007 than in the period 1994-2000, while it cannot be explained by the other control variables. The war-coefficient is consistently positive and significant[14].

Finally, turning to project finance, a significant positive effect of project finance on economic growth in LDCs is found. The quantitative impact of project finance on growth in the LDCs is substantial. Recall that on average the LDCs have a ratio of 3.59% project finance to GDP over the two 7-year periods. Further, project finance shows a coefficient estimate of 0.077. A country that currently does not use project finance can increase its average growth by 0.28% (=0.0359*0.077), if it moves to the average level of project finance. As another example let us take Ethiopia[15], as one of the countries that currently does not employ project finance. If Ethiopia increases its average cumulative project finance to GDP over the two 7-year periods to one of the countries that have a high level of project finance to GDP[16], like Mozambique with 26.16% (2001-2007), Ethiopia would increase growth by as much as 2.01% (=0.2616*0.077) annually. Kleimeier and Versteeg (2010) find a somewhat stronger effect of project finance on economic growth[17]. In their study, a county that currently does not employ any project finance can increase its annual growth by 0.56% if it moves to the average level in the sample of 0.014% project finance to GDP.

[14] This latter result is a bit puzzling as most empirical evidence points towards either insignificance or negative effects (see e.g. Koubi (2005)). There are however theoretical explanations in support for a positive effect especially when analyzing average data over a period of time. The main argument is that growth increases in the periods just after the end of a war. Taking a look of our data it turns out that our war effect is mainly driven by only six countries so another possibility is that special factors were actually present for those countries. We have not investigated this topic further as the war variable is not one of our variables of main interest but we leave it in the model now that it has actually turned out significant.

[15] Ethiopia is used for illustrative purpose. Any other country with no project finance over the two 7-year periods could be used.

[16] Other countries with high average cumulative project finance to GDP over the two 7-year periods are for example Djibouti (18.82%) and Chad (25.79%). Laos has a value of 31.9% but due to missing values only observations for the second sub period can be used for this country.

[17] In their study Kleimeier and Versteeg (2010) use a log-linear model. Therefore, one cannot directly compare the coefficients of their study to those in this study.

As pointed out by Kleimeier and Versteeg (2010), it is not clear if the positive growth-effects of project finance are triggered by benefits unique to project finance or due to general benefits of foreign capital. Therefore, FDI is included in the equation as an additional variable. However, including FDI together with project finance in one regression is not without risk. Depending on the composition of the equity part, project finance can be a form of FDI. Recall that a project finance deal commonly consists of around 30% equity. For deals in LDCs the equity part is most often provided by foreign investors. Note also that an investment is classified as FDI if at least 10% of the equity is contributed by an investor from abroad. Given this definition, some of the project finance deals are likely included in the FDI data as well[18]. Nevertheless, equation (1) can provide an impression of the different growth-effects of project finance vs. FDI. Even with FDI in the model, project finance is still significant. This indicates that the growth-effect of project finance is unique and not due to the effect of foreign capital in general. FDI is as stated earlier not significant and even has a negative sign.

The estimation results shown in column two are results based on OLS but only using the observations for sub period one. In column three the results for sub period two are found. As the two sub periods cover seven years each there may be a reason to believe that maybe the results have changed from the first to the second sub period. Hence based on a comparison between columns two and three the issue of model stability can be discussed. Also later in the robustness section we report results of estimations using alternative modelling approaches that in our case only work for the second sub sample and then column three will provide a more "fair" comparison for e.g. the IV estimation results. Due to the use of lagged PF as an instrument when using IV methods, we can only get results for the second sub period in this case. Focusing on the estimate of PF, we see that this coefficient is positive and significant for both sub periods although it is somewhat smaller for the most recent sub sample. The coefficient of inflation is negative in both sub periods but only significant in the first. For the first sub period regulatory quality is significant while government consumption is significant only for the second sub sample. For both of these explanatory factors the signs are the same for both sub periods. The coefficient of education turns out insignificant for the second sub sample but again has the same sign. We run a Chow type test for a structural break in equation one with respect to the two sub periods. Results from this test are: F-stat = 0.99 with p-value = 0.468 (and in the version of the tests that uses heteroscedasticity-corrected standard errors: Q-stat = 21.4 and the p-value = 0.045 for a Chi Square distribution with 12 degrees of freedom). The hypothesis is accepted based on the F-version of the test and borderline rejected at the 5% level for the Chi square version of the test. Hence we do not see this as a major problem for stability of the model although of course one has to keep in mind that the relative importance of the explanatory factors may change somewhat as time passes.

Finally, in columns four and five we report the results of the SUR estimation. As can

[18] Surprisingly, the correlation between project finance and FDI is 0.23 and hardly significantly different from zero.

be seen from the table the signs and sizes of the coefficients do not change much compared to the OLS sub sample values. In general the standard errors in the SUR case are larger than for OLS, and therefore more coefficients appear insignificant. This is probably due to the relatively small number of observations in our study.

To sum up: in none of the regressions the coefficient of project finance exhibits a negative sign, irrespectively of the estimation method used. We consistently find a positive effect of project finance on growth in the LDCs. The size of the effect varies somewhat by sub period but in all cases it seems to contribute significantly to the growth in the LDC's. In addition, for the first sub period regulatory quality and educational level seem to be important for growth while government consumption seems more important during the second sub period.

5. Robustness Checks

5.1 The Issue of Data Quality

In this sub section we report results of OLS regressions for pooled data from both of our sub periods but with different selections of countries or observations excluded. Sub sets are excluded based on data quality considerations and hence this exercise can be seen as a robustness check of the data quality. The results are reported in Table 3.

For comparisons reasons, the first column of Table 3 is just repeating the full sample results of Table 2. In the second column we report results of a sample that only includes observations where the education variable is based on more than one year from each 7-year period. If a country has missing values for the education variable, then a hypothesis can be, that also the quality of the remaining data for that country is questionable.

In the third column we exclude the Maldives, Bhutan and Eritrea, all countries for which we have performed linear extrapolations to obtain information for all explanatory factors. Finally, in column four we report results from a sample without Haiti, Laos, Tanzania and Yemen, the four countries where only the observation from one of the sub periods can be used. In all of these cases almost all of the previously significant coefficients are still significant, of the same sign and of approximately the same size. Hence, we find no strong indications that our results are in general sensitive to the data quality as investigated by exclusion of sub groups of countries or specific observations of countries.

5.2 Alternative Models and Estimation Methods

The results reported in Table 4 contain estimates from a panel data country fixed effect model and also from a 2 SLS IV estimation of equation (1). The first column of Table 4 is repeating the OLS results of the second sub sample for comparison reasons as the panel estimation basically relies on the differences in variable values between the two sub periods and the IV estimation relies on lagged project finance (from the first sub period for the data of the second sub period) as the instrument.

Table 3: Results of robustness checks for growth in LDCs with sub sets of countries and/or observations excluded

Variables	Full sample and OLS[a] (from table 2 for comparison)	Only observations with the education variable based on more than one year[b]	Sample without Maldives, Bhutan and Eritrea (countries with linear extrapolations)	Sample without countries with data for just one sub period (Haiti, Laos, Tanzania and Yemen dropped)
Intercept	0.014	0.041	0.016	0.013
	(0.031)	(0.028)	(0.033)	(0.032)
Project finance	0.077***	0.066***	0.077***	0.074**
	(0.022)	(0.020)	(0.022)	(0.031)
FDI	-0.005	-0.003	-0.006	-0.003
	(0.008)	(0.007)	(0.009)	(0.009)
ODA	-0.002	0.002	-0.005	-0.002
	(0.004)	(0.005)	(0.004)	(0.004)
Log init. GDP	0.000	-0.002	-0.002	0.001
	(0.005)	(0.004)	(0.005)	(0.005)
Inflation	-0.001***	-0.002***	-0.002***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Population	-0.002	-0.710	0.337	-0.050
	(0.387)	(0.323)	(0.400)	(0.429)
Openness	0.014	0.015	0.015	0.012
	(0.013)	(0.012)	(0.016)	(0.014)
Reg. quality	0.027***	0.023***	0.022***	0.027***
	(0.005)	(0.005)	(0.005)	(0.005)
Gov. Consump.	-0.090**	-0.097***	-0.095	-0.092**
	(0.037)	(0.034)	(0.058)	(0.036)
Education	0.052**	0.044*	0.042	0.053*
	(0.025)	(0.025)	(0.028)	(0.028)
Period dummy	0.012**	0.009*	0.015***	0.011**
	(0.005)	(0.005)	(0.005)	(0.005)
War dummy	0.031***	0.031***	0.028***	0.031***
	(0.007)	(0.006)	(0.007)	(0.007
Adj R^2	0.52	0.53	0.50	0.50
No. Obs.	72	66	66	68

Note: Values in parentheses are robust standard errors. Significance: *** at 1% level, ** at 5% level and * at 10% level. Superscript 'a': A version of this model extended by a Sub-Saharan dummy shows no significance of this dummy. These results are available from the authors upon request. Superscript 'b': in this case first period observations for Burundi, Central African Republic, Madagascar, Sierra Leone are dropped, and for Guinea-Bissau both sub periods are excluded.

In column 2 of Table 4 we report results of a panel country fixed effects estimation of equation (1). For the panel estimation each time period is one of our 7-year periods so the panel just consists of two observations in the time dimension. Yet this is enough to remove firm specific heterogeneity with respect to the intercept term of the model. We consider this a great advantage as the LDCs of our sample are very different[19]. In the panel estimations we are not able to use IV methods at the same time. The results in column 2 show that the coefficient of project finance is significant and somewhat larger than the OLS estimate. In addition ODA, openness, regulatory quality and education are significant and have the expected signs. Hence, our results also seem robust when the data are analyzed in this way.

As mentioned previously there may be a problem of adverse causality in equation (1). Initially, in the OLS estimations, we would argue that using averages or cumulative values over the 7 year periods we are trying to avoid this potential reverse causality. As pointed out in the literature on FDI and project finance, it is likely that foreign capital is invested in countries that experience high growth rates. If this is the case, the OLS regression will overstate the effect of project finance on economic growth. Instead of using averages and cumulative values for fairly long sub periods, another way of solving the potential endogeneity problem is by means of IV estimation. As usual the finding of an appropriate instrument is challenging. In the present study we follow the idea of Kleimeier and Versteeg (2010) and use lagged project finance as our instrument. Their argument for this choice of instrument is that flows of capital are fairly persistent over time. Due to the length of the sub periods, and the fact that lagged project finance (in addition to the other explanatory variables) significantly contributes to the explanation of the present project finance, see column four of Table 4, we will argue that lagged project finance is a valid instrument[20].

The results of the IV/2SLS estimation are shown in the third column of Table 4. The coefficient of project finance is still significant and has about the same size as in the panel approach case. Government consumption is significant and of the expected sign in the IV case as well. Overall, the results continue to support the findings that project finance promotes economic growth in the LDCs. In their study, Kleimeier and Versteeg (2010) also find an increase in the coefficient of project finance in the IV regressions, compared to the original OLS. The increase might result from a measurement error where the OLS results are biased towards zero. The instrumental variables estimation corrects for this measurement error.

[19] In the panel regression we do not use initial GDP as a regressor as that would complicate the model by adding a dynamic element that may bias the coefficient estimates. We choose this simple solution to the problem as initial GDP is never close to being significant in any of our models and estimations.

[20] In the literature it is also proposed to use the real exchange rate as an instrument. This instrument was, however, not a valid one for our study. As suggested by an anonymous referee, we have also tried to use lagged values of FDI, ODA and initial GDP as instruments. Again none of these variables qualifies as a valid instrument in our case. Finally, we have also investigated the possibility of using measures of mineral and oil reserves in the LDC as instruments. Also this approach proved unsuccessful.

Table 4: Results of robustness checks using alternative estimation methods for growth in LDCs. (The dependent variable is growth in column one to three and project finance in column four)

Variables	OLS 2001-2007 (from table 2 for comparison)	Panel data approach. Country fixed effects.	IV estimation Lagged PF used as the instrument.	IV first step: PF regressed on lagged PF and the other explanatory variables.
Intercept	-0.034	-0.069***	-0.031	0.004
	(0.056)	(0.020)	(0.056)	(0.093)
Project finance	0.054**	0.124***	0.117**	-
	(0.024)	(0.015)	(0.045)	
FDI	-0.007	-0.004	-0.018	0.222***
	(0.009)	(0.005)	(0.012)	(0.078)
ODA	0.001	0.015**	0.003	-0.020
	(0.008)	(0.006)	(0.008)	(0.023)
Log init. GDP	0.011	-	0.009	0.000
	(0.008)		(0.008)	(0.000)
Inflation	-0.038	-0.001	-0.034	-0.315**
	(0.037)	(0.000)	(0.038)	(0.123)
Population	-0.132	0.064	-0.120	0.366
	(0.513)	(0.334)	(0.575)	(2.979)
Openness	0.024	0.028*	0.021	-0.010
	(0.020)	(0.015)	(0.024)	(0.068)
Reg. quality	0.014	0.039***	0.018	-0.045
	(0.010)	(0.008)	(0.012)	(0.037)
Gov. Consump.	-0.165	-0.072	-0.148*	-0.048
	(0.063)	(0.084)	(0.074)	(0.277)
Education	0.034	0.143***	0.048	-0.160
	(0.033)	(0.029)	(0.039)	(0.176)
War dummy	0.045***	0.052**	0.045***	0.017
	(0.009)	(0.020)	(0.010)	(0.033)
Lagged PF	-	-	-	1.241***
				(0.262)
Adj R^2	0.41	0.73[a]	0.33	0.47
No. Obs.	35	34	35	35

Notes: Values in parentheses are robust standard errors. Significance: *** at 1% level, ** at 5% level and * at 10% level. Superscript 'a': this R^2 is artificially high due to the country fixed effects.

6. Conclusion

In this study we have analyzed the effect of project finance on economic development in a sample of the least developed countries. To our knowledge we are the first ones to focus this kind of study specifically on this group of countries. As the group of least developed countries is the group of countries that may benefit the most from this type of investments we believe that our results will be of high interest. Following the tradition in the field, our empirical model is inspired by the neoclassical growth model. Trying to exploit our data as much as possible econometrically, we offer results based on both OLS and IV estimation and we also use panel data techniques. Irrespectively of the model or method used, we find a significant positive effect of project finance on economic growth.

Also, apart from the significant effects of project finance we are able to identify an additional group of variables that helps explain growth in the LDC: higher regulatory quality, lower government consumption and a higher level of education seems to be of importance for economic growth. The significance of these variables are, however, not as consistently robust as the results for project finance. Finally, from a policy perspective, our results are of interest as they may suggest that lenders, especially international development organizations like the World Bank, the International Finance Corporation (IFC) and the African Development Bank, should not cut back on project finance to LDC countries in times of a financial crisis. This is a general suggestion due to the quite robust finding of a positive impact of project finance on economic growth in these countries.

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Appendix 1

Countries included in the analysis

Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Congo, Djibouti, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti (only 1st sub period), Laos (only 2nd sub period), Lesotho, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Nepal, Niger, Rwanda, Senegal, Sierra Leone, Solomon Islands, Sudan, Tanzania (only 1st sub period), Togo, Uganda, Vanuatu, Yemen (only 1st sub period), Zambia.

Appendix 2

The data

Growth	Measured as real GDP per capita growth in constant 2000 USD. Retrieved from the World Development Indicators Online from the World Bank (2010).
Initial GDP	Initial level of GDP for each sub period. Retrieved from the World Development Indicators Online from the World Bank (2010).
Inflation	Measured as the percentage change in the GDP deflator, which is the ratio of GDP in current local currency to GDP in constant local currency. Inflation is a proxy for macroeconomic stability. The data are retrieved from the World Development Indicators Online from the World Bank (2010).
Population growth	Measured as the annual percentage population growth. Retrieved from the World Development Indicators Online from the World Bank (2010).
Openness	Measured as the sum of exports plus imports relative to total GDP (output). This should proxy the openness of the country to international trade. The data are retrieved from the World Development Indicators Online from the World Bank (2010).
Regulatory Quality	Captures perceptions of the ability of a country's government to employ sound policies and regulations that help promote private sector development. The indicator is estimated by surveys from a large number of enterprises, citizens and experts of both developing and developed countries. The indicator range from about -2.5 to + 2.5, with higher values indicating better governance. Data is retrieved from Kaufmann et al. (2009).

Government Consumption	Measured as the general government final consumption expenditure to GDP. The general government consumption expenditures also include most expenditure on national defense and security. The data are retrieved from the World Development Indicators Online from the World Bank (2010).
Education	Measured as the ratio of total enrollment (regardless of age) in secondary education relative to the population of the age group that officially corresponds to the level of secondary education. As stated by the World Bank, after secondary education, the basic education is completed, and a foundation for lifelong learning is developed. Retrieved from the World Development Indicators Online from the World Bank (2010).
FDI	Measured as the inflow of FDI as percentage of GDP (the sum of these ratios over each 7 year period). FDI is a long-term investment in which a foreign investor (a resident from another country) owns at least ten percent of the equity. The data are retrieved as USD at current prices and current exchange rates in millions from the Beyond 20/20 Web Data Server from the UNCTAD, World Investment Report (2009). The data is then converted to real dollar values using the US GDP deflator provided by the World Development Indicators Online from the World Bank (2010)
ODA Grants	Measured as real disbursements of ODA grants relative to the country's GDP (the sum of these ratios over each 7 year period). Data on disbursements are preferred over ODA commitment, as growth is more likely to be affected by actual money transfers. ODA grants are chosen instead of total ODA (The OECD's Creditor Reporting System differentiates between ODA grants, grants-like ODA, ODA loan and ODA equity), since including ODA loan would risk accounting double for some of the money that has flowed into the country. This is because several of the PF deals were financed partially by the World Bank and therefore are possibly reflected in ODA loans. The data are retrieved from the OECD's Creditor Reporting System in current USD million and converted to real dollar values using the US GDP deflator provided by the World Development Indicators Online from the World Bank (2010).

PF	Measured in real USD million relative to GDP (the sum of these ratios over each 7 year period). The data are retrieved from the Dealogic – Loan Analytic Database (This database covers more than 120.000 loan transactions, including project finance loans, since 1980. The deal signing date is used as reference date for the yearly data. All deals in currencies other than US$ were converted at the exchange rate at signing date. The reported deal volumes only reflect the debt financing part and not the total deal volume, which further includes an equity part of on average 10%-30%.) in current USD and converted to real dollar values using the US GDP deflator provided by the World Development Indicators Online from the World Bank (2010)
War dummy	This dummy takes the value 1 if the country were at war in the time period and zero otherwise. UCDP/PRIO Armed Conflict Dataset Gleditsch et al. (2002).
Time Dummy	Dummy that indicates all observation from the period 2001 to 2007

Business concentration through the eyes of the HHI

George Djolov[1]

Abstract

This paper examines the understanding of business concentration through the Herfindahl-Hirschman Index (HHI), by showing that this index is conceptually a model according to which this concentration is the consequence of a renewal process. This process is prompted by firms engaging in different types of economic activity as the means by which to vie for market share. The resultant rivalry produces departures between the market shares of firms. These departures ultimately transmit into differing concentration levels attributable only to the economic activity with which firms vie. As a consequence, while the HHI is commonly interpreted to be a screening indicator of market structure, it is in fact first and foremost a screening indicator of market conduct, which incidentally doubles-up as an indicator of market structure. As part of this, the paper shows that while the HHI cannot identify the exact economic conduct that produces the corresponding business concentration of the observed market structure, it does reveal that whatever this conduct is, it is always subordinated to some type of regenerative or revitalising process.

Keywords: Business concentration, Market conduct, Market structure, Renewal processes

JEL Classification: C15, C46, L11

1. Introduction

There is an established thinking in the economics field that while statistical theory is helpful in the measurement of business concentration, for instance through the likes of the Herfindahl-Hirschman Index (HHI), it is not helpful with understanding what is the driving force behind this concentration. Nutter (1968, p. 219) was among the first to spell this out, giving the following detailed explanation:

> "Observed density distributions of firm size are almost always unimodal and skewed upwards: firms are clustered about a relatively limited range of sizes with a longer taper toward the larger sizes than toward the smaller ones. It is reasonable

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> to suppose that this characteristic shape results at least in part from a … growth process, and some economists have therefore tried … to approximate observed size distributions by lognormal, Yule, Pareto, and similar distributions…. Even if good fits could always be obtained … a collection of curves would mean little without some theoretical framework for interpreting them. Unfortunately, no systematic theory of industrial structure has yet emerged from studies of this type to command … agreement among … economists. In the absence of such a theory, measures of industrial concentration are generally confined to descriptive indexes not amenable to formal statistical analysis."

Almost thirty years later, Davies (1996, pp. 105-106) has supported Nutter's conclusion, observing that while statistical theory has proven successful in accounting for the characteristically positive skewness of firm size distributions, it offers no understanding of the forces at work that determine business concentration. Through an illustration of the HHI, in light of it being the most practically relevant measure of business concentration, the present paper seeks to demonstrate that such thinking is mostly a matter of belief. This exposition will firstly proceed with the innate statistical mechanics of the HHI in light of new evidence showing that the Chi-square distribution is the approximate sampling distribution of the HHI (Djolov, 2013, pp. 213-214). From this evidence, it will become apparent that in and of itself the HHI is a model in the sense of being a conceptual portrayal of economic activity, according to which a renewal process drives this activity. By extension the same process drives business concentration. To make this easier to absorb, the model-based nature of the HHI will be empirically confirmed through a simulation. Zickar (2006, pp. 427-428) advises that there are two main advantages to doing this type of analysis. One, simulation permits for a firm control over the compilation and analysis of estimates by making their generation a controlled event. This is not always achievable or feasible with primary or secondary data, which in one or another way are always subjected to the vagaries of field collections. In turn, this makes the artificial data from simulation preferable to work with. Two, as simulation mimics the outcome of a real situation, this becomes especially valuable when it is otherwise impractical or impossible to collect primary or secondary data in the volume that is needed to confirm a theoretical supposition. Both of these advantages matter currently because the artificial generation of the HHI estimates becomes controllable and hence a relatively secure event for confirming the model-based nature of the HHI. From here-on, the economic framework, which connects to the statistical framework of the HHI will be considered, to explain why the HHI is intertwined with a renewal process in economic activity. It will become clear that the renewal process on which the HHI is predicated, firstly operates on the implicit assumption of Max Weber's characterisation that economic activity is purposefully done with the intention to alter prices and competition itself (Weber, 1947, p. 145, p. 167), and secondly it also rests on the implicit assumption of Milton Friedman's characterisation that the modus operandi of economic action is essentially to create proprietary knowledge, obtain direct and indirect government assistance, or secure government sanctioned private collusion (Friedman,

2002, pp. 26-27, pp. 128-130). For illustrative purposes, a practical illustration of this explanation will be given using the Australian retail banking industry as an example. This example will assist with showing how the renewal process functions practically in affecting business concentration through the economic activity of firms. In the end, a conclusion will be drawn, to recapture the main arguments presented.

Over the course of the discussion, there are a number of operative assumptions being made, namely:

a. In accordance with Gini (Gini, 1947, p. 24; Gini, 1965, pp. 94-95), the Gini index is treated as a measure of relative variability, and likewise the same extends to the HHI given this latter index is a variant of the Gini index.
b. To promote easier understanding as well as any other independent verification of results, the statistical analysis is confined to common, well-understood statistical methods (Andrews, 2007, p. 342).
c. The terms business concentration, market concentration, and industry concentration are synonymous with each other, and hence used interchangeably. Likewise the same is done with the terms market and industry.

2. HHI's Statistical Mechanics

The starting point in considering the statistical mechanics of the HHI is a recent finding that shows that the HHI is a variant of the Gini index whose approximate sampling distribution is the Chi-square distribution (Djolov, 2013, p. 211). According to the first aspect of this finding, the HHI is given by the sum of 1 and the squared Gini index (G) of firms' market shares, divided by the number of firms (n):

$$HHI = \frac{G^2 + 1}{n} = \frac{G^2}{n} + \frac{1}{n} \tag{1}$$

Expression (1) readily permits to establish what degrees of freedom are inherent in the HHI. To remind, degrees of freedom (df), are the number of independent variations or the so called unrestricted chances for variation in the measurement being made (Sharma, 2010, p. 261). These chances of variation apply as much to the moments describing the measurements – as for instance their location, scale, skewness and kurtosis – as they do to the constituent elements of the construct or instrument producing them (Gini, 1965, p. 105). In the present case, the HHI is the instrument for the measurement of business concentration and the sample estimates it gives rise to are the measurements of business concentration themselves. Applying the foregoing definition of degrees of freedom to the HHI as per expression (1) shows that the HHI has two independent sources of variation. In short, as a construct comprising two constituent elements of variation, the HHI has two degrees of freedom. The one source of variation – 1/n – describes whether firms' market shares are uniform, i.e. unvarying, while the second source of variation – G^2/n –

describes the similarity of firms' market shares relative to uniformity. In this context firms' market shares are identical if the relative variation between them is the same. Then the HHI will tend towards its known lower limit of 0. On the other hand, firms' market shares are not identical if the relative variation between them is not the same. The extreme of this is achieved whenever there is only 1 firm, and this is attained when absolutely speaking there is no relative variability. Then the HHI will tend towards its known upper limit of 1. Knowledge of the limits of the HHI exposes that the scale of its inherent distribution as measured by the range, which is the difference between the upper and lower limits, is 1. From here the location of its inherent distribution can be also determined.

This leads us to the second aspect of the above-referred to recent finding, namely that the approximate sampling distribution of the HHI is the Chi-square distribution. It is approximate because the exact probability distribution of the sample HHI is unknown except for knowing that whatever this distribution is, it is unimodal and positively skewed. The cited works of Nutter (1968, p. 219) and Davies (1996, pp. 105-106) have already suggested as much by their referral to positive skewness being something characteristic of business concentration. The fact that we are being confronted with an approximation for the sampling distribution of the HHI as opposed to something exact, should not lessen its significance. As Kleinke (1979, p. 163) notes, approximations in general serve three purposes:

a. They provide computational simplicity, which does not necessarily come at the expense of accuracy, and as such they practically offer computational solutions that are not arduous to implement;
b. They enable the formulation of an estimator that can be subjected to statistical analysis, as much as an estimator attained from an exact solution;
c. Lastly, and perhaps most important of all, they give insight into the nature of a statistic that may otherwise be impossible to attain through an exact solution.

This last point essentially captures the benefits from having an approximation with a known distribution for the HHI. It is known that for the Chi-square distribution, the ratio of its scale to location is the square root of double the inverse of its degrees of freedom (Evans et al., 2000, p. 53; Krishnamoorthy, 2006, p. 156). Or:

$$\frac{scale}{location} = \sqrt{2 \bullet df^{-1}} \tag{2}$$

To remind, the scale of a distribution refers to its spread, and its location to its typical value. Since in the present case we have two degrees of freedom (df = 2) and a unit value for scale (scale = 1), it follows that expression (2) reduces to:

$$\frac{1}{\sqrt{2 \bullet 2^{-1}}} = location \Rightarrow location = 1 \Rightarrow location = scale \tag{3}$$

Thus, as expression (3) highlights, the location and scale of the inherent HHI distribution are equal. The meaning of this is that the typical value of the HHI, which varies from case to case, is given by its spread. Stated more simply, the HHI's typical value is the relative value it assumes within the limits of its continuum. This is understandable since, as can be seen from expression (1), by including the Gini index in its formulation, the HHI is also a measure of relative variability. Like the Gini index it too captures the extent to which this variability is bunched together in few observations. That is, the HHI is a measure of concentration. By focusing on this concentration in the context of firms' market shares, it acts as an index of business concentration.

It will be of interest to draw attention that for Kendall and Stuart (1977, pp. 48-49) the distinction between concentration and relative variability was merely one of semantic idiom. The two are the same, just going by a different name. Respectively, it should come as no surprise that the sample HHI follows the variance distribution, i.e. the Chi-distribution. By implication, given that as a concept the HHI has two degrees of freedom, it follows that a likely candidate for its inherent distribution is the Chi-square distribution with two degrees of freedom. This well-known distribution is also called the Rayleigh distribution (Hirano, 2006, pp. 6987-6988). From expression (3), it is clear that the HHI adheres to the shape of this distribution without any modifications to its location and scale as per the equality between the latter two. Thus, as a concept, the HHI should be considered to be subordinated to the basic, i.e. unmodified Rayleigh distribution. The ensuing section is concerned with confirming this by means of simulation.

3. HHI's Inherent Distribution

The four main methods to generate artificial data for the purpose of producing simulated estimates are bootstrapping, jack-knifing, balanced repeated replications, and cross-validation (Diaconis and Efron, 1983, pp. 107-108). On review of the practices of these methods, Efron and Tibshirani (1991, pp. 390-391) advised that there is no right or wrong decision as to which method to use for simulation. The important thing firstly is to choose a simulation method in the same way as choosing any other statistical technique, namely taking the simplest that would be applicable to one's situation since this will ease the difficult task of interpreting the final results, and secondly to implement the selected method as accurately as possible. Acting on this advice, in the present case bootstrapping is used. As Press et al. (2007, p. 810) explain the basic idea behind the bootstrap is to take a representative sample, and to carry on repeatedly sampling this with replacement – analogously to reshuffling a card deck – until more data is created from which to estimate a statistic. Essentially by reshuffling the representative sample, an estimate of the statistic is derived from each reshuffle until in the limit the generated number of estimates is collectively able to show the statistic's distribution.

In the present case, the bootstrap is done with the Leontitsis and Pagge algorithm (Leontitsis and Pagge, 2007, pp. 337-338). To recall, to execute an algorithm is to carry out a mechanical procedure for achieving a specified result much like using a calculator to

perform some mathematical operation of interest (Copeland, 1996, p. 335, p. 337). In the present instance, the specified result is the confirmation that the likely candidate for the inherent distribution of the HHI is the Rayleigh distribution. The Leontitsis and Pagge (LP) bootstrap algorithm is promising in this regard because it has 95% accuracy in detecting the likely distribution of a statistic. The algorithm attains this level of accuracy by relying on two established facts:

a. A representative sample for the accurate estimation of a statistic can be created with as few as 20 measurements (Lehr, 1992, pp. 1099-1100; Van Belle, 2008, pp. 30-34).
b. In the estimation of a statistic, a 5% lack-of-precision is attainable with a minimum number of 800 measurements, if any error in measurement is limited to at most 1 in 3 measurements (Van Belle, 2008, p. 34).

Based on the aforementioned, the LP bootstrap algorithm involves the following three steps:

a. Create a representative sample consisting of a randomly selected seed of 20 observations. This sample must resemble the situation being studied.
b. Sample this seed repeatedly at random with replacement for 1000 times, to create 1000 data sets each of 20 observations.
c. From the 1000 data sets, compute 1000 estimates of the statistic under study, and either analyse or plot these to get the statistic's distribution.

Analogously, running the LP algorithm on the HHI also involves three steps:

a. Creating a representative sample consisting of a random selection of 20 market shares, which exhibit positive skewness in their distribution. In the present instance the Pearson skewness coefficient of this distribution is a positive 41%, signalling moderate positive skewness. As described by Nutter (1968, p. 219) and Davies (1996, pp. 105-106) at the beginning, positive skewness is the anticipated resemblance for the distribution of firm market shares.
b. Re-sampling randomly with replacement 1000 times the random seed of 20 market shares to create 1000 replicated data sets each of 20 observations.
c. Computing the HHI for each data set from expression (1), to create 1000 estimates of the HHI, from which in turn its inherent distribution is determined.

Table 1 gives the percentiles of the distribution of the HHI estimates from running the LP algorithm. It is known that the percentile values of such generated distribution provide estimates of the lower and upper confidence limits of a statistic at a designated confidence level (Wood, 2004, pp. 180-181). This method of confidence interval derivation

is commonly referred to as the percentile method, because it takes the percentile values of a statistic's bootstrap distribution, to be the lower and upper limit estimates of its confidence interval at the adopted level of significance, regardless of the statistic's underlying distribution (Efron, 1988, p. 296).

The 5% significance level is a common lack-of-precision yardstick for a confirmatory test, and the same convention is followed in the present instance since there is no reason to suppose that an alternative significance level will do better.

Table 1: Percentiles of simulated HHI values

Percentiles (%)	**HHI values (%)**
100.0 (maximum)	6.95
99.5	6.87
97.5	6.75
90.0	6.59
75.0 (3rd quartile)	6.44
50.0 (median)	6.24
25.0 (1st quartile)	6.02
10.0	5.82
2.5	5.54
0.5	5.26
0.0 (minimum)	5.01

Note: Calculations are done from generated values of the HHI by the LP bootstrap algorithm.

Thus, at the 95% confidence level, or alternatively at the 5% significance level, the 95% confidence interval for a statistic is given by the values of the 2.5th and the 97.5th percentile of its bootstrap-derived distribution, since these are the corresponding percentiles for this confidence or significance level. Inferring from Table 1, the resultant 95% confidence interval for the HHI irrespective of its distribution is:

$$\Lambda_{HHI}^{95\%} = \left(5.54\%, 6.75\%\right) \tag{4}$$

However, if conceptually the HHI is inherently Rayleigh distributed, then at the 5 significance level, its critical Rayleigh value, i.e. the tabular Chi-square value with 2 degrees of freedom, is 5.99%. As can be seen from expression (4), this value falls within the limits of the 95% confidence interval for the HHI, thereby indicating that a null hypothesis

in favour of the Rayleigh distribution cannot be rejected. In short, we have just gained an empirical confirmation that as a *concept* the HHI is inherently Rayleigh distributed. As reminded in the 2008 edition of the Oxford Dictionary of Statistics, as well as by the prior work of Samuels (1974, pp. 73-74, p. 83), the Rayleigh distribution is the distribution of the distance between the points in the data emanating as the outcome of a spatial renewal process. Thus, while the HHI is an index of business concentration, it is in fact a model of business concentration predicated on a renewal process that ends up separating firms apart, essentially by creating differences in their market shares. The implication of this finding is now considered in the following section.

4. Implications of HHI's Inherent Distribution

So far we have found that conceptually the HHI is inherently subordinated to the Rayleigh distribution, which directly implies that as a concept the HHI is a model of business concentration, which evolves according to a renewal process. This is because the Rayleigh distribution is established by such a process, and by default the same extends to the HHI.

After a detailed review of renewal processes, Mitov and Zazanis (2008, p. 1220) reached the conclusion that:

> "Alternating renewal processes arise in a natural way in many situations … where working (busy) periods … interchange with idle periods."

As observed by Mitov and Zazanis (2008, p. 1220), the classical statistical explanation for this alternation in the human sciences is the existence of some regenerative or revitalising action, which brings new and more vigorous life to prevailing conduct before leading to two types of renewal events. One being the moment of bringing-in an introduction, the other being the moment when this introduction is accommodated or made operative. The busy periods of human activity transpire when these events occur, whereas the periods of idle human activity arise when these events do not occur. The regenerative or revitalising action is itself initiated by a preferential attachment to a desired method of operation (Albert et al., 2000, p. 379, p. 381; Rybski et al., 2009, p. 12641, p. 12645). Moreover, as Albert et al. (1999, p. 130) observe, this initiation is dependent on an intelligent agent who can interpret the consequences of any regeneration and/or revitalisation, in order to become informed as to the relevant course of action to take in reaching the desired method of operation.

The foregoing depiction of how a renewal process should be interpreted in the human sciences has a number of immediate parallels to the economics field. For instance, as Max Weber (1947, p. 167) spells out, economic activity is any activity a firm does with the known opportunity for exchanging products for the purpose of orienting prices and competition. It is a small step from here to appreciate that this orientation cannot happen without informed actions designed to bring something into existence such as a product introduction or its respective adoption for usage. In turn, behind such actions is a preferred

way, i.e. a method by which the firm wants to do this. After an extensive review, Milton Friedman (2002, pp. 26-27, pp. 128-130) outlined the existence of three such methods:

a. Creation of proprietary knowledge, which is the technical and operational information a firm exercises to produce products;
b. Securing direct and indirect government assistance; and
c. Government vetted private collusion.

There is nothing special in the methods referred to by Friedman. Almost one-hundred years earlier Sir Giffen (1904, p. 188) had already identified the same, and more recently Baumol (2002, p. 15, p. 67) finds that the first method dominates firm operations whenever pursuit of the last two methods is absent or limited in scope to them. What is different about the methods is the nature of the renewal process they operate by.

As a method of economic activity, the act of creating proprietary knowledge revolves around creating knowledge that is exclusively held by the firm, through a range of ownership instruments by which it vies for market share (Reekie, 1989, p. 105-106). Examples of these instruments include trade-marks, branding, royalties, copyrights, patents, as well as trading and production licenses. Firms, whose market position rests on the ownership of such instruments, already automatically participate in a renewal process of supplying the market they operate in. As Pretnar (2003, p. 901) explains the reason for this is that the outcome of creating proprietary knowledge is a different product innovation or imitation, with the effect that the stock of knowledge available for use in further production is more knowledge come the next round of renewed economic activity. This is what makes the creation of proprietary knowledge a gradual cumulative process. As Pretnar (2003, pp. 894-897) clarifies, the coupling of a firm's market position with the creation of proprietary knowledge, means that this knowledge is exclusive to the firm which holds it, in the sense that no other firm has access to the same market position with the same knowledge. Since this type of vying for market share is not foreclosed to any other firm, then economic activity by such competing means turns into a renewal process exemplified by ongoing product innovations and imitations. This process comes to a halt if the firm losses the ownership of its proprietary knowledge by any free-riding means (Pretnar, 2003, p. 895, p. 897). In that case the firm is driven away from creating any such knowledge precisely because it cannot establish ownership for it. If this was to be the case for all firms, then none will want to create proprietary knowledge, and so by extension the renewal process fostered by this knowledge will be terminated. Such market situations are exemplified by retarded or ceased product innovations and imitations. Thus, the principal function of economic activity predicated on the act of creating proprietary knowledge, is to establish a renewal process, where each firm's pricing and competing decisions limit or prevent other firms from taking ownership of its proprietary knowledge (Pretnar, 2003, p. 897). Firms who can better interpret the consequences of these decisions relative to others also become well informed as to the course of action that will either give them an advantage,

or a lead in the market. In response, differences in market shares emerge so that those firms in the lead gain more market share than those firms in the following. This will see a market concentrating, and likewise the HHI will bear this out by measuring what the concentration is. Effectively, what the HHI will be measuring, is whether the observed differences in market shares arising from such a renewal process are relatively different from the same process producing a situation of no difference. If there are such differences in market shares, then business concentration is present and vice versa.

Without doubt, the lineage from proprietary knowledge to competitive economic activity is direct. To picture this, we can easily think of instances where such knowledge intimates the existence of a renewal process, which is incubated from a new idea, a better new product, more innovative pricing strategies, a new technique of production, as well as more innovative ways of firm structuring and restructuring. Kirzner (1997, p. 49) suggests that sometimes the by-products of the renewal process might be easier to see than the introductions themselves. For example, if the new product is a technological breakthrough that induces the production of more output at lower costs than ever before, economies of scale are an obvious spin-off. The same goes for any newly patented production technique that gives a firm superior costs of production and distribution that no other rival can share in. Then the resultant absolute cost advantage becomes an evident result. So too is the product variety created, if the better new product a firm introduces is distinctive from anything else available on offer.

By contrast, it is often hard to recognise that the remaining two methods of economic activity – government assistance and government vetted private collusion – also function through a renewal process. Tollison (1982, p. 575) and Tullock (1993, p. 22) have pointed out that this is a renewal process where the action is on firms capturing artificially contrived benefits from government-bestowed privileges. This is done through the introduction of legislative instruments in the case of government assistance, or politically sanctioned gentlemen agreements in the case of private collusion. Some common examples include: subsidies, tariffs, quantitative or supply restrictions, licensures, secured profit margins or guaranteed rates of return, stipulated prices, prescribed trading practices, cartelisation and any other collective monopoly fixture. Lal (2012, pp. 498-500) finds that while the underlying nature of these legal and political instruments has remained intact, over time their proliferation has increased, in the sense that the variety or variations they come in has grown. As George Stigler (1988, pp. 210-214) explained, each such introduction rests on the action of the benefitting firm or firms enlisting the support of a State organ, to confer the sought after benefit or privilege. It is known that such privilege gives the benefitting firm an entrenched market position as opposed to the case of having to vie for this position by means of creating proprietary knowledge (Buchanan, 1993, pp. 29-30). This in and of itself is the reason why the firm or firms to benefit will act to enlist the express or implied support of the State, provided they can correctly indentify if the State is in the business of giving this support (Lal, 2012, p. 499). But the effect of such activity, if successful, is to make the market closed from rivalry or weakened by its suppression. For the benefitting firm or firms market dominance is the gain, reflected in their relatively higher market share, as

distinct from that of the firms without the privilege. Consequently business concentration also arises, but its sources come from renewable actions by firms wanting to legally or politically shut-out rivalry in their favour. The resultant market concentration will be captured by the HHI, which will now measure if the observed differences in market shares arising from this type of renewal process, are relatively different from the same process producing a situation of no difference. Here too, if such differences in market shares exist, then business concentration is present and vice versa. What is different from the situation of firms creating proprietary knowledge is the cause of the concentration, which now is to be traced to the enlistment of government assistance or political approval.

Due to the principal of neutrality, as a statistical index, the HHI is silent on identifying what the cause of the observed business concentration is, except firstly to indicate that such concentration exists, and secondly that as per the type of economic activity pursued, there are three possible reasons for it. The index cannot explain which reason holds. This is incumbent on economic theory to explain. It is also clear that compared to economic textbook orthodoxy, the primary diagnostic function of the HHI is different from that normally assigned to it, as an index of business concentration that is suggestive of prevailing market structure. For example, Ertl and McCarrell (2002, p. 9) and Besanko et al. (2013, pp. 172-173) advise that if the HHI falls between 0% and 20% it signals the presence of perfect competition, if it is between 21% to 40% it signals the presence of monopolistic competition, if it is between 41% to 70% it signals the presence of oligopoly, and lastly if it is between 71% to 100% it signals the presence of monopoly as the prevailing market structure.

In the context of the above-considered discussion, it is apparent that as the initiator of different types of renewal processes, it is perpetually reinventing economic activity that is responsible for anyone of the aforementioned market structures. Ultimately, as the economic activities responsible for these processes unfold, the result is differently-bred business concentration. Not unexpectedly, the economic activity responsible for the renewal process becomes conflated with the resultant market structure it brings. A naïve deduction from here would to infer that the HHI is just an index of business concentration that is predictive of market structure. It is much more than this. Firstly, in terms of its primary diagnostic function, the HHI is an index of business concentration to the extent of signalling that this concentration is due to market conduct. This is in the sense that such conduct is attributable to different types of economic activity as already seen. Secondly, as a spin-off of this, it happens to incidentally be able to suggest what the market structure from this conduct is. This however is a secondary diagnostic function of the HHI, because it does not draw a lineage to the explanatory reasons for the observed, i.e. estimated business concentration. By contrast, the primary diagnostic function of the HHI does.

In the next section the above diagnostic functions of the HHI are demonstrated. For illustrative purposes this is done with an example of the Australian retail banking industry.

5. Illustration

It was shown in the previous section that the HHI has two diagnostic functions.

According to the first and primary function, it is an index of business concentration that is indicative of the presence of this concentration as a result of: renewable economic activity in the creation of proprietary knowledge, the securing of government assistance, or the partaking in private collusion. According to its secondary function the HHI is an index of business concentration indicative of prevailing market structure that predicatively reveals what market conditions exist, and how they compare to a situation of monopoly should any other market structure be encountered. Table 2 captures what conventional economic theory holds about the market conditions firms face in different market structures associated with particular HHI values, in addition to the expected outcomes of these structures at these values, relative to monopoly.

As the contents of Table 2 show, while the secondary diagnostic function of the HHI gives it attractive screening abilities as to the anticipated consequences associated with a particular business concentration level, this function departs from the primary diagnostic function of the HHI in two ways. Firstly, it makes the index silent on the fact that what is responsible for the observed business concentration level, and the signal this sends about the likely market structure and its outcomes, is some kind of pervasive economic activity. Secondly, that the identified structure and its outcomes are traceable to three kinds of economic activity as elaborated already. Consequently, the primary diagnostic function of the HHI does not seek to replace the secondary one. It adds to it, by highlighting that whatever the detected business concentration, this concentration is explainable by the economic activity it is incubated from. Thus knowing what the observed market structure and its outcomes are as suggested by the HHI, is just as important as knowing what produced it. Here the HHI suggestively signals that we should look for market conduct that is responsible for proprietary knowledge, government involvement, and collusion. While the HHI will numerically give an estimate of the business concentration belonging to each of these situations, it will not show the type of conduct that created it. The reason for this is the same as that for any other data. As Forrester (1980, p. 558) explains:

> "Missing from numerical data is direct evidence of the structure and policies that created the data. The numerical data do not reveal the cause-to-effect direction between variables. …That still leaves unanswered the question of internal causality."

The same also holds for the values of the HHI. As per their primary diagnostic function, these values will only inform whether there is business concentration due to distinct kinds of perpetual economic activity, but will not answer which of them caused the observed concentration. There is another, statistical way, to understand this. It stems from the inclusion of the Gini index in the HHI. As known, the Gini index measures the extent to which a distribution of values deviates from a uniform distribution (Gini, 1947, p. 24). Specifically, the Gini index identifies this deviation, by identifying whether the changes in the values from their mean produce any displacement in their rankings, as compared to a situation of no displacement in their ranks. By analogy, the meaning of this for the HHI is that, it detects business concentration according to whether changes in firms' market shares

Table 2: Market conditions and outcomes of prevailing market structures

	Perfect Competition	Monopolistic competition	Oligopoly	Monopoly
HHI Range, %	$0 \leq HHI \leq 20$	$20 < HHI \leq 40$	$40 < HHI \leq 70$	$70 < HHI \leq 100$
Market conditions faced by firms	Free entry	Free entry	Entry is restricted	Entry is restricted
	Complete product information	Complete product information	Incomplete product information	Incomplete product information
	No private collusion	No private collusion	Private collusion is possible	No private collusion
	Product variety is missing	Product variety exists	Product variety is possible	Product variety is limited or missing
	Equal access to production technologies	Equal access to production technologies	Equal access to production technologies is possible	Unequal access to production technologies
	Capital and labour are immediately mobile	Capital and labour are immediately mobile	Capital and labour are not immediately mobile	Capital and labour are not immediately mobile
	No market power	Market power is immediately contestable	Immediate contestability of market power is possible	Market power is not immediately contestable
Market outcomes with monopoly as baseline	Industry output is 100% higher than in monopoly	Industry output is 90% to 95% higher than in monopoly	Industry output is 60% to 75% higher than in monopoly	Baseline
	Price-cost margin at industry level is 99% lower than in monopoly	Price-cost margin at industry level is 90% to 95% lower than in monopoly	Price-cost margin at industry level is 60% to 75% lower than in monopoly	Baseline
	Industry profit is 99% lower than in monopoly	Industry profit is 82% to 90% lower than in monopoly	Industry profit is 36% to 56% lower than in monopoly	Baseline
	Consumer surplus is 300% higher than in monopoly	Consumer surplus is 263% to 280% higher than in monopoly	Consumer surplus is 156% to 206% higher than in monopoly	Baseline

Sources: Andreosso and Jacobson (2005, pp. 104-114), Besanko et al. (2013, pp. 172-173), Cabral (2000, pp. 89-95), Carlton and Perloff (1994, p. 243), and Ertl and McCarrell (2002, p. 9).

from the mean share displace their rankings, as compared to a situation of no changes in their ranks. As such, the HHI does not answer what type of economic activity produces this displacement (the value of which captures the observed business concentration). Clearly then, failure to incorporate any such activities in accounting for any estimated HHI value, removes the context or background that could explain why the HHI estimate is revealing of a particular market structure as opposed to any other. In this sense, the job of the HHI is not only to point out what business concentration is expected out of a particular market structure, but also to alert that there are specific economic activities that could explain it. This point will now become clearer with the illustrative example of business concentration in the Australian retail banking industry.

In 2011, the Australian Trade Commission published the findings of its review into the Australian banking market, in its report Australia's Banking Industry. One of the reviewed banking sectors was the retail banking industry, which the Commission examined by a snapshot, as at 2010, of the banks registered at that time to grant loans. Table 3 gives the market shares of this sample of firms as extracted from the Commission's report (2011, p. 14). The market shares are derived as the proportion of the loaned amount by each bank relative to the total amount loaned by all banks at that time. Based on the figures in Table 3, the Commission (2011, p. 5) concluded that:

> "Australia's retail banking sector is relatively concentrated….While the major… banks have dominant market shares across most consumer … lines, there is … increasing competition from … lenders … and … specialist finance companies."

The Commission did not clarify how this conclusion was arrived at, except to present it as a statement of fact. Certainly, looking at the numbers alone will not reveal according to which standard is Australia's retail banking industry relatively concentrated, or why it is undergoing increased competition at the same time as being concentrated. This of course can be seen by performing an HHI analysis on the figures in Table 3.

Table 3: Australian retail banking industry

Firms (Banks)	**Market share in 2010, %**	**Rank, from worst to best**
Investec Bank	0.010	1
Rabobank	0.020	2
Beirut Hellenic Bank	0.031	3
Bank of Cyprus	0.032	4
Bank of China	0.033	5
Arab Bank Australia	0.036	6
Members Equity Bank	0.370	7
AMP Bank	0.530	8

Macquarie Bank	0.612	9
HSBC Bank	0.670	10
Citigroup	1.190	11
Bank of Queensland	1.626	12
Bendigo and Adelaide Bank	1.993	13
Suncorp-Metway	2.497	14
ING Bank	3.390	15
Bank of Western Australia	3.690	16
Australia and New Zealand Banking Group	15.730	17
National Australia Bank	16.020	18
Commonwealth Bank of Australia	24.610	19
Westpac	26.910	20
Total	**100.000**	

Source: Australian Trade Commission (2011, p 14).

The first step in the HHI analysis is to estimate the HHI for the industry. By solving for the Gini index in expression (1), Djolov (2013, p. 212) finds a robust estimator of the HHI given by:

$$HHI = \frac{4\left(\sum_{i=1}^{n} ix_i\right)^2 - 4(n+1)\sum_{i=1}^{n} ix_i + (n+1)^2 + n^2}{n^3} \tag{5}$$

For reminder, a robust estimator is any estimator, which maintains its accuracy in the estimation of a statistic whenever the encountered data conditions change (Morgenthaler, 2007, p. 272, pp. 277-278).

The second step in the HHI analysis is to estimate the corresponding confidence intervals for the point estimate of the HHI. Here, Djolov (2013, pp. 215-216) shows that because McKay's approximation for the sample coefficient of variation extends to the sample Gini index, McKay's confidence intervals for the sample coefficient of variation are equally applicable to the Gini index. Consequentially, the first or original McKay confidence interval, with respect to the HHI is given by:

$$\Lambda_1^{HHI} = \left(\frac{\sqrt{nHHI - 1}}{\sqrt{\left|(nHHI-1)\bullet\left(\frac{\chi_u^2}{n}-1\right)\right| + \frac{\chi_u^2}{n-1}}}, \frac{\sqrt{nHHI - 1}}{\sqrt{\left|(nHHI-1)\bullet\left(\frac{\chi_l^2}{n}-1\right)\right| + \frac{\chi_l^2}{n-1}}} \right) \tag{6}$$

While, the second or modified McKay confidence interval with respect to the HHI is given by:

$$\Lambda_2^{HHI} = \left(\frac{\sqrt{nHHI-1}}{\sqrt{\left|(nHHI-1)\bullet\left(\frac{2+\chi_u^2}{n}-1\right)\right|+\frac{\chi_u^2}{n-1}}}, \frac{\sqrt{nHHI-1}}{\sqrt{\left|(nHHI-1)\bullet\left(\frac{2+\chi_l^2}{n}-1\right)\right|+\frac{\chi_l^2}{n-1}}} \right) \quad (7)$$

In both expressions, the lower and upper critical Chi-square values (χ^2) are denoted by "l" and "u" respectively. They may either be obtained from a Chi-square distribution table with n-1 degrees of freedom, or in the event of large samples for which tabular Chi-square values are not available, from the familiar normal-based Wilson-Hilferty approximation.

Given that expressions (6) and (7) are effectively confidence intervals for the Gini index expressed in terms of the HHI, if they are applied to data containing only the number of observations and the HHI, then they give the lower and upper estimates for the Gini index. In turn, to get the lower and upper confidence limits for the HHI, these estimates will have to be run through expression (1).

The calculation results of the first and second step of the HHI analysis with the figures from Table 3 are presented in Table 4. For reminder, lack of precision in estimation is derived from the width of each interval, and the bias from estimation is obtained as half the width of each interval. A 95% confidence level is selected merely for illustrative purposes. Any other level from among the conventionally available ones, such as the 90% or the 99% confidence level, is just as usable depending on the particular application involved.

Table 4: HHI analysis of Australian retail banking industry

HHI statistics	**Estimates**
Point estimate	7.7%
95% HHI confidence limits from original McKay confidence interval	6.3% , 8.5% Bias = 1.1% Lack of precision = 2.2%
95% HHI confidence limits from modified McKay confidence interval	6.3% , 8.8% Bias = 1.3% Lack of precision = 2.5%

Note: Calculations are firstly done with expressions (5), (6), and (7), and the solutions from the latter two expressions are re-entered into expression (1) to get the HHI confidence limits.

Of the two intervals, the HHI confidence limits from the original McKay confidence interval are the ones carried forward in the third step of the HHI analysis, since this interval has comparatively smaller loss of precision and smaller bias to the same counterparts from the modified McKay confidence interval.

In the third step of the HHI analysis, the computed HHI estimate of 7.7% and its lower confidence limit of 6.3% and upper confidence limit of 8.5%, as attained at the 95% confidence level, are matched to the market conditions and outcomes outlined in Table 2. This is done to determine the likely market conditions and/or outcomes that prevail in the Australian retail banking industry. It is the interpretation of the numbers at this step that gives an insight into the Commission's view on the retail banking industry. Examined according to the HHI point estimate, the view by the Commission that the retail banking industry is relatively concentrated, is unsupported since its value of 7.7% indicates that the industry operates under a perfectly competitive market structure. Similarly, the estimates of the HHI's lower and upper confidence limits, of 6.3% and 8.5% respectively, corroborate this to be a persistent market structure for the industry, since none of them overlap with the anticipated HHI range of other market structures. By the same token, the foregoing HHI numbers support the Commission's view that the industry is open to increasing competition. In this regard, the secondary diagnostic function of the HHI makes it possible to describe from the industry's market shares in Table 3, what its observed business concentration suggests about its likely market conditions and/or outcomes. But, it is also clear that performing the HHI analysis up to the information disclosure the secondary function gives, is unsatisfactory. This is due to this information being silent on identifying the economic activities that can account for the observed business concentration level, or the consequences it is associated with. For instance, in the current instance, we are left to grapple with a picture of the retail banking industry that is not entirely conforming to expectations – it is competitively unconcentrated as opposed to competitively concentrated. *This is why an HHI analysis should not leave out its primary diagnostic function*. Essentially this function of the index runs concurrently with its secondary counterpart, by requiring that the market or trade environment underpinning the economic activities leading to the observed HHI must be considered inseparably from its estimates.

In the present example, the Australian Trade Commission (2011, pp. 13-19, pp. 44-46) advises that the trading environment of Australia's retail banking industry has five main attributes:

a. The firms with the four largest market shares as reported in Table 3 are legally prohibited from merging, which in effect bars them from collectively monopolising the industry;
b. Firms are legally compelled to fully disclose to consumers the contents of any loanable offer, which in effect encourages a market nexus with complete information;

c. By regulation, government is excluded from market participation by government intervention or political participation, which in effect means a market functioning without government assistance or government induced private collusion, such that the competing means available to firms are limited to the creation of proprietary knowledge;
d. By regulation, the market is open for anyone to enter, in the sense that any firm can become a licensed supplier of capital provided it accepts it has to operate according to the foregoing requirements, which in effect means that consumers have more competing offers from different firms to choose from, irrespective of whether this leads to product variety or more of the same being offered.
e. By regulation, firms are given free contracting abilities to trade and maintain their property rights in the products they offer, which in effect means that no firm looses ownership in its proprietary knowledge to any other firm that may want to free-ride on it.

Lachmann (1992, p. 25, pp. 28-29, p. 31) defined an open market in one of two mutually consistent ways. On the one hand, it is a market composed of economic activity including only the creation of proprietary knowledge. Alternatively, it is a market composed of economic activity excluding any type of government assistance and government-vetted private collusion. The juxtaposition between either of these definitions and the above-described trading environment of Australia's retail banking industry, readily reveals that this industry operates as an open market since firms only have the ability to acquire market presence through the power of the property they create, as per the products – in the form of the varied loans – they offer to consumers.

Extracting from Newman's work (2000, pp. 412-413), an open market may be seen as the result of firms purposefully designing or evolving the best possible conduct for contesting each other, which takes us full circle to renewal processes as discussed earlier on. Imagine then a market where a competing firm – in this case a bank – wants to grow product choice as much as possible. The principal activity of the firm is producing competing offers – in this case loans. Such an offer starts in the market with a moderate frequency of demand that can replace large numbers of other existing or prospective offers if left unchecked. So the job of the other competing firms is to counteract this competing offer in order to prevent its spread from eating away their actual or potential share of the market. The best way to minimise such possible damage that the competing offer may inflict, is to separate the market into equally sized segments if the competing offer is provided uniformly, i.e. in the same way to everyone in the market. However, if there is more of the offering to some consumers than to others, the possible damage is minimized by dividing the market into segments whose sizes in terms of the numbers of consumers vary in inverse proportion to the rate at which the competing offer is supplied to the different consumers. This inverse proportionality is readily reconcilable with the already communicated finding, that business concentration depicted by the HHI is inherently distributed according to the Rayleigh distribution, where the probability of the occurrence of an event is inversely proportional to

its different possibilities (Evans et al., 2000, pp. 167-168). In turn, if the event in question is the act of countering a replacement offer, the probability of this act – which will work to alter market concentration – by prospectively dividing a market into segments, will be inversely proportional to the possibility of the replacement occurring (the latter being captured by the rate at which the replacement enters a segment). Consequentially, the size of a market segment will increase proportionately to the decrease in the replacement offer's rate of entry in the segment, because the market share prevalence of the counter offer in the segment will be proportionately higher. The reverse will hold in the opposite situation. Either way, each firm's conduct becomes highly sensitive to that of competing rivals, by forcing them to design or evolve activities that have ingenuity, specifically through the perpetuation of proprietary knowledge and/or independent actions that are limited in their prospects for collusion or government aid. Individually or together, each of these actions are robust, as they enable the firm to gain or maintain market share, while also being fragile in that the firm could reduce or lose its market share if its rivals perform these actions better. Thus, as known, open markets are in a continual state of firm rivalry, which works against them becoming permanently concentrated. This explains the current finding of the retail banking industry being competitively unconcentrated, as expected from the perfectly competitive market structure signalled by its HHI, while at the same time also helping to explain why the Australian Trade Commission finds the industry to be competitive. The current explanation also suggests that the Commission's concurrent view that the industry is relatively concentrated actually presumes a concentration level at which firm rivalry is unstoppable. In such a context, it is possible to conclude, as the Commission has, that in the presence of relative concentration, competition prevails. But to clarify, the concentration is only relative to the extent that competition in the industry is unaffected by its magnitude. Hence the Commission's finding of a relatively concentrated industry with increasing competition.

The foregoing concludes the illustration on the diagnostic functions of the HHI as set out to demonstrate. The next section summarises the work thus far.

6. Conclusion

This paper began by recalling that according to established thinking in the economics field, the HHI or more generally statistical measures of business concentration are merely descriptive indices of such concentration incapable of formal statistical analysis and disconnected from the economic theory on the formation of industrial structure. At least in the case of the HHI, the present work finds that these suppositions are of questionable substance. For instance, Schumpeter's (1961, p. 66; 1976, pp. 84-85) seminal works have demonstrated that the formation of industrial structure begins and ends with a renewal process, which is made real by the three types of economic activity considered here, namely the creation of proprietary knowledge, the levitation to government assistance, and the explicit or implicit sanctioning by government of private collusion. By finding that conceptually the HHI is inherently Rayleigh distributed, it emerges that the underlying

behaviour of this index is likewise governed by a renewal process, given that this distribution is only established by such a process. It was shown that in the context of human activity in commerce, the statistical explanation for such process rests on regenerative or revitalising actions in economic activity. This gives the basis to differentiate between two types of diagnostic functions embedded in the HHI. These are identified as the primary and secondary diagnostic function. The primary diagnostic function of the HHI is contained in the ability of the index to measure business concentration primarily as an outcome of market conduct. This is because each index value is an estimate of business concentration fostered by any of the aforementioned three possible methods of economic activity. A by-product of the HHI's primary function is its secondary diagnostic function, which is contained in the ability of the index to anyhow give an estimate of business concentration, irrespective of the economic activity responsible for it or the resultant market structure it points to. Consequentially, the HHI should be seen as a screening indicator of market conduct, which incidentally doubles-up as an indicator of market structure.

The HHI's diagnostic functions become obvious only after enlisting the support of statistical theory. This is done by calling attention to the fact that the Chi-square distribution is the approximate sampling distribution of the HHI. Then this fact is used to show that as a theoretical construct, the HHI is inherently distributed as a special case of the Chi-square distribution – called the Rayleigh distribution – that only comes about by a renewal process. In the present instance, the renewal process involves economic activities thereby reinforcing that the HHI is a measure of business concentration. This same statistical theory also shows that the index is perfectly capable of formal statistical analysis that is subordinated to the familiar Chi-square distribution. Such an analysis highlights that the HHI is primarily an index of suggestive market conduct diagnosis, and secondarily an index of suggestive market structure diagnosis. This is in line with the correspondingly different but interwoven diagnostic functions of the index.

The above casts doubt on any premise that as an index of business concentration the HHI will offer no understanding of the forces at work that determine this concentration. As the current work demonstrates, this premise is only true to the extent that while the HHI cannot identify the exact economic activity that accounts for the observed business concentration level, or the consequences it is associated with, it does suggest that the explanation for it must be sought for in the renewal process governing the three distinct methods of economic activity. These are the activities that a firm chooses to compete for market share. In the illustrated example of the Australian retail banking industry, the renewal process was tied to economic activity resting on the creation of proprietary knowledge, as the mechanism that gives each firm the technical and operational abilities to produce competing offers, whether they are counteroffers or replacements. But depending on the particular case involved, the encountered economic activity will be different and so might be the features of its renewal process. Then the HHI estimates will point to business concentration in terms of the suggestive market conduct that is explainable or identifiable with the method of economic activity prevailing in the case. It is clear however that whatever the case, a formal HHI statistical analysis of it, offers a systematic economic theory for interpreting

its business concentration. By contrast, and questionably so, the current uses of the HHI assume otherwise (Andreosso and Jacobson, 2005, pp. 98-99).

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Directional accuracy for inflation and unemployment rate predictions in Romania

Mihaela Simionescu[1]

Abstract

The main objective of this study is to assess the usefulness and rationality of the inflation and unemployment rate forecasts made for Romanian by three experts in forecasting: F1, F2 and F3. All the unemployment rate forecasts over the horizon 2001-2013 provided by all experts do not provide valuable information for future decisional process. According to Pesaran-Timmermann test, the directional forecasts of F3 and the autumn expectations of F2 are useful and rational.

Keywords: forecasts, directional accuracy, inflation rate, unemployment rate

JEL Classification: C52, C53, E27, E37

1. Introduction

Macroeconomic forecasts are the support of decisional process in economic and financial policies. The ability to predict macroeconomic variables changes and modify directions will affect the business confidence, consumer subjectivity, and foreign direct investment (Chang et al., 2011). Therefore, it is necessary to assess the rationality of directional predictions, but also their usefulness.

The common approach to evaluate the predictions' usefulness consists in the measurement of the error's magnitude, using accuracy measures like mean square error (MSE) (Diebold and Mariano, 2002), or log of the mean squared error ratio (log MSER) (Armstrong and Collopy, 1992; Hyndman and Koehler, 2006). However, these measures do not have an economic interpretation and they neglect the presence of outliers. These are reasons for the development of directional forecasts that were presented initially by several others (Merton, 1981; Henriksson and Merton, 1981). Later, this technique was used for assessing the macroeconomic forecasts (Pesaran and Timmermann, 1994; Artis, 1996; Öller and Barot, 2000; Pons, 2001).

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In this study, the directional accuracy was assessed, using only the predictions' signs, and the final values. The errors' magnitude has been neglected. In order to make the predictions robust to the presence of outliers, the high and the low errors received the same importance. It was assessed the directional accuracy of Romanian inflation and unemployment rate, using three important institutes: European Commission, Institute for Economic Forecasting and National Commission for Prognosis. There are various studies regarding the assessment of directional accuracy for IMF and OECD predictions of the G7 countries (Pons, 2000; Öller and Barot, 2000; Pons, 2001; Ashiya, 2003; Ashiya, 2006). Other studies are interested in the rationality and usefulness predictions for the G7 countries, the forecast being provided by OECD (Ash et al., 1998). Kumar (2010) used a time-Varying parameter vector auto-regression model for predicting emerging market exchange rates, obtaining a good degree of accuracy.

The paper is structured as it follows. The second section describes the methodology while the third one presents the forecasts data set provided by the three forecasters and the directional accuracy is assessed. The last section gives a brief conclusion.

2. Methodological background

In order to check if the predictions are 'valuable' the comparison is made with the naïve forecast that supposes that the value in the actual period will remain the same in the next period. Schnader and Stekler (1990) and Stekler (1994) used the contingency table approach in order to check the probabilistically independence between the sign of the predicted, respectively actual change. The null hypothesis of this directional accuracy test assumes the independence between the actual and the predicted value. The forecasts are valuable if the independence hypothesis is rejected (Merton, 1981). The real and the forecast values of the variable changes are presented in a 2×2 contingency table. Different tests are use in this case: Fisher's exact test, chi-square test, and the test proposed by Pesaran and Timmermann (Pesaran and Timmermann, 1992).

Table 1: Contingency Table for macroeconomic forecasts

Actual (A) / Forecasted (F)	negative change	positive change	Subtotal
negative change	n_{00}	n_{01}	n_{00}
positive change	n_{10}	n_{11}	n_{10}
Subtotal	n_{00}	$n_{\square 1}$	N

Source: author's construction

Note: there is a total number of N observations, subscript i for n_{ij} shows the forecasted outcome, subscript j for n_{ij} shows the actual result, $i\,(j) = 0$ implies negative change, and $i\,(j) = 1$ implies positive change.

The most used test is based on the contingency tables (chi-square test). This test was used in many previous studies (Schnader and Stekler, 1990; Stekler, 1994; Leitch and Tanner, 1995; Artis, 1996; Ash et al., 1998; Joutz and Stekler, 1998). The statistic of this test is:

$$\hat{\chi}^2 = \sum_{i=0}^{1}\sum_{j=0}^{1}\frac{(n_{ij} - n_{i\bullet}n_{\bullet j}/N)^2}{n_{i\bullet}n_{\bullet j}/N} \tag{1}$$

Wickens (1989) concluded that this test can become too conservative because the independence assumption can be wrongly accepted. Therefore, it is recommended the use of Yates' continuity correction (Yates, 1934), based on the following statistic:

$$\chi^2_{\text{Yates}} = \frac{N(|n_{00}n_{11} - n_{01}n_{10}| - N/2)^2}{n_{00}n_{10}n_{00}n_{01}} \tag{2}$$

Another problem of the chi-square test is the continuous distribution hypothesis for the chi-square, but the computation uses discrete categories. The discrete frequencies approximation can generate an inaccurate approximation of the test statistic in case of very low expected frequencies. For an accurate test requires no more than 20% of the cells should have frequencies less than 5 and all cells should have frequencies greater than 1 (Everitt, 1992).

In order to solve the problem of low expected frequencies, the Fisher's exact test for contingency tables is employed. This test is based on a hyper-geometric repartition for directly computing the independence probability. This probability for a 2×2 contingency table is computed as:

$$p = \frac{\binom{n_{00}}{n_{00}}\binom{n_{10}}{n_{10}}}{\binom{N}{n_{00}}} = \frac{n_{00}!n_{10}!n_{00}!n_{01}!}{n_{00}!n_{01}!n_{10}!n_{11}!N!} \tag{3}$$

Pesaran and Timmermann (1992) proposed a non-parametric test on the correct forecast of the directional accuracy. It supposes the estimation of the probability of independence between results and predictions. This statistic of this test follows a chi-square distribution with one degree of freedom. The general standardized test statistic for assessing the predictive performance has the following form:

$$S_n^2 = \frac{(\hat{p} - \hat{p}^*)^2}{\text{Var}(\hat{p}) - \text{Var}(\hat{p}^*)} \square \chi^2(1) \tag{4}$$

$\hat{p} = (n_{00} + n_{11})/N$: Sample's estimate of the probability of a correctly signed prediction

$$\text{Var}(\hat{p}) = [\hat{p}^*(1 - \hat{p}^*)]/N$$

$\hat{p}_f = n_{10}/N$: probability of positive change in predicted outcomes

$\hat{p}_a = n_{01}/N$: probability of positive change in actual results

$\hat{p}^* = \hat{p}_f \hat{p}_a + (1-\hat{p}_f)(1-\hat{p}_a)$: estimator under the null hypothesis

$$\text{Var}(\hat{p}^*) = [(2\hat{p}_f - 1)^2 \hat{p}_a(1-\hat{p}_a) + (2\hat{p}_a - 1)^2 \hat{p}_f(1-\hat{p}_f) + 4\hat{p}_a\hat{p}_f(1-\hat{p}_a)(1-\hat{p}_f)/N]/N .$$

Pesaran and Timmermann (1994) provied also the generalization of their test when actual values and predictions are grouped in more than two classes. The test is useful when a joint assessment of two predictions is made, no requirement being necessary regarding the forecasts' independece (Sinclair et al., 2011).

3. The assessment of the directional accuracy for inflation and unemployment rate forecasts

The experts' predictions for inflation rate and unemployment rate in Romania will be used, the horizon covering the period from 2001 to 2013.

The evolution of forecasts for all the forecasters is presented in Figure 1.

According to the above graph, the errors associated to the unemployment rate predicts are higher than those for inflation predictions for all the experts.

First of all, the forecasts was assessed using the prediction error (Stekler, 1994; Joutz and Stekler, 2000; Clements et al., 2007). Some statistics are computed for the predictions of inflation and unemployment rate: mean absolute deviation (MAD), standard deviation (SD), the maximal and the minimum value.

From Table 2 it results that the F1 outperforms the the other experts that provide periodically forecasts for inflation rate. The lowest MAD for inflation rate forecasts was registered for the spring version, while the lowest SD for the automn one. For the unemployment rate predictions, F3 is recommended. The first scenario is the best in term of MAD, while the second is more suitable according to SD criterion. The unemployment rate forecasts based F2 are also more accurate that the inflation expectations of F1 forecasts. The indicators are computed in Table 2.

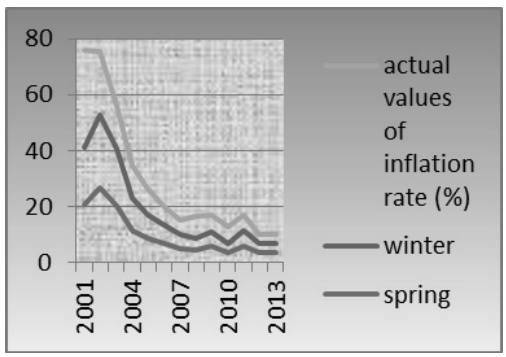
Table 2: Measures of forecasts errors

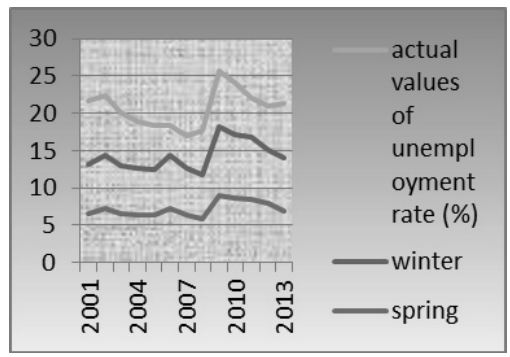
Forecasts' provider	Type of forecast	Inflation rate				Unemployment rate			
		MAD	SD	Max	Min	MAD	Std.	Max	Min
F1	Spring version	2,342	4,484	13,8	-4,9	1,400	1,637	2	-3,3
	Winter version	2,381	2,309	14	-5,1	1,292	1,544	2,1	-3
F2	Spring version	2,505	3,695	4,350	-10,300	1,377	1,482	1,200	-3,300
	Autumn version	2,450	4,043	4,250	-11,200	1,478	1,136	0,112	-3,800
F3	First scenario	4,495	8,343	0,600	-29,500	1,148	1,222	0,700	-2,300
	Second scenario	4,701	8,824	0,697	-31,461	1,162	1,175	0,500	-2,060

Source: author's computations

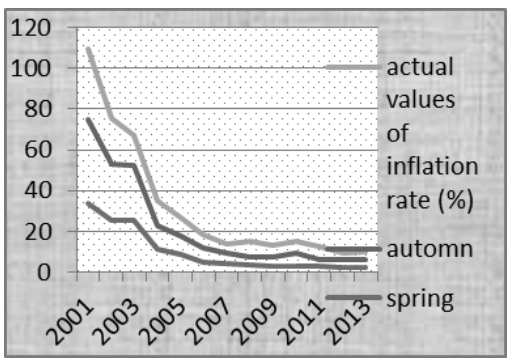
Figure 1: Romanian inflation and unemployment rate forecasts

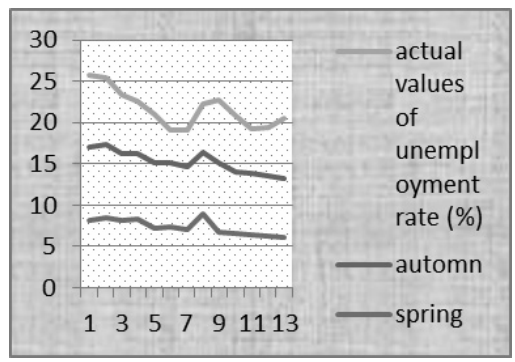
F1



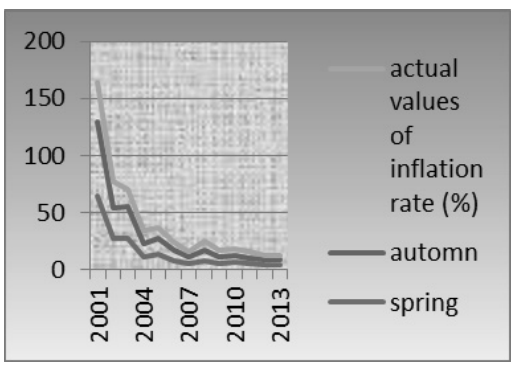


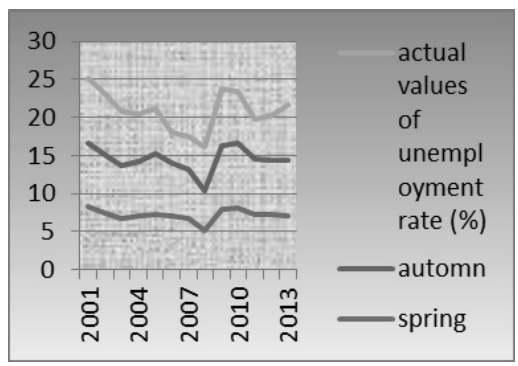
F2





F3





Source: author's graph

The directional accuracy approach is based on the acceleration (deceleration) of growth forecast. The directional predictions usually consider no change in government policies, nominal exchange rates, and dollar-denominated oil prices.

The data are organized in a contingency table.

n_{00} - negative change in registered values and negative change in predictions

n_{01} - negative change in registered values and positive change in predictions

n_{10} - positive change in registered values and negative change in predictions

n_{11} - positive change in registered values and positive change in predictions

It was computed the number of correct (n_{00} and n_{11}) and incorrect (n_{01} and n_{10}) direction forecasts that were predicted by the three institutions. According to contingency tables made for all the experts, the cells frequencies are very low, this method being unsuitable for this particular case. In Table 3, the contingency tables are presented for the three types of forecasts providers.

Table 3: Contingency tables

Forecasts' provider	Type of forecast	Inflation rate				Unemployment rate			
		n_{00}	n_{01}	n_{10}	n_{11}	n_{00}	n_{01}	n_{10}	n_{11}
F1	Spring version	6	1	3	1	4	4	1	2
	Winter version	6	1	3	1	5	4	1	2
F2	Spring version	8	3	1	1	4	4	3	2
	Autumn version	8	1	1	3	5	4	1	2
F3	First scenario	7	2	0	3	4	4	3	2
	Second scenario	7	2	1	3	4	4	3	2

Source: author's computations

If the sum of inputs in the two cells of the leading diagonal ($n_{00} + n_{11}$) is high, three statistics could be computed, the null assumption of the tests stating that the prediction change is independent from probabilistic point of view of the actual change (Pons, 2000). The results of the application of directional accuracy tests are displayed in Table 4.

Table 4: Tests for directional accuracy

Institutes	Forecast periods	Inflation rate			Unemployment rate		
		$\hat{\chi}^2_{\text{Yates}}$	p	S_n^2	$\hat{\chi}^2_{\text{Yates}}$	p	S_n^2
F1	Spring version	0,316	0,003	1,139	0,113	0,003	0,381
	Winter version	0,316	0,003	1,139	0,003	0,031	0,034
F2	Spring version	0,037	0,462	0,445	0,048	0,408	0,243
	Autumn version	2,731	0,050	8,409	0,003	0,031	0,034
F3	First scenario	2,892	0,003	4,801	0,048	0,408	0,243
	Second scenario	1,411	0,112	5,569	0,048	0,408	0,243

Source: author's computations

The three statistics were computed to study the directional accuracy of unemployment and inflation prediction. The results show that for all the unemployment forecasts and for most of the inflation rate forecasts the null hypothesis was not rejected, which means that the forecasts are not valuable in the directional predictions.

According to Pesaran-Timmermann test, the inflation forecasts of F3 and the autumn predictions of F2 are valuable at 5% level of significance. To sort the accuracy of Romanian inflation and unemployment rate for direction forecast the following hierarchy was obtained: F3, F2 and F1. The statistics support the propositions that inflation forecasts are better than unemployment rate predictions in Romania.

4. Conclusions

This paper assessed the directional accuracy of the inflation and unemployment rate predictions made by F1, F2 and F3, using three nonparametric directional accuracy assessment methods. The results showed that most of the forecasts are not valuable, only for inflation rate the predictions of F3 were valuable according to Pesaran-Timmermann test. The advantage of this approach

The disadvantage is that there are differences in the directional accuracy between forecasters because of the transition economy and the different information about Romanian economy collected by the forecasts' providers.

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Role of fiscal policy for private investment in Pakistan

Ghulam Rasool Madni[1]

Abstract

Fiscal policy has much controversial debate regarding its effectiveness on private investment. Taxation and government expenditure are two main instruments of fiscal policy. This paper is aimed to analyze the effect of fiscal deficit and other variables on private investment of Pakistan. The data time span for this study is 1979-2012. After finding the integration order of all variables by Augmented Dicky Fuller Test, the impact of variables is analyzed by utilizing the Auto Regressive Distributed Lag approach of Cointegration which is a better estimation technique for small sample size. Error Correction Model is applied for short run dynamics. The results reveal that fiscal deficit, rate of interest, inflation and external debt are affecting negatively the private investment in Pakistan while exchange rate and exports have a positive impact on private investment.

Keywords: Fiscal Policy, Private Investment, co integration

JEL Classification: E62, C22

1. Introduction

Fiscal policy plays a vital role as developmental tool in developing countries. The government policies regarding expenditures and taxes often result as imbalances in revenues and expenditures that cause to increase in public debt. Increasing public debt can affect investment and saving either directly or indirectly by interest rate and inflation. As a result, it can dampen the macroeconomic growth in these economies.

There are three contrasting views regarding the relationship between fiscal deficit and investment. These views are supported by theoretical and empirical analysis. The neoclassical economists are of view that financing of increased fiscal deficit through public borrowing can increase the interest rate and thereby result in crowding out of private sector investments. Blejer and Khan (1984) and Beck (1993) proved the neoclassical view of fiscal deficit and investment. When government steps up its borrowing in the domestic market to fulfill current consumption, then private sector has less opportunities for lending

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so private investment decreases. On the other side, due to same interest rate for government and private sector, banks prefer lending to government due to fewer chances to be default. Resultantly increased government spending financed by domestic borrowing at the expense of private investment can affect economic growth. This approach can be named as substitution approach.

Keynesian economists advocate that when government spending increases then it stimulates the domestic economic activity by a greater proportion through the multiplier process and crowds in private investment, especially when the economy is not at full employment level. The composition of government expenditures will determine the extent of crowding in. Husnain et al. (2009) found that private sector can benefit only if the public sector investment is in infrastructure, education and health that involve large fixed costs and long gestation period. Buiter (1999), Aschauer (1989), Greene and Villanueva (1990), Baldacci, Hillman and Kojo (2004) analyzed that public spending and private investment are compulsory so this approach can be recalled as complementary approach.

Beside the substitution and complementary approach, the third view is based on the Ricardian Equivalence Theorem. It states that deficit of current period will be equal to the present value of future taxation that would be required to finance the deficit. So the savings of individual households will increase because they expect that in future tax level will increase. As a result, the national savings will increase and therefore offset any increase in rate of interest. Thus, there will be no change in private investment and rate of interest. Bahmani-Oskooee (1999) found that fiscal deficits will not have much impact on aggregate demand if household spending decisions are based on the present value of their incomes that takes into account the present value of their future tax liabilities.

Many studies suggest that different type of government spending has different impact on private investment as described by Edelberg, Eichenbaum and Fisher (1998), Blanchard and Perotti (2002), Dotsey (1994) and Darrat (1998). In this paper, it is attempted to analyze that how fiscal deficit and other variables affect the private investment for a developing economy of Pakistan covering the period of 1979 to 2012.

2. Historical Aspects of Fiscal Deficit and External Debt

2.1 Fiscal Deficit

Fiscal deficit means a situation when government expenditures exceed than its generated revenues. Uzair (2004) concluded that fiscal deficit has got greater attention after Brettonwoods, during the last two decades most of the developing countries including Pakistan have faced fiscal deficits and is considered as one of the major source of macro economic imbalances. But it is also difficult to conclude that whether reduced fiscal deficit causes a positive effect on the economy or not. If there is reduction of developmental expenditures in spite of expansion of revenues, then it has a negative effect on economic growth in long run.

After having a look on Pakistan economy, we come to know that fiscal deficit was only 2.1% of GDP in 1960's and it increased to 5.3% of GDP in 1970's due to 1971's war. After that, it decreased to 7.1% of GDP in 1980's and further reduced to 6.9% of GDP in 1990's due to commitments made with International Monetary Fund (IMF) by Structural Adjustment Program (SAP). In 2000's, fiscal deficit was reduced to 4.5% of GDP.

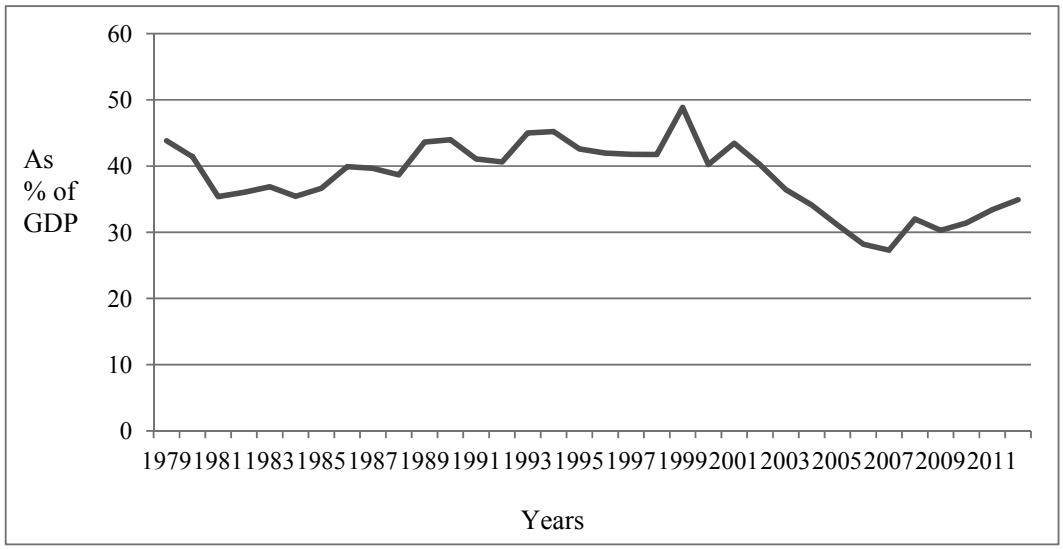
Figure 1: Trends in Fiscal Deficit in Pakistan as % of GDP

2.2 External Debt

When domestic savings are not capable to fulfill the requirements of private investment then government have to borrow from external sources or foreign savings. External borrowing is carried to increase the economic growth by investing in those sectors that have not sufficient resources from domestic financing. But excess of external debt causes some other severe problems like sovereignty of the country.

Pakistan is facing the financial crisis since its independence. There was a temporary relief during Afghan war and incident of 9/11 but after that debt problem became more severe. External debt was on average 43.2% of GDP in 1970's and declined to 36.8% of GDP in 1980's. There was a rising trend in 1990's and it reached to 60% of GDP on average. In the beginning of 2000's, economy of Pakistan started to improve due to American aid and macroeconomic indicators were better significantly so external debt reduced to 28.1% of GDP in 2011-12.

Figure 2: Trends in External Debt in Pakistan as % of GDP



3. Literature Review

Fatima et al. (2011) explored the impact of fiscal deficit on investment and economic growth for the economy of Pakistan over the period of 1980 to 2009. The two stage least square method is adopted to estimate the simultaneous equation model. GDP growth and investment are considered as dependent variables while fiscal deficit, investment, exports, imports, foreign aid, inflation, real interest rate and population growth are taken as independent variables. It is concluded that fiscal deficit affects economic growth of country very adversely because of poor tax collection, inelastic tax system, complex tax laws, and heavy reliance on foreign trade taxes, large tax exemptions and incentives. Results also show that there is persistence deficit in balance of payments that creates fiscal deficit. Improvement in tax system and lowering the interest rate are policy implications for government in this study.

Ali and Ahmad (2010) examined the effects of fiscal policy on macroeconomic activities over the period 1972-2008 for the economy of Pakistan. They applied the auto regressive distributed lag model and error correction model to determine the long and short run effect of fiscal policy on economic growth of Pakistan. Fiscal deficit and current account deficit are used as fiscal variables while private investment and inflation are treated as control variables. They found that long run relationship exists overall fiscal deficit and economic growth. Non development expenditure and politically motivated expenditure restrains the economic growth. They also analyzed that fiscal deficit positively affects up to some threshold level and it was considered in the narrow band of 3 to 4 percent of GDP. They advised that if government is able to reduce its budget deficit, eventually it would get

rid of the vicious circle of debt overhanging problem, because the debt-GDP ratio would increase only if the fiscal deficit as a percentage of GDP exceeds the real GDP growth rate.

Alesina et al. (2002) evaluated the effects of fiscal policy on investment using a panel of 18 OECD countries namely; Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom and United States covering the time period of 1960 to 1996. A VAR model is applied and results show that fiscal policy plays an important role for private investment. There is a sizeable negative effect of public spending on private investment. Various types of taxes also have negative effects on profits but the effects of government spending on investment are larger than those of taxes. These results support the non Keynesian effects of fiscal adjustments.

Paiko (2012) explored the implications of deficit financing on private investment in Nigeria covering the period from 1990-2007. The researcher derived five equations to determine relationship of different variables. The results show that government expenditure crowds out private investment by explaining above 92% of the total variation in private investment. Budget deficit has also a negative relationship with private investment. It is analyzed that external debt has negative and significant impact on private investment. To avoid crowding out effect, it is recommended that deficit should be financed through the capital market.

Akpokodje (1998) used time series data to examine impact of fiscal policy on private investment. The long run regression results proved that a fiscal policy weakened by fiscal deficit has strong and significant effect on private investment in Nigeria.

Blejar and Khan (1984) found that fiscal deficit have a negative impact on private investment in Thailand and Argentina and public expenditure or consumption crowds out private investment.

Rama (1993) and Solamano (1993) proved for the economy of Nigeria that fiscal deficit has indirect impact on private investment because real interest rate rises in response of domestic debt financing.

Blanchard and Perotti (2002) analyzed that increase in public spending and taxes have a negative impact on private investment.

Looney (1995) analyzed the impact of government expenditure on investment and suggests that private investment does not suffer from government's non infrastructural investment.

Hyder (2001) used the vector error correction method for Pakistan and proved a complementary relationship between public and private investment.

Aisen and Hauner (2008) analyzed for sixty advanced and emerging states by using reduced form equation. The conclusion of study showed that budget deficit have negative effect on interest rate during 1985-1994 and effect was positive after 1995. Overall conclusion divided into three groups. Firstly budget deficit have positive effect on interest rate, secondly this effect varied from country to country and thirdly effect of budget deficit depends upon interaction terms.

Chaudhary and Abe (1999) found that budget deficit is responsible for high inflation, low growth and crowding out of private investment in Pakistan.

Ahmad and Qayyum (2008) examined the effects of government spending and macroeconomic uncertainty on private fixed investment in service sector of Pakistan from 1972 to 2005 and found that an increase in government spending and interest rate discourage private investment.

4. Model Specification and Methodology

4.1 Model Specification

In this section, a framework is derived to investigate the impact of fiscal policy on private in an economy.

Obstfeld and Rogoff (1995) presented a lifetime utility function. According to them, the consumption index, on which utility depends, is given by

$$C= \left[\int_0^1 c(z)^{(\theta-1)/\theta} dz \right]^{\theta/(\theta-1)} \tag{1}$$

Where $\theta > 1$ and $c(z)$ is a home individual's consumption of product z. If $p(z)$ is the price of good z, then consumption based money price index is

$$P = \left[\int_0^1 p(z)^{1-\theta} dz \right]^{1/(1-\theta)} \tag{2}$$

If r_t is the real interest rate earned on bonds between dates t and $t+1$, F_t and $M_t$denote the stocks of bonds and money held by consumer, then individual's budget constraint is

$$P_tF_t + M_t = P_t(1+r_{t-1})F_{t-1} + M_{t-1} + p_t(z)y_t(z) - P_tC_t - P_tT_t \tag{3}$$

Where y is the individual's output and T shows the real taxes paid to government. An individual maximizes a utility function that depends positively on consumption and negatively on work effort, which is positively related to output.

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} \left[\log\left(Cs + \delta Gs\right) \frac{x}{1-\in} \left(\frac{Ms}{Ps}\right)^{1-\in} - \frac{k}{2} Ys(z)^2 \right] \tag{4}$$

Where U_t is utility at time t, β is discount factor ($o < \beta < 1$), C is consumption index, Ms is the nominal money supply and Ps is the price level. Ys is the output of good z and K is the parameter, Gs stands for government spending. In this case, an individual's demand for product z in period t is

$$C_t(z) = \left[\frac{pt(z)}{Pt} \right]^{-\theta} C_t \tag{5}$$

Here θ is the elasticity of demand with respect to relative price. Now government consumption for product z is

$$G = \left[\int_0^1 g(z)^{(\theta-1)/\theta} dz \right]^{\theta/(\theta-1)} \tag{6}$$

It is assumed that government purchases do not directly affect private utility. Government expenditures are financed by tax revenues or seignorage.

$$G_t = T_t + \frac{M_t - M_{t-1}}{Pt} \tag{7}$$

G_t is government spending, T_t is taxes while M shows the seignorage. By combining the private and government demand, we get following demand function for good z in the period t.

$$y_t^d(z) = \left[\frac{p_t(z)}{P_t} \right]^{-\theta} (C_t + G_t) \tag{8}$$

Where

$$C_t = nC_t + (1-n)C_t \tag{9}$$

is private consumption demand. And

$$G_t = nG_t + (1-n)G_t \tag{10}$$

is government consumption demand.

There is a notable work to examine the transmission channels of fiscal policy by Baldacci et al. (2004). The Generalized Method of Moments was applied and found the total factor productivity channel to be most effective, through which fiscal policy affect macroeconomic activities.

According to Baldacci et al. (2004), general equilibrium model can be used to examine the effects of fiscal policy.

$$M = f(FP, Xt) \tag{11}$$

Where FP represents fiscal policy variables, M is for macroeconomic activities like investment, fiscal deficit and inflation and vector X stands for vector of control variables. To find out the impact of fiscal policy variables on macroeconomic activities, following model is estimated as:

$$M = \alpha_0 + \alpha_1 FP + \alpha_2 X + \mu \quad (12)$$

Where M stands for macroeconomic activities, FP shows the fiscal components and X represents the control variables.

No doubt, investment plays a vital role for economic growth of an economy. Different researchers used different variables to determine the private investment in developing countries. Solimano (1992) found that domestic output, real interest rate, public investment, external debt, credit availability, exchange rate and macroeconomic stability are the important factors for private investment in developing countries. Ribeiro and Joanilio (2003) used real GDP, real interest rate, public sector investment, real exchange rate, ratio of private sector credit to GDP, external debt, change in inflation rate and foreign direct investment as determinants of private investment in Pakistan. Keeping in view the private investment equations of these authors, following variables are selected for Pakistani economy.

$$PI = f(FD, INT, INF, ER, ED) \quad (13)$$

Where *PI*= private investment, *FD*= fiscal deficit, *INT*= rate of interest, *INF*= inflation, *ER*= exchange rate, *ED*= external debt.

4.2 Methodology

The presence of unit root in time series data is checked by applying Augmented Dicky Fuller Test. After finding the integrating order of variables, the long run ARDL model is estimated because it is a reliable approach for small sample size. In the next step, the error correction model is determined for short run dynamics.

4.3 Data and Variables

A consequential research requires an adequate and reliable data of all the variables. The data for this paper consists of annual observations for the period 1979-2012. The real values of variables are used instead of nominal values for estimation. The data set for the most of variables have been taken from Pakistan Economic Survey (Various Issues)[1], Handbook of Statistics on Pakistan Economy[2] and World Development Indicators[3]. The details of the variables are given below:

ER = Exchange Rate. It is constructed by taking the data of domestic prices, nominal exchange rate and foreign prices

ED = External Debt as percentage of GDP

[1] Published by Ministry of Finance, Islamabad, Pakistan

[2] Handbook is Present at the official website of State Bank of Pakistan, Karachi

[3] The WDI data set is available on the official website of World Bank

FD = Fiscal Deficit as percentage of GDP
INF = Inflation Rate =Consumer Price Index
PI = Private Investment as percentage of GDP
X = Exports as percentage of GDP
INT = Rate of Interest = 9-months T-bill rate

5. Empirical Analysis

The integration order of variables describes that all variables are integrated at order of I(0) or I(1) then F-statistics is calculated in order to test the existence of long run relationship. The calculated F-statistics value is 5.13 while the critical Bound values are at 10% level of significance (2.035-3.153), at 5% level of significance (2.365-3.553) and at 1% level of significance (3.027-4.296) so it shows that there is long run relationship among the variables. Before estimating the coefficients, lags are selected via Schwartz Bayesian criterion which is given below.

Table 1: Lags Defined Through VAR-SBC

VARIABLES / LAGS	PI	INT	FD	INF	ED	ER	X
0	2.27	0.75	0.92	0.23	1.99*	0.55*	1.47*
1	2.18	1.04	0.56*	0.20	2.55	4.04	1.87
2	1.98*	0.54*	0.70	0.14*	2.13	3.71	2.31

Note: * Shows minimum Schwarz SBC.

After finding the long run relationship and lag order of variables, coefficients are estimated by using ARDL technique. The mathematical form of ARDL model is as follows;

$$\Delta PINV = \alpha_0 + \sum_{i=0}^{n} \alpha_1 \Delta INT_{t-i} + \sum_{i=0}^{n} \alpha_2 \Delta FD_{t-i} + \sum_{i=0}^{n} \alpha_3 \Delta INF_{t-i} + \sum_{i=0}^{n} \alpha_4 \Delta ED_{t-i} + \sum_{i=0}^{n} \alpha_5 \Delta ER_{t-i} + \sum_{i=0}^{n} \alpha_6 \Delta X_{t-i} + \beta_1 PINV_{t-1} + \beta_2 INT_{t-1} + \beta_3 FD_{t-1} + \beta_4 INF_{t-1} + \beta_5 ED_{t-1} + \beta_6 ER_{t-1} + \beta_7 X_{t-1} + \varepsilon_t$$

In this model, private investment (PINV) is dependent variable while interest rate (INT), fiscal deficit (FD), inflation rate (INF), external debt (ED), exports (X) and exchange

rate (ER) are taken as independent variable. All data is applied after log transformation. The diagnostic tests are also applied to check the efficiency of data. The estimated results are given below.

Table 2: Estimated Long Run Coefficients for Private Investment Equation

Dependent Variable: Private Investment				
Regressors	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
INT	-0.20*	0.04	-4.43	0.00
FD	-0.23*	0.05	-4.36	0.00
INF	-0.05***	0.03	-1.65	0.10
ED	-0.92*	0.10	-8.38	0.00
ER	0.30	0.23	1.26	0.22
X	0.36**	0.15	2.33	0.03
R^2 =0.96 Adjusted R^2=0.94 DW-stat =1.94 Serial Correlation LM Test=0.75(0.48) ARCH Test =0.73(0.48) White Heteroscedasticity =0.70(0.74) Jarque-Bera Test =0.51(0.77)				

Note: *and **shows significance at 1% and 5% level of significance.

The results obtained shows that interest rate have negative and significant impact on investment. High interest rate reduces the power of private sector to get loans so investment decreases due to high interest rate. It is evident that fiscal deficit negatively affects the investment. It might be due to fact that fiscal deficit lowers the access to bank credits by the private sector because of much loans by the government. Hence, fiscal deficit causes to crowd out investment. It is clear from the results that coefficient of inflation is negative and significant. It is due to that high inflation rate increase the cost of production and creates the shortage of supply, which lowers the investment. Exchange rate positively affects the private investment. The appreciation of exchange rate decreases the demand for home country's goods and services abroad. So it decreases the investment in the country. It is shown that external debt has negative impact on investment because investors lose their confidence by fluctuation of the economy. Exports of the country have also positive effect on investment because the demand of home country's goods increases which have attraction for investors to invest more.

After estimating the long run relationship, the error correction model for short run dynamics is estimated. The ECM form of growth model is following;

$$\Delta PINV = \alpha_0 + \sum_{i=0}^{n} \alpha_1 \Delta PINV_{t-i} + \sum_{i=0}^{n} \alpha_2 \Delta INT_{t-i} + \sum_{i=0}^{n} \alpha_3 \Delta FD_{t-i} + \sum_{i=0}^{n} \alpha_4 \Delta INF_{t-i} +$$

$$+ \sum_{i=0}^{n} \alpha_5 \Delta ED_{t-i} + \sum_{i=0}^{n} \alpha_6 \Delta ER_{t-i} + \sum_{i=0}^{n} \alpha_7 \Delta X_{t-i} + ECM_{t-1} + \varepsilon_t$$

The estimated results are following;

Table:3 Estimated Short Run Coefficients

Dependent Variable: Private Investment				
Regressors	**Coefficients**	**Std. Error**	**t-Statistic**	**Prob.**
ΔINT	-0.26*	0.03	7.60	0.00
ΔFD	-0.29*	0.04	-6.40	0.00
ΔINF	-0.03	0.03	-1.00	0.37
ΔED	-0.84*	0.13	-6.25	0.00
ΔER	0.38	0.23	1.65	0.28
ΔX	0.43**	0.16	2.65	0.05
ECM_{t-1}	-0.67**	0.27	-2.47	0.00
R^2 =0.94 Adjusted R^2=0.91 DW-stat =1.88 Serial Correlation LM Test=0.08(0.91) ARCH Test =1.78(0.19) White Heteroscedasticity =0.91(0.59) Jarque-Bera Test =0.85(0.65)				

Note: *and **shows significance at 1% and 5% level of significance.

The estimated lagged error correction term ECM_{t-1} is negative and significant. The significance of error term represents the long run relationship of variables estimated in the above described model. The feedback coefficient is -0.67 which indicates that 67% disequilibrium is corrected in the short run. The results also indicate that INT and FD have significant negative effect in short run while X has significant positive impact in short run. INF and ER have not a significant effect in short run.

6. Conclusion and Policy Implications

The basic purpose of this paper is to analyze the impact of tools of fiscal policy on private investment for the economy of Pakistan covering the period from 1979 to 2012. First of all, Augmented Dicky Fuller test is applied to test the presence of Unit Root in the variables. Results of test suggest that all variables are stationary either at I(0) or I(1). On the basis of derived results, Autoregressive Distributed Lag Model is applied to examine the impact of variables in long run as well as in short run.

Results indicate that fiscal deficit has negative impact on private investment. When government lends more from commercial banks or other domestic institutions to finance its expenditure, then private investors have fewer chances to get loans. So reduction in private investment leads to slow down the economic growth.

By decreasing the interest rate, attraction can be created for investors to invest more because it has negative effect on private investment. Result derived in the paper is also supported by economic theories that enlighten the negative impact of rate of interest on investment.

To increase the level of private investment in the country, there is need to decrease the inflation rate because inflation increases the cost of production and investors have less attraction to invest in the country. Due to high inflation rate, it is difficult to compete in international market.

External debt is affecting badly the level of private investment in Pakistan. It has multiple negative impacts on the economy. Rising debt causes to fluctuate more the economy rapidly and investors hesitate to invest in highly debited economies.

Exports of the country have also positive impact on the private investment. If the domestic goods compete the international markets then investors like to invest more to earn their profit and it causes to increase the foreign reserves of the country.

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The effects of the implementation of value-based management

Valentin Beck[1]

Abstract

Many managers are caught in a dilemma: between a desire to maximize the value of their companies and the demands of 'stakeholder theory' to take into account the interests of all the stakeholders in a firm. The way out of the conflict lies in a new way of measuring value. The purpose of this paper is to explore how value-based management is perceived, implemented, and utilized in leading automotive corporations in Germany, and to examine factors that influence the decision to utilize it. The data was gained by using in-depth interviews with financial managers of German automotive corporation to study their opinions of and experiences with value-based management systems and metrics. The findings of the empirical study and primary research shows the problems of value-based management implementation in failing to achieve the right balance between all actors of agency conflict.

Keywords: value-based management, shareholder-value, performance measurement, technique

JEL Classification: G32, M21

1. Introduction

Over recent years, the global automotive industry has generally experienced continual growth. The major market actors of this industry are original equipment manufacturers (OEMs), and suppliers of various value-added stages. As a result of the economic growth following the financial market and economic crisis, managers of OEMs, such as Daimler, refer to the past few months as being the most successful ones in their corporate history. OEMs of highly developed economies can maintain and expand their market position only if they increase their enterprise value continuously (Hekkert et al. 2007, p. 413). For this purpose, the corresponding department of OEMs uses value-based management tools which have also been established as a key objective in German automotive enterprises (Kaufmann / Götzenberger 2006, p 183).

Value-based management is a tool to reduce the lack of goal congruence between the objectives of the management and those of the shareholders of the organization. Surveys

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show that nowadays a large number of companies are using value-based management not only to increase shareholder value but also to make themselves more attractive to investors and creditors. However, value-based management is not rather a process that should be permanently implemented in the corporation, and which defines objectives as well as individual control instruments. Satisfactory with the result of the implementation of value-based management strategies is confirmed by some of the large multinationals, including Coca Cola and Briggs & Stratton, which have successfully implemented value-based management strategies. Several studies have been considering in connection with implementing value-based management can be found in the literature (Lewis, 1994; Rappaport, 1998; Ryan Jr., Trahan, 1999; Martin, Petty, 2000; Morin, Jarrell, 2001; Haspslagh et al., 2001; Koller et al., 2005). Nevertheless, there is little empirical evidence on the factors that explain if value-based management improves automotive companies' performance.

To answer this question, I provide some evidence for the effects of value-based management control and show to which extent value-based management affect the management control system.

The paper is organized as follows: Section 2 gives the basic theory of effects of implementation of value-based management in general. The third section presents in details the methodology of the research object and data. Section 4 and 5 present the results of this survey and conclusions of the paper.

2. Effects of implementation of value-based management

The value-based management approach is difficult to implement because basically it requires a distinct mindset. Profits, bonuses based on earnings and performance measurements associated with accounting returns influence the implementation process of value-based management. In such an environment, it is not easy to dedicate the whole organization to the creation of value. Weaver states that the whole administrative body as Chief Executive Officer, the board of directors or governors, top and middle level management and other key staff is the driving force to implement value-based management (Weaver 2003, pp. 5-10). It is important that they all are involved because each manager performs his duties under a different set of rules and regulations.

One feature of value-based management is that it splits up the whole organization into small branches or divisions; therefore it must be implemented by a cross-functional group. This dedicated group of personnel is used to carry out the transformation of traditional management to value-based management. This group of managers should be highly competent in managing day-to-day affairs and communication. The team must have the following goals (Ruth & Keith 2008, p. 55):

- Directing the implementation of value-based management,
- Open communication about value-based management,

- Organizing and manipulating the gradual implementation of value-based management around different divisions of the organization,
- Playing a vital role between the staff and the executive body,
- Resolving priority issues, i.e. what are the demands of higher authorities and what is possible with available resources,
- Conducting meetings to familiarize each individual with respect to value-based management,
- Arranging necessary training programs for key staff to convince them about the significance of value-based management,
- Modifying existing performance measurement tools or creating new standards of performance management which best suit value-based management, e.g. instead of profit, focusing on cash and
- Resolving minor problems between top level management and operational levels.

Due to the aim of creation of value the incentives to key staff must be correlated with their performance. Conventional incentive processes which are associated with money should be modified. An important point is that rewards must be given on the basis of existing standards, for example, the forecast of future value is a very subjective incentive approach. In fact, the process of creation of value takes a long time; therefore the best approach is to connect the growing measures with the value. It is better to estimate the incentive measures at the start of each financial year while managers should have real-time data about the value and cost of capital. This will increase objectivity in the organization. The value of the capital and the cost of capital must be clearly communicated to each manager. Establishing the mindset of the employees is a difficult task. In fact, it is one of the most challenging aspects of value-based management. Much depends on the manager's personal traits and how he convinces the staff to work harder for the increase of organizational value. He can stimulate the workers by informing them that with the growth of the organization's wealth, not only the shareholders but also the workers will receive benefits. Managers should apply different motivational theories to encourage employees to achieve the basic aims of the corporation (Stewart 1991, p. 25).

Against the competition, value-based management needs the creation of benchmarking value. Value-based management should be linked with the basic aim and strategy of the organization as well as the standard operating procedure and decision-making processes. It is the responsibility of managers to differentiate between good and bad capital. If capital is generated at a level higher than the cost then it is called good capital, and in the opposite case, it is called bad capital (Chen & Dodd 1998, p. 73).

In order to determine the organizational and employee's performance through the value-based management approach, it is necessary for the managers to acquire information about performance aspects. Generally the main purpose of the measure is to check and enhance individuals' and collective performance. The performance measure normally

considers the evaluation, control, budgeting, motivation, promotion, learning and improving aspects of the organization with respect to personnel, strategies, process and systems (Behn 2003, p. 600).

More detailed advantages, as illustrated on valuebasedmanagement.net, are as follows:

- Maximizing value-creation,
- Improving strategies for coping with increased complexity and greater uncertainty and risk,
- Preventing undervaluation of stock,
- Encouraging value-creating investments,
- Streamlining planning and budgeting,
- Increasing transparency of a company,
- Supporting transactions in globalized and deregulated capital markets,
- Aligning interests of high level managers with those of shareholders and stakeholders,
- Facilitating the use of stock for mergers or acquisitions,
- Facilitating communication with investors, analysts and stakeholders,
- Improving internal communication,
- Setting management priorities clearly,
- Facilitating improvement of decision- making,
- Helping balance short-term, mid-term and long-term trade-offs,
- Improving resource allocation,
- Setting effective compensation targets and
- Preventing takeovers.

Ronte stated that recognizing that value-based management is a paradigm shift, management must have the drive to make it succeed, and the quality and quantity of communication is essential. It also requires resources, often more than normally required. It helps if the process is implemented in small stages, in order to build confidence and learn along the way (Ronte 2010, p. 40).

According the Chartered Institute of Management Accountants value-based management has a positive impact on almost all areas of an organization, especially in management and decision-making. In Europe, its implementation varies. In Germany, Ireland, Switzerland and Austria, 75% of the largest corporations are implementing value-based management, in the UK about two thirds, half in France and about a third in Norway and Sweden. There were few negative comments about it, and the difficulties encountered in implementing it were all related to people rather than technology. Cultural change was mentioned as the biggest issue. Only a quarter of people interviewed said that implementing

value-based management was difficult (The Chartered Institute of Management Accountants (CIMA), 1999).

Selected works on the implementation of value-based management have been already published. Since the issues raised in these works often differ considerably from one another, it seems reasonable to provide some categorization and structure. An essential difference between the works is that some of them are based exclusively on theoretical considerations, while others are based on empirical data. The issues raised in the papers in connection with implementing value-based management can basically be organized as follows:

Table 1: Categorized papers

Article	**Training**	**Participation of the employees**	**Internal communication**	**Support of top management**	**Goal system**	**Planning system**	**Control system**	**Information system**	**Compensation system**	**External communication**
Lewis (1994)	X	X	X	X	X	X		X	X	
Rappaport (1998)	X		X	X	X	X			X	X
Ryan Jr./ Trahan (1999)	X	X		X			X			
Martin/ Petty (2000)	X			X	X				X	
Morin/ Jarrell (2001)	X			X		X			X	X
Haspeslagh/ Noda/ Boulos (2001)	X			X					X	
Koller/ Goedhart/ Wessels (2005)	X	X		X	X		X	X	X	X

Source: Author's own illustration

It seems reasonable to bring together the categories of 'Training', 'Participation of the employees', 'Internal communication' and 'Support of top management' into a single success factor, 'Assuring acceptance'. The other categories represent very different facets of business, and cannot therefore be compressed into one or more success factors.

Consequently, each of these categories corresponds to a success factor. Organizational structure determines whether conditions are appropriate for the implementation of a value-based controlling system, and is therefore the deciding factor in whether or not it is a suitable approach. Personnel management and whether or not the system is accepted are, however, crucial aspects in determining the extent to which it reaches its full potential. Consequently, these three factors determine the basic conditions within the company for the implementation of value-based controlling.

Value-based management is a quest for prosperity and profit for both the employees and of course for the shareholders. Although, the literature review provides evidence that companies which attach importance to human values provide high standards of life for their shareholders and employees, even so, only a comparatively small number of value-based organizations exist in the competitive market.

Shareholders and top order management definitely receive more benefits by the implementation of shareholder value theory, and economists also logically assert that when the business activities make the best use of the shareholder value, then employees, customers, contractors and distributors will be more affluent. In order to run organizations under value-based management, shareholders have to depend greatly on their top level managers. But it has been observed that the managers who control the allocation of corporate assets and returns cannot create value for shareholders. In this situation, the free cash flow should be distributed to the owners, who can then dedicate these assets to some other standby use (Ryan Jr./ Trahan, 2007).

Value-based management deals with numerous performance measures which are implemented by top level management based on reliable information. Thus, a comprehensive value-based management system comprises strategic planning, establishment of value drivers, financial measures, analysis of internal and external factors, and the consistent supervision of skilled, efficient and active top level management.

3. Methodology

An empirical study was carried out to contribute to this research field. The framework of the study was to determine the effectiveness of value-based management in companies in the automotive sector. The hypothesis was formulated and analyzed:

"Value-based management improves automotive company's performance."

The following questions were to be addressed:

- What are the effects of value-based management control?
- To which extent does value-based management affect the management control system?

In-depth interviews were carried out in 16 German companies of the automotive industry. Interviewees were OEMs and suppliers in the automotive sector. The companies that are represented in these segments can be assumed to be intensely engaged with the questions surrounding value-based management. The selection criteria for the survey were revenue, employees, and regional relevance of the respective companies. This resulted in a baseline total of 16 companies for the study, 11 of which participated in the survey. The interviewed companies were clustered into OEMs and suppliers. In cluster 1 the most well-known German OEMs were selected for interviews based on revenues. Also in cluster 2 the most important suppliers were selected regarding the revenues. The response rate of 68.75% is extremely satisfying. It should also be noted that the OEMs surveyed represented almost the entire sector in Germany.

Table 2: Survey response rate

	Response	**Response %**
OEMs	4 of 6	66.67
Suppliers	7 of 10	70.00
Total	11 of 16	68.75

Source: Author's own illustration

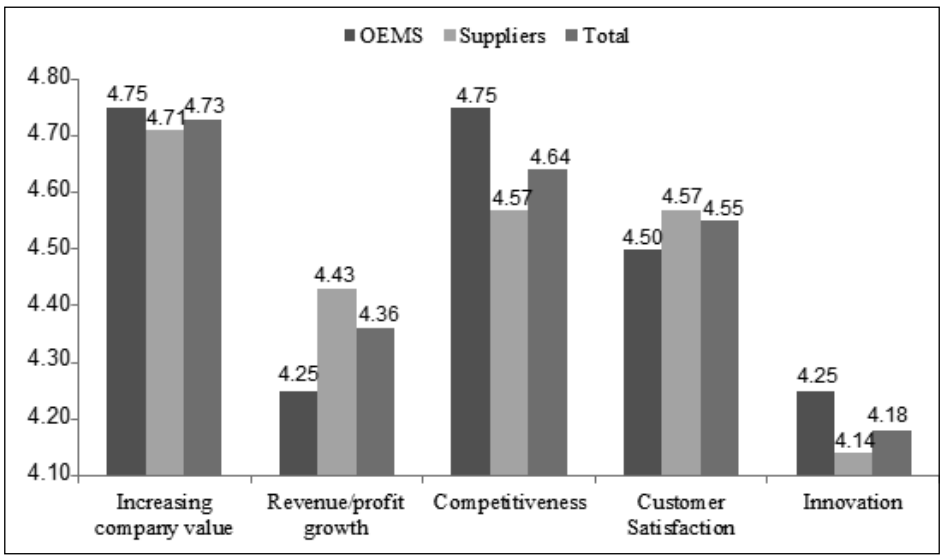
The aim of these interviews was to find out how value-based management improves automotive company's performance. After analyzing and interpreting the data, surprisingly, the results do not confirm the significant improvements through value-based management in all aspects as assumed, especially not at strategy development and the power of decision.

For the purpose of examining the research questions, a poll was chosen using a standardized questionnaire guideline, in order to include as many automotive companies as possible within a manageable period of time, and to thus gain a broad overview of the status and the factors influencing a value-based management of the company. The questionnaire was developed in different processing stages (Lamnek 2010, p. 349), and according to more recent macro-economic theory, as well as current national and international literature on the subject of value-based management. The questionnaire was subsequently put through a preliminary test in September of 2013, in the context of which interviews were conducted with five scientific and practical experts (Helfferich 2009, pp. 182-185). Following this, after the adaptation/revision of the interview guideline, data collection was conducted in a period from October to December 2013. Interviewees were departmental heads, such as Chief Controllers. The interview guideline was conceived to result in a complete as possible picture of the implementation status of value-based management in the automotive sector. The interviews are problem-oriented, with open, semi-structured questions (Mayring 2002, p. 67). The interviews allow the interviewee to speak as freely as possible, but with a focus on the research subject, which the interviewer explains at the beginning of the interview.

4. Analysis and discussion

Depending on company conditions, these are subject to various influences. The questions under "Relevance of value-orientation as corporate objective" were originally focused on the primary corporate objectives and target groups. Seven of the 11 companies regard the increase of company value as their primary corporate objective. Overall, this objective is in first place, with an average relevance of 4.73 points. Among the OEMs, however, first place is shared between increasing the company value and competitiveness.

Figure 1: Primary corporate objectives
(answers are on a scale of 1 "not relevant" to 5 "very relevant")



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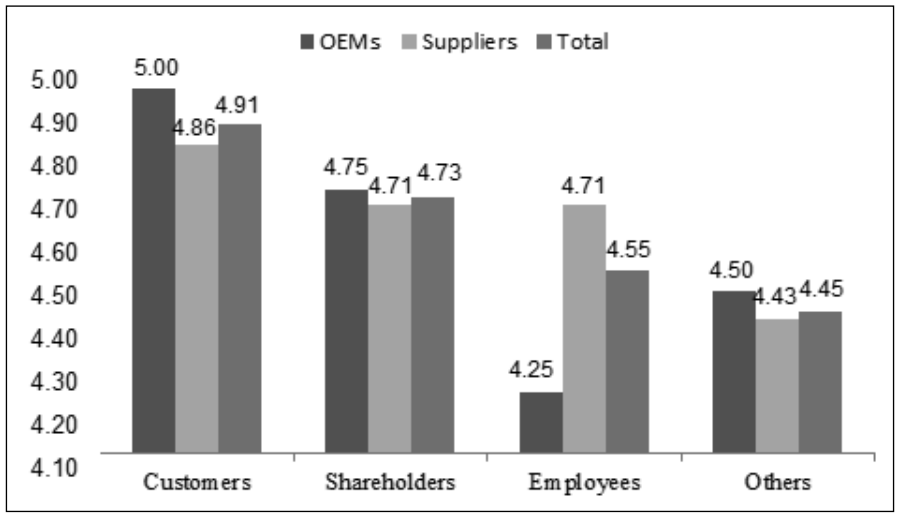
When asked about the primary corporate objective, interviewees frequently emphasized that the corporate objective was in safeguarding all interests. This is a strong indication of the presence of the stakeholder perspective in German automobile companies. Furthermore, the companies state that the control of operative areas is important.

In the questions about corporate target groups, it becomes evident that the customer target group is weighted higher than the shareholder group (e.g. stockholders). One obviously wants to maintain a strong focus on the interests of other stakeholders.

Figure 2: Corporate target groups



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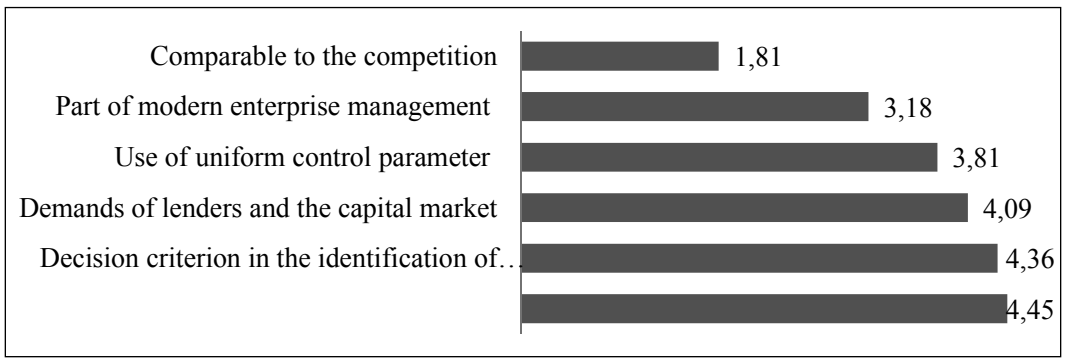
The question about factors relevant to the introduction of a value-oriented management system resulted in the following figure.

Figure 3: Relevant factors for the introduction of value-based management (weighted average number)



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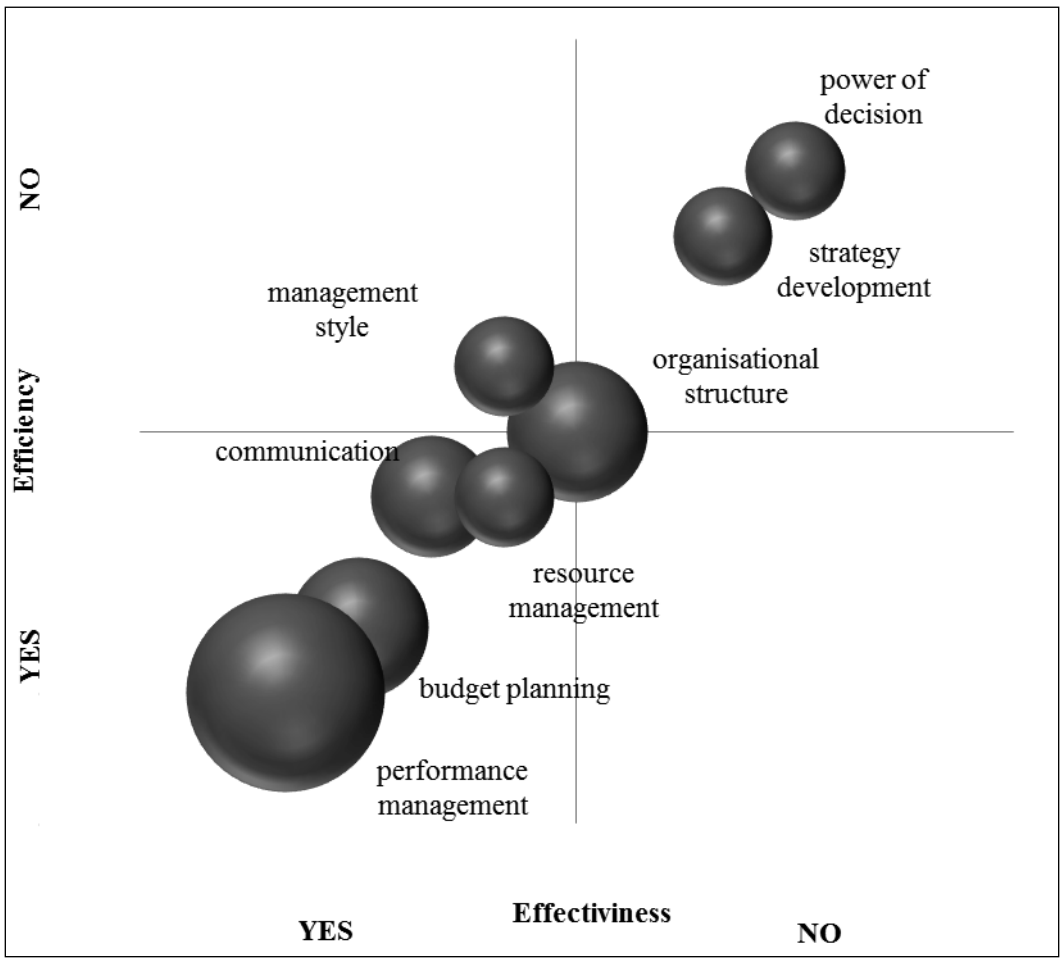
The majority of companies acknowledge that the implementation of value-based management resulted in an efficient allocation of capital, and thereby to an increase of company value. External factors, such as the demands of lenders and the capital market for high rates of return may be relevant, but are not decisive to the implementation of a comprehensive shareholder value-orientation.

To the question "What has value-based management achieved in your company thus far", companies responded that above all, the level of confidence in value reporting has been increased. This has created a standard for success that is less vulnerable to manipulation, and which can be used as a comparative factor in the international context. Furthermore, it has resulted in opportunities to synchronize the internal and external accounting organizations, thereby creating a uniform and consistent data basis and control foundation.

Regarding the aspect of the affetctiveness of value-based management control systems the companies gave following answers:

Figure 4: Affected characteristics of value-based management control systems



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The interview partners also gave the range of importance (scale: 4 very important to 1 not important) of affected characteristics of value-based management control systems. The

importance factor is shown in the figure 4 in the size of the bubble. Figure 4 shows that the most important aspect of value-based management for the interviewees is the performance management. At the second place the budget planning and organizational structure was mentioned. Communication was ranged with the third place and at least the management style, resource management, strategy development and decision power.

The following conclusions can be drawn: The companies apply predominantly flat, decentralized structures. Such structures make it possible to calculate value creation for separate entities within their own responsibilities, related to their activities. The participated centralized companies are still fairly flat. However, with value-based management it does decentralize certain responsibilities as appears from the figure above. Targets are set lower into the organization in line with the value-based strategy. Companies became more businesslike upon value-based management, instead of consensus seeking. Decision rights lie at decentralized level. Business units have autonomy in making decisions without approval from the Board of Management (unless it concerns amounts above a certain level). Communication is based on dialogues. Previously, communication was predominantly top-down, where lower entities were only executing corporate directives. Strategy development is based on value creation and involves lower hierarchical levels. Resources are managed and assigned to the most value-adding activities, based on strategic plans and budgets. This counts for financial resources, but also for human resources. Resources and capabilities are therefore applied to those activities that show the most value creating potential. This implies that activities are divested in case they do not fit the business model or create insufficient value. The resources that are released or received are subsequently allocated to value creating activities. Budgeting still is an important instrument, but rooted in value creation and plans that follow from dialogues. Value drivers and non-financials have impact on the amounts, strongly related with strategy. In order to be able to respond quicker to changing circumstances in the company's environment and have managers enact proactively and entrepreneurial. In most cases, performance measurement has extended financial measures with (nonfinancial) value drivers. These are based on accountability and controllability. At some companies performance measurement also includes personal development, for instance by encouraging taking risks or personal objectives.

Surprisingly, the results by testing the hypothesis "Value-based management improves automotive companies' performance" do not confirm the significant improvements through value-based management in all aspects as assumed, especially not at strategy development and the power of decision. These results, in general, fail to support hypothesis "Value-based management improves automotive companies' performance". However, the result shows that the most of the interviewed companies dedicate that the implementation of value-based management resulted in an efficient allocation of capital, and thereby to an increase of company value. Interesting is that external factors as the demands of lenders and the capital market may be relevant for high rates of return, but are not decisive to the implementation of value-based strategy. It is conspicuous that value-based management control system has no positive effect to the power of decision, strategy development and management style. It seems that there came little support from the top management. Nevertheless, especially the

internal communication is equitably top-down. Planning system is still an important part in a company. Value drivers and non-financials have impact on the amounts, strongly related with strategy. To respond quicker to changing circumstances in the company's environment and have managers enact proactively and entrepreneurial, in most cases, performance measurement has extended financial measures with (nonfinancial) value drivers. These are based on accountability and controllability.

5. Conclusion

Value-based management is a quest for prosperity and profit for both the employees and of course for the shareholders. Although putting a value-based management system in place is a long and complex process, successful efforts share a number of common features.

This paper focused on the effects of the implementation of value-based management particular reference to German automotive companies. A general review was conducted of different improvement of automotive companies' performance through value-based management. Using in-depth interviews to study the investment evaluation practice in German automotive companies produced some methodological findings. According the literature value-based management has a positive impact on almost all areas of an organization, especially in management and decision-making. Therefore the decision was to test the hypothesis "Value-based management improves automotive companies' performance". However, unexpectly the results do not confirm the significant improvements through value-based management in all aspects as assumed, especially not at strategy development and the power of decision. The result help to diagnose the problems of value-based management implementation in failing to achieve the right balance between all actors of agency conflict.

Although, there are some limitations to the current study, this paper has shown avenues for future research. This study can be used as a basis for future studies. A quantitative survey could be prepared and carried out, involving a larger number of companies focusing on the persistence for the last five post-adoption years. Many questions could be rephrased and reformulated, and many important ones added. Finally, research on impact of the value-based management could be worth conducting.

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