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Optimal equity capital requirements for Swiss G-SIBs*

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Abstract: This paper extends the analysis of Junge and Kugler (2013) on the effects of increased capital requirements on Swiss GDP and obtains the following main results: First the Modigliani-Miller effect is robust with respect to a substantial extension of the data base and yields an offset of capital cost of 46 percent. Second, the Translog production function estimate results in a time-varying elasticity of production with respect to the price of capital which is in line with the findings for other countries. Third the unweighted capital (leverage) ratio for Swiss G-SIBs is approximately 6 percent for Basel III Tier1 and 4.4 percent for CET1. This corresponds to risk-weighted capital ratios of 17 percent and 12.5 percent, respectively. The estimates show that the recently revised Swiss Too-Big-To-Fail capital ratios for G-SIBs are lower than the optimal levels. However, the oft-debated proposal to raise the equity-to-asset ratio to 20 to 30 percent is not warranted by our analysis.

JEL-Classification: G21, G28, E20, E22

Keywords: Financial regulation, Bank equity capital requirements, Capital structure, Elasticity of substitution, Translog production function

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1. Introduction

This paper seeks to contribute to the discussion of the optimal equity capital requirements for banks from a society's perspective. In a previous paper about the impact of higher equity capital requirements on the Swiss economy, we had limited ourselves to a comparison of the social costs and benefits and concluded that the long-run benefits exceed long-run costs by a substantial multiple.[1] In this paper we present an attempt to determine the optimal leverage and capital ratios for Switzerland's global systemically important banks (G-SIBs).

This is desirable for a number of reasons.

First, the economic debate about the appropriate minimum level of regulatory capital requirements for banks from a society's perspective is an open question. On the one end Admati and Hellwig (2013, p. 179) argue that there are no social costs associated with higher equity capital requirements and propose a leverage ratio requiring equity capital on the order of 20 to 30 percent of total assets. On the other hand, banking industry representatives continue to emphasize that in particular higher equity capital requirements reduce the availability of credit and retard economic growth.[2] The conflict over the minimum appropriate level of banking capital blocked the finalisation of Basel III at the beginning of 2017. Some members of the Basel Committee on Banking Supervision (BCBS) emphasized that only strongly capitalized and highly liquid banks can support economic growth, while others argued that the pendulum of the Basel III revisions had already swung too wide and undermined the economic recovery.[3]

Second, in October 2015, Switzerland amended its Too-Big-To-Fail (TBTF) legislation and decided to raise the required going concern leverage ratio for Switzerland's G-SIBs – Credit Suisse and UBS – to 5 percent.[4] This decision was based on the recommendation of the "Group of Experts on the Further Development of the Financial Market Strategy in Switzerland" that Switzerland should be among the countries with the most stringent capital requirements.[5] Designing Swiss capital requirements along the same lines as foreign standards is one choice as well as the orientation on international competitiveness.[6] As relevant as they are these considerations should be complementary in nature. However, they do not address the key question of whether the new TBTF capital requirements are appropriate from a society's point of view. An optimal level of bank equity capital should be determined by some aggregate welfare objective, taking into account that higher equity capital requirements benefit the economy by reducing the likelihood of banking crises while simultaneously imposing economic cost in terms of a lower potential economic output.

Third, the debate about the social cost and benefit of higher capital requirements can only be settled by empirical analysis. In comparison to our 2013 paper, we can now utilize an extended database

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[1] Junge and Kugler (2013).

[2] See for example the comments of Sergio Ermotti, UBS CEO, in the Neue Zürcher Zeitung (January 7, 2017).

[3] See for example the speech of Stefan Ingves (2017), Chairman of the Basel Committee and Governor of Sveriges Riksbank.

[4] FINMA (Swiss Financial Market Supervisory Authority FINMA) 2015.

[5] Group of Experts, Report (2014).

[6] Schweizerische Eidgenossenschaft (2016).

mainly in three areas: (i) Updated time series to estimate the Modigliani-Miller (M-M) effect including a period with a sharp reduction in leverage after the financial crises and allowing us to check the robustness of our earlier estimates. (ii) Use of a Translog production function with a time-varying elasticity of substitution between capital and labor, which is estimated with a completely revised and updated data series for the Swiss capital stock. This corrects for a weakness of our 2013 cost of capital calculation, where we used a Constant Elasticity of Substitution (CES) production function with an elasticity of substitution estimate close to 1. The latter appears rather high, as both economic theory and empirical results for other advanced countries suggest a value which is clearly below 1 and around 0.5. (iii) New capital quality conversion factors: An overlap of reporting dates between published capital requirements of CS and UBS under both Pre-Basel III and new Basel III definitions allowed us to determine conversion factors for a common reporting period. When we wrote our 2013 paper this information was not available.

Based on this improved data situation, we extend our previous paper and seek to determine the optimal leverage and capital ratios for the Swiss G-SIBs.

Switzerland's domestically systemically important banks (D-SIBs) do not come within the scope of our examination because these banks are not publicly traded on the Swiss stock exchange and therefore cannot be included in the methodological approach pursued in this paper.[7]

The Swiss TBTF legislation stipulates that TBTF banks must fulfil minimum requirements for two different types of loss-absorbing bank capital: equity capital to absorb current operating losses in order to reduce the likelihood of G-SIBs failing (going concern capital) and equity-like capital to fund an orderly resolution in order to reduce the impact of failing (gone concern capital).[8] In our examination, we focus on the level of going concern equity capital for the Swiss G-SIBs, taking as a given the gone concern capital requirements. Going concern capital is composed of Common Equity Tier1 (CET1 capital) plus Additional Tier1 capital (AT1). CET1 refers to loss absorbing equity of the highest quality and AT1 must meet the requirement to absorb losses, either through a write-down or conversion into ordinary shares. So the definitions of CET1 and Basel III Tier1 capital provide the appropriate regulatory basis to determine optimal equity capital requirements in terms leverage and capital ratios.

There are good reasons for a strict separation between the cost-benefit analysis of going concern and gone concern capital requirements. First at all, the costs of gone concern capital for failed banks must be compared to the benefits of orderly resolutions and, by definition, cannot be subsumed under a specification of social benefits resulting from a reduced likelihood and severity of bank crises. Second, the quality and cost of capital also differ between going and gone concern capital. Going concern capital is a tested loss absorber. The greater the cushion of CET1 and AT1, the more losses a bank can withstand while remaining financially viable. In contrast, gone concern capital can be composed of lower capital qualities. It can include Tier2 capital, senior subordinated debt and

[7] The three Swiss D-SIBs are Raiffeisen Gruppe, Zürcher Kantonalbank and PostFinance. The Swiss TBTF legislation requires that D-SIBs have to meet a lower minimum going concern leverage ratio of 4.5 percent. It is interesting that, in contrast to Credit Suisse and UBS, the three Swiss D-SIBs have comfortable levels of capital.

[8] See Financial Stability Board (FSB,2014) for an explanation of the need gone concern bank capital in addition to going concern bank capital.

bail-in-able debt, in short capital instruments that are less certain loss absorbers. Thus, it is essential to investigate separately the social costs and benefits for going concern and gone concern capital.[9]

Our article is arranged as follows. In section 2 we present the M-M proposition of capital structure irrelevance for banks, review the existing evidence and re-estimate the size of the M-M effect for Switzerland's G-SIBs using an extended sample period. In section 3 we investigate the implications of the M-M effects and calculate the banks' overall cost of funds and the social cost of higher equity capital requirements using the Translog framework. In section 4 we recapitulate the estimates of our 2013 paper for social benefits and derive a social benefit curve for additional equity capital requirements. In section 5 we compare the social cost and benefit associated with higher equity capital requirements and determine optimal leverage and capital ratios under different capital definitions. Finally, section 6 concludes.

2. The M-M framework of capital structure irrelevance

2.1 Empirical Evidence of the M-M effect

As shown by Modigliani-Miller, a company's overall cost of funds is unaffected by the mix of equity and debt under perfect capital markets and in the absence of taxes and subsidies. An increase in equity will simply lower its risk and consequently the required return on equity. Higher equity or less leverage also makes the bank's debt safer and implies less financial risk for debt. Ultimately a new equilibrium is established with lower required rates of return on equity and debt, a new mix of more equity and less debt and unaffected overall funding costs.[10] The translation of this mechanism into a testable econometric framework for banks was first explored by Kashyap, Stein and Hanson (2010) as well as Miles, Yang and Marcheggiano (2011) and was applied to Swiss data by Junge and Kugler (2013). The framework is derived from the Capital Asset Pricing Model (CAMP) and the M-M theorem. By assuming that the risk of bank debt is zero the following linear relationship between equity risk and leverage is obtained:[11]

$$\beta_{equity} = \beta_{asset} \frac{E + D}{E} \tag{1}$$

where β_{equity} is the equity risk of the banks, β_{asset} is the risk on the banks assets and $\frac{E+D}{E}$ is banks' leverage (L) with its equity (*E*) and debt (*D*) components.

According to equation 1 a reduction in leverage (i.e. an increase in equity) leads to a proportional decline of equity risk. For example, assume a bank that initially has a leverage of 40 and an equity market beta of 2. If equity is doubled, and hence leverage is halved to 20, equity beta declines from 2 to 1.

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[9] A first analysis of the social costs and benefits for gone concern capital was presented by the Financial Stability Board (FSB, 2015). These estimates suggest that the costs of gone concern capital are very small.

[10] As a numerical example assume a bank with a CHF 100 balance sheet financed by CHF 97 in debt and CHF 3 in equity. The return on debt is assumed to be 5% and the return on equity 25%. The overall costs of capital WACC are: 5.6% = [(5%*0.97) + (25%*0.03)]. If the bank decides to reduce debt to CHF 95 and raise equity to CHF 5, the bank is less risky than before. Under full M-M validity the required rate on equity will drop from 25% to 21.75% and the required return on debt from 5% to 4.75%. WACC however remains unchanged at 5.6% = [(4.75%*0.95) + (21.75%*0.05)].

[11] See in particular Miles et al (2011) for a presentation of the theoretical basis of equation (1).

As pointed out in a recent study by Clark, Jones and Malmquist (2015),[12] equation 1 is an appropriate specification for TBTF banks that benefit from implicit government guarantees and from deposit insurance in general. In this situation, the market perceives the debt of TBTF banks as risk-free and the adjustment to changes in leverage will be channelled through equity as stated in equation 1. In contrast, for smaller, non-TBTF banks the debt mechanism for adjustment cannot be ignored and the present framework is less appropriate.

Equation (1) can be tested directly by running a regression of β_{equity} on leverage and testing the hypothesis that the intercept is equal to zero if we have a full M-M effect. Alternatively, we can generalize (1) by considering the log-linear model $\beta_{equity} = \beta_{asset} L^c$ and test the full M-M hypothesis that c is equal to 1. The intercept term of this regression is now log(β_{asset}) and should have a negative sign.

The linear variants of equation 1 can be empirically tested in two steps using the general Swiss Performance Index:

1. The estimation of quarterly equity beta as defined within the CAPM

$$\Delta p_{i,t,n} = \alpha_{i,t} + \beta_{i,t}\Delta p_{t,n}^{SPI} + \epsilon_{i,t,n} \qquad (2)$$

$$\begin{aligned} where\ \Delta p_{i,t,n} &= daily \log stock\ return\ of\ bank\ i \\ \Delta p_{t,n}^{SPI} &= daily \log stock\ market\ return\ of\ the\ Swiss\ Performance\ Index\ (SPI) \\ \epsilon_{i,t,n} &= daily\ error\ term \end{aligned}$$

2. A regression of the form

$$\beta_{i,t} = a + bL_{i,t} + \vartheta_i + \delta_t + \varepsilon_{i,t} \qquad (3)$$

$$\begin{aligned} where\ \beta_{it} &= estimated\ \beta\ of\ bank\ i\ in\ quarter\ t \\ L_{i,t} &= leverage\ of\ bank\ i\ in\ quarter\ t \\ \vartheta_i &= bank\ specific\ effect \\ \delta_t &= time\ \text{specific effect} \\ \varepsilon_{i,t} &= error\ term \end{aligned}$$

So far, there are only a few empirical studies available that investigate the significance and size of the M-M effect. Kashyap et al (2010) and Miles et al (2011) show the existence of sizeable M-M effects for both the USA and the UK. Similar results are presented by ECB (2011)[13] for a sample of 54 large international banks, by Junge and Kugler (2013) for Switzerland and recently by Clark et al (2015) for the USA. Table 1 provides an overview of the estimated sizes of the M-M effect from different empirical studies which report their findings differently. In Table (1) we present various ways to compare the estimated M-M effects.

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[12] These authors point out that equation 1 is a variant of the Hamada framework. See Hamada, R. S. (1969).

[13] ECB (2011).

Table 1: Gauging of the Modigliani-Miller (M-M) offset

Data Inputs	54 largest global banks		USA		UK		Switzerland (Junge, Kugler, 2013)		Switzerland (Bernardi, 2015)
	ECB (Dec. 2011)		Kashyab et al (2010)	Clark et al (2015)	Miles et al (2011)		TBTF banks, Other banks	TBTF banks	Swiss IRB banks (CS, UBS and BCV)
M-M Offset based on regression analysis	linear vers. 1 1995-2011	linear vers. 2 1995-2011	linear 1976-2008	linear 1996-2012	linear 1997-2010	log linear 1997-2010	log linear 1999-2010	log linear 1999-2010	linear 1999-2014
(i) Estimated elasticity of beta with respect to leverage						69.2%	76.3%	54.5%	
(ii) Change in observed beta given a 100% increase in equity (halving in leverage) as a percentage of a change in beta under full M-M validity	40.9%	71.8%	70.5%		71.0%				
(iii) M-M effect derived from changes in WACC assuming a 100% increase in equity (halving in leverage).				100.0%	45.7%				9.1%
(a) Estimated coefficient: linear regressions of Leverage Ratio or Leverage	-0.045	-0.079	-0.0453		0.031				0.07
(b) Median (average) Leverage Ratio	5.00	5.00	7.00						
(c) Median (average) Leverage					30	30	45 (TBTF) 14 (Other banks)	45	
(d) Median (average) Beta	1.1	1.1	0.90		1.3	1.3	1.4 (TBTF) 0.3 (Other banks)	1.4	

Lines (i) to (iii) report our calculation of the M-M effect based on the information provided by the authors of each study.
Lines (a) to (e) report the data provided by the authors of each study.
Empty cells indicate “no data available” or not meaningful.

The estimated coefficients of the log-linear regressions are a direct measure of the M-M effects. With 100 percent M-M validity the elasticity of beta with respect to leverage is 1. Miles et al (2011) for the UK and Junge and Kugler (2013) for Switzerland report statistically highly significant and quite large direct elasticity estimates implying M-M offset in a range between 55 and 76 percent (see line (i) of Table 1).

Second, in cases of linear regressions, the estimated coefficients cannot be compared easily across alternative studies (line (a), Table 1). However, if the median (average) values of the bank equity betas and the bank leverage are reported as shown in lines (b) and (c), we can gauge the size of the M-M offset. This is shown in lines (ii) and (iii) of Table 1. In line (ii) we calculate the observed change in beta as a percentage of the change in beta assuming full M-M validity.[14] The linear regressions for both US and UK banks imply sizeable M-M offsets of 71 percent. Also the ECB-estimates for 54 large international banks suggest a range of M-M offsets between 41 and 72 percent. It is interesting to note that all these samples are typically composed of the larger, domestic or global systemically important banks.[15]

Finally, a third alternative for measuring the size of the M-M offset is offered by comparisons of estimated *WACC*-changes with a *WACC*-change under full M-M validity. Miles et al (2011), Junge and Kugler (2013), Clark et al (2015) and a UBS-supported study by Bernardi et al (2015) provide *WACC*-based results that can be used in this comparison. The M-M effects are summarized in line (iii). Again, the effects are sizeable for the UK (46 percent) and USA (100 Percent).[16] Further comparison of Clark et al (2015) with banks of different asset-size classes shows that the M-M effect is smaller for non-TBTF banks. The conclusions from their analysis are: First, the M-M theorem finds the strongest support among the US TBTF banks where implicit government guarantees are most material. Second, failure to differentiate by asset size leads to underestimation of the M-M effect.

In sharp contrast to all other empirical studies Bernardi et al (2015) find a very weak M-M effect, as low as 9 percent, for a range of larger and smaller Swiss banks.[17] In the light of the analysis of Clark et

[14] The ECB uses this measure in order to allow a comparison of the estimated coefficients with the full M-M proposition. A full M-M impact implies that when the equity doubles (or leverage is halved), the beta should decline by half. In the case of the ECB findings, the average leverage ratio of the banks is 5% and the average beta 1.1 [see Table 1, lines (b) and (c)]. Hence, if the leverage ratio doubles to 10%, the beta should fall to 0.55. Table 1, line (a), shows that the coefficient of the leverage ratio is -0.045. A doubling of the leverage ratio implies that the beta will fall by -0.225 to 0.875 (since 0.045*5 = 0.225). Under full M-M validity betas would fall by 0.55, which implies an M-M effect of 41% (=0.225/0.55). See ECB (2011), p. 129.

[15] The US sample is composed of large banks with greater than 10 bn. in assets in 2008Q4 USD, see Kashyap et al (2010), Table 1. The UK sample includes Lloyds Banking Group, RBS, Barclays, HSBC, Bank of Scotland and Halifax, see Miles et al (2011).

[16] Clark et al (2015) estimate an intercept statistically not significantly different from zero, which implies an M-M offset of 100 percent.

[17] The estimations of Bernardi et al (2015) consist of two steps. First, they estimate the increase in capital requirements for the Swiss banking system in general and the IRB banks in particular resulting from the BCBS plan to revise the Standardized Approach to bank capital for credit risk and to employ the revised Standardized Approach as a floor for bank capital based on the IRB approach. Second, they estimate the effect of these higher capital requirements on the *WACC*-based spreads for two scenarios: (i) a no M-M effect scenario or constant equity returns versus (ii) a scenario with the cost of equity reduced by the M-M effect. The no M-M effect scenario yields a spread impact of 33 bps while the scenario with M-M effect yields 30 bps (see Bernardi et al (2015) Table 21, line 5). Clearly, the difference between 33 bps and 30 bps is very small. Nevertheless, in order to put this result in perspective with other *WACC*-based empirical findings, we gauged the effect as

al (2015) and from our own experience the Bernardi et al (2015) results seem to suffer from a failure to adequately stratify the sample of banks by asset size.

The empirical relevance of the M-M offset presented in Table 1 can be summarized as follows. First, with the exception of one study, the evidence clearly suggests that the M-M offset is sizeable, i.e. in the range of 40 to 70 percent, and even 100 percent for the US TBTF banks. Second, strong M-M offsets are typical for G-SIBs and D-SIBs because for these banks the assumption of zero debt beta is more appropriate than for smaller banks. Third, and not surprising, the M-M offset varies across different countries, different banking systems and different economic and institutional conditions.

2.2 The M-M effect revisited for the Swiss G-SIBs

In our 2013 study we employed quarterly data from 1999 and 2010 and estimated an M-M offset of 55 percent (log-linear) for the two Swiss G-SIBs. Much has happened since 2010. In response to the Swiss TBTF legislation both banks more than doubled their common equity (CET1) levels. In mid-2015 Credit Suisse reported a CET1 ratio of 10.3 percent of RWA and UBS a ratio of 14.4 percent which can be compared to a benchmark of 4.5 percent of RWA at the end of 2010.[18] In addition both banks enhanced their liquidity ratios and are in the process to implement the TBTF resolution requirements. Although all these measures enhanced the crisis resilience of the two banks, they should not reduce the size of the M-M offset.

Table 2 reports the results of linear and log-linear regressions of equity beta on lagged bank leverage in line with equation 2. Lagged bank leverage is used as regressor in order to avoid potential endogeneity problems. The panel characteristic of the data is taken into account by fixed bank effects as well as a fixed or random time effect. The random time effect model is adopted in order to get an efficiency gain in estimation when the Hausman test shows no significant correlation of the regressor and the time effects.

Table 2 shows the estimates for the full sample and a sample split in 2010. For the full sample we have to adopt the two way fixed effects model because bank as well as time effects are highly statistically significant and appear to be correlated with the residuals (according to the Hausman Test).

The estimates of the log-linear model are highly statistically significant with a slope coefficient of 0.534 which is very close to the value reported by Junge and Kugler (2013). As to the linear regression we notice a positive and significant intercept and a significant slope coefficient of 0.0175 which implies an elasticity (M-M offset) of 0.46 evaluated at the means of beta and leverage.[19] A significant intercept confirms the existence of a partial M-M effect. The estimates for the first sub-period until 2010 are very close to those of the full sample. For the second sub-sample the slope

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follows: Under the no-validity assumption of M-M, the required return on equity remains constant and *WACC* rises by 33 bps. In the second scenario WACC increases by 30 bps. Thus, the *WACC* impact is about 90% of the "no M-M" scenario (30/33=90.9%). Put differently, the M-M offset is about 10% as large as it would be if M-M held exactly.

[18] The definition of CET1 was introduced with the announcement of the Basel III framework at the end of 2010. A rough estimate of the CET1 capital ratio of the two Swiss G-SIBs can be derived from the Comprehensive Quantitative Impact Study (QIS) of the BCBS, see BIS (December 16, 2010) and Junge and Kugler (2013), footnote 21.

[19] See footnote 17 above on calculation of the M-M offset.

coefficient is larger than the first sub-sample, namely 0.0292 implying an elasticity (M-M offset) of 0.533 at the means, whereas the directly estimated log-linear elasticity is 0.649. The two sub-sample estimates are within one standard error of each other and we find, therefore, no sign of a structural break in the regressions. Note that we could use the random time effect specification in the second sub-period according to the Hausman test. Moreover, the sizably lower adjusted R-squared in the random effect model is to be expected, as the time dummy variables in the fixed effect model contribute to the R-squared whereas in the random effects model these effects are in the error term.

Table 2: Bank equity beta and bank leverage

	Linear	Log-linear	Linear	Log-linear	Linear	Log-linear
Frequency Time period	Quarterly 2001Q2-2015Q2	Quarterly 2001Q2-2015Q2	Quarterly 2001Q2-2009Q4	Quarterly 2001Q2-2009Q4	Quarterly 2010Q2-2015Q2	Quarterly 2010Q2-2015Q2
Bank effect F-statistics	Fixed 12.2225***	Fixed 17.7367***	Fixed 9.5651***	Fixed 15.1629***	Fixed 4.5103**	Fixed 4.9486**
Time effect F-statistic	Fixed 5.7657***	Fixed 5.7033***	Fixed 5.5793	Fixed 15.1629***	Random -	Random -
a (constant)	0.8269*** (0.1605)	-1.5512*** (0.4225)	0.6778*** (0.2148)	-1.7322*** (0.5025)	0.6753** (0.3093)	-1.7731** (0.7218)
b	0.01754** (0.003904)	0.5340*** (0.1157)	0.01832*** (0.00471)	0.5551*** (0.1157)	0.02920*** (0.01007)	0.6487*** (0.2188)
t-statistic H0: b=1	-	4.0277***	-	3.8543***	-	1.6056
Adj. R-squared	0.7132	0.7132	0.7001	0.6903	0.1031	0.1437
Hausman test	-	-	-		2.4799	2.0465
Mean Beta	*1.54*		*1.57*		*1.49*	
Mean Leverage	*40.38*		*48.47*		*27.18*	
Gauging the M-M Effect of the linear regression	*0.460*		*0.566*		*0.533*	

*,**,*** indicates significance at the 5 percent, 1 percent and 0.1 percent level, respectively (null hypothesis for t-statistics: b=0, a=0). Standard errors are given in parentheses.

In summary, the results of Table 2 not only confirm our earlier findings, they show that the M-M offset for the Swiss TBTF banks is robust across sub-periods and sizeable amounting to about 50 percent of what is predicted under full M-M validity. This applies equally to the linear and the log-linear specification of the regression. Particularly important is the stability of the size of the M-M offset given the changes in regulatory and the economic conditions for the Swiss G-SIBs after 2010.

3. Social cost of additional capital requirements

3.1 Bank funding costs

If the M-M offset is incomplete as in the case of the Swiss G-SIBs, higher capital requirements will increase the funding cost of banks. The banks will pass along the additional cost to borrowers and bank lending rates will rise. This in turn raises the economic costs of capital formation and leads ultimately to a permanent drop in GDP.

In our model the banks' funding costs are the weighted average cost of capital, *WACC*. As we assume that debt has a zero beta, the cost of debt is equal to the risk-free rate R_f. Thus, we neutralize one channel through which the impact of higher capital requirements on funding cost works, and therefore tend to overestimate capital cost changes. As discussed in section 2, however, the debt channel is not of crucial importance for G-SIBSs.

Given these assumptions the the banks' weighted average cost, *WACC*, is:

$$WACC(LR) = R_{Equity}\frac{E}{D+E} + R_f(1 - \frac{E}{D+E}) \tag{4}$$

where R_{Equity} is the expected return on equity and R_f the risk-free rate. $\frac{E}{D+E}$ is the leverage ratio (LR). Since we estimated the size of the M-M effect as a function of leverage (rather than the leverage ratio), we rearrange equation (4) in terms of leverage. For this we replace $\frac{E}{E+D}$ by $\frac{1}{L}$, where L stands for leverage.

$$WACC(L) = R_{Equity}\frac{1}{L} + R_f\left(1 - \frac{1}{L}\right) = R_{Equity}\frac{1}{L} - R_f\frac{1}{L} + R_f \tag{5}$$

Next we apply the CAPM in order to include the results of our regressions between leverage and β_{equity} in equation (5). The CAPM states that the required return on equity, R_{Equity}, is proportional to the (bank specific) beta, β_{equity}, times the equity market risk premium, R_p.

$$R_{Equity} = R_f + \beta_{Equity} \cdot R_p = R_f + \left(\hat{a} + \hat{b}\,L\right)R_p \tag{6}$$

where $\hat{a}$ is the constant and $\hat{b}$ is the coefficient on leverage from our beta regressions (see Table 2).

Substituting equation (6) into equation (5) yields:

$$WACC(L) = R_f + \left(\frac{\hat{a}}{L} + \hat{b}\right)R_p \tag{7}$$

Equation (7) shows that *WACC* is an inverse function of leverage and depends on the regression estimates $\hat{a}$ and $\hat{b}$. These coefficients are based on Pre-Basel III definitions of leverage, i.e. of the ratio of Balance Sheet Assets to BIS Basel II Tier1 capital. In order to express *WACC* in terms of the definitions of the Basel III Accord, we need to convert the Pre-Basel III definition of leverage accordingly. Assuming that C_{con} is the conversion factor between the Pre-Basel III and the Basel III definition of leverage, equation (7) is adjusted as follows:

$$WACC(L_{Basel\_III}) = R_f + \left(\frac{\hat{a}}{C_{con} \cdot L_{Basel\_III}} + \hat{b}\right)R_p \tag{8}$$

Equation (8) includes all elements to calculate the overall funding cost of the Swiss G-SIBs which can be rewritten in terms of the leverage ratio:

$$WACC\left(LR_{Basel\_III}\right) = R_f + \left(\frac{\hat{a} \cdot LR_{Basel\_III}}{C_{con}} + \hat{b}\right) R_p \tag{9}$$

Thus, *WACC* is a linear function of the leverage ratio. Since $\hat{a}$ and $\hat{b}$ are positive, higher capital requirements imply higher cost of capital. The conversion factor C_{con} ensures that the leverage ratio is expressed in terms of Basel III Look-through (Fully applied) leverage ratio. Annex 1 explains in detail the different definitions of the leverage ratio and the derivation of the conversion factors.

In the base case of the calculations developed below the parameters of the variables in the equations are as follows: $\dot{\hat{a}}$ = 0.8269 and $\hat{b}$ = 0.01754 are the estimated regression coefficients over the sample from 2001 and 2015. The conversion factor C_{con} = 0.713 (=0.77/1.08, see Annex 1). As risk-free money market rate, R_f , we use the repo reference rate of the SNB, which was about 1 percent during this period. For the equity market risk premium, R_p , we assume a lower (5 percent) and an upper (10 percent) level to take account of the well-known fact that equity risk premiums vary greatly in size over time. All parameters and their values used in our analysis are summarized in the Tables of Annex 3.

Table 3 shows the increase in *WACC* for the Swiss G-SIBs caused by a 1 percentage point increase in the leverage ratio. Two basic scenarios are compared: (i) the estimated M-M offset on *WACC* resulting from the linear regression 2001Q2 to 2015Q2 and (ii) the *WACC* impact under the assumption that the required return remains invariant to leverage, i.e. there is no M-M offset. Moreover, all calculations show the *WACC* before and after conversion to the final Basel III standards of post 1 January 2018. Thus, results are expressed in terms of the Basel III Tier1 Look-through (Fully-applied) and CET1 Look-through (Fully-applied) definition of the leverage ratio.

Table 3 confirms the observations already made in our 2013 paper:

1. The M-M effect matters. Comparison of the *WACCs* calculated on the basis of the empirically observed M-M effect (left-hand side of Table 3) with those calculated under the assumption of no M-M validity (right hand section of Table 3) shows that the M-M effect reduces the *WACC* increase by 46 percent.
2. Not surprisingly, the new more stringent capital requirements under Basel III imply systematically higher *WACCs* compared to Pre-Basel III levels. They are about 40 percent (for Tier1) respectively 80 percent (for CET1) higher than the corresponding pre-Basel III *WACCs*.
3. Increases in the leverage ratio lead to proportional changes in *WACC*. A 1 percentage increase of the leverage ratio raises the Basel III Tier1-based (look-through) *WACC* by only 5.8 bps (assuming an equity premium of 5 percent) and by 11.6 bps (assuming an equity premium of 10 percent). The corresponding *WACCs* for Basel III CET1 are higher amounting to 7.4 and 14.9 bps, respectively.

Table 3, Swiss G-SIBs: Impact on *WACC* resulting from a 1 percentage increase of the leverage ratio measured in bps.

Leverage Ratio	Linear regression		No M-M effect	
	Impact on WACC (RP =5%)	Impact on WACC (RP =10%)	Impact on WACC (RP =5%)	Impact on WACC (RP =10%)
Pre-Basel III	4.1	8.3	7.7	15.4
Basel III Tier 1 Look-through	5.8	11.6	10.8	21.5
Basel III CET1 Look-through	7.4	14.9	13.8	27.6

3.2 The responsiveness of GDP to the banks' cost of capital

The starting point is the simple approach adopted by Miles, Yang and Marcheggiano (2011, 21-22), which is based on production function for GDP with capital (K) and labour (L) inputs and technological progress represented by a time trend Y=f(K,L,t). If factor prices are equal to marginal products, elasticity of production with respect to the price of capital can be written simply as a function of the substitution elasticity $\sigma_{KL,t}$ and the elasticity of production with respect to capital $S_{K,t}$ (equal to the income share of capital), whereby the subscript (t) reflects the possibility that the elasticity of production, $E_{Y,PK,t}$, with respect to the price of capital, $P_{K,t}$, as well as $\sigma_{KL,t}$ and ${S_{K,t}}_t$ can change over time:

$$\frac{dY_t}{dP_{K,t}}\frac{P_{K,t}}{Y_t} = -\,\sigma_{KL,t}\,\frac{S_{K,t}}{1-S_{K,t}} = -E_{Y,PK,t} \qquad (10)$$

Equation (10) is based on growth theory and therefore provides an estimate of the long-run impact of an increased price of capital on production. In line with the neoclassical growth theory a permanent increase in the price of capital leads to permanent change in the level of production but has no long-term effect on its growth rate, which is determined by labour supply growth and technical progress.

If we adopt the CES production function the σ and S_K are constant parameters. In our 2013 paper we followed this approach and estimated an elasticity of substitution between capital and labour for the real (nonfinancial) sector of approximately equal to 1, as in the special case of the Cobb Douglas production function. This is surprising given the estimates for other advanced countries which are usually clearly lower than one. Moreover, recently new statistics for Switzerland’s capital stock and the income distribution between capital and labour were published for the period 1995 to 2014, which provides an opportunity to check the case in a more flexible Translog framework. The Translog framework is based on a quadratic logarithmic approximation of the production function. This allows for a time varying rate of substitution and production weight of capital and includes the Cobb Douglas function as a special case[20].

[20] For an introduction to the estimation of Translog production function see Berndt (1991, Chapter 9).

The estimation of the Translog production function is reported in detail in Annex 2. It results in an elasticity of substitution varying between 0.42 and 0.44 during the period 1995-2014. Together with the time series of the capital cost share ($S_{K,t}$) and the elasticity of substitution ($\sigma_{KL,t}$), we are able to calculate a time-varying estimate for the elasticity of production with respect to the price of capital as given in equation (10), i.e. $E_{Y,PK,t}$. This crucial parameter for our analysis varies between 0.34 to 0.27 with a mean and median approximately equal to 0.31. Interestingly this parameter reached its absolute maximum before the financial crisis and decreases in absolute value since 2008, implying a weaker reaction of GDP to capital costs changes in recent years (see Annex 2, Figure 7) .

The Translog production elasticity of 0.31 lies clearly below the estimate of 0.43 used in our 2013 paper. However, compared to other advanced countries the production elasticity of 0.43 appears too high. Miles et al (2011) and Clark et al (2015) apply a production elasticity of 0.25 on the basis of empirical studies related to the UK and USA.[21] The advantage of our new Translog estimate is that it is more plausible than the CES estimate and of the same order of magnitude as the UK and US estimates.

As a next step, we need to determine the capital costs for the Swiss companies in line with the assumed market risk premiums of 5 percent and 10 percent. To this end we first estimate the equity beta of the Swiss non-financial companies, i.e. we run a similar regression as in equation 2 for the period 2001 to mid-2015, this time, however, with returns on the index of the Swiss corporate sector (excluding financial and insurance companies) as left-hand variable ($p_t^{Corp\_SPI}$) and returns of the SPI as right-hand variable in addition to the intercept alpha:

$$\Delta p_t^{Corp\_SPI} = \alpha_t + \beta_t^{Corp} \cdot \Delta p_t^{SPI} + \epsilon_t \tag{14}$$

Not surprisingly the beta for Swiss non-financial companies, β^{Corp} turns out to be slightly above 1, namely 1.1. Next, we apply CAPM and calculate the capital costs for the Swiss non-financial companies P_K under the same assumptions as we calculate the return on equity for the banks. Given the two risk premiums (5 percent and 10 percent), we determine a lower (6.5 percent) and an upper estimate (12 percent) of the capital cost for Swiss non-financial companies.

As the Swiss TBTF legislation applies to the Swiss G-SIBs, only these institutions are under pressure to increase lending rates.[22] Consequently economy-wide lending rates will increase only by a certain proportion, determined by the role of the G-SIBs in the transmission channel. Since in our approach the impacts of higher *WACCs* are channelled through the Swiss corporate sector, the relevant market share is the share of G-SIBs in external financing of the Swiss corporate sector. This share is 10.8 percent.[23]

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[21] See in particular J. Smith (2008), Barnes et al (2008) and C.I. Jones (2003).

[22] In principle, the Swiss TBTF legislation applies to both the Swiss G-SIBs and the D-SIBs. However, currently the D-SIBs are out of scope, because details of their regulation are still open. Moreover, the Swiss D-SIBs are well capitalized.

[23] The share of the “all Swiss banks” in external financing of Swiss companies is 35% and has been stable for years (see Trend, M.I.S. (2013). The market share of the two Swiss G-SIBs in domestic lending is 31% (see: SNB, Bankenstatistisches Monatsheft, Kreditvolumenstatistik). Thus, the relevant G-SIBs' share in external financing of the Swiss corporate sector is 10.8% (=0.35*0.31).

Finally, we assume that any rise in *WACC* is passed on one-for-one by banks to their customers. This is a simple and transparent assumption avoiding a complex extension of the model.

The above discussion can be summarized as GDP Multiplier (GDPM) in equation (15).

$$GDPM = \frac{E_{Y,PK,t} \cdot SEF}{R_f + (R_P \cdot \beta_{Corp})} = \frac{E_{Y,PK,t} \cdot SEF}{P_{K,t}} \tag{15}$$

Equation (15) states that the responsiveness of output depends on the share of external financing of the Swiss corporate sector by the G-SIBs, SEF, the elasticity of production with respect to the price of capital, $E_{Y,PK,t}$, and the price of capital, $P_{K,t}$. For example, take an increase of *WACC* by 11.6 bps (see Table 3, Basel III Tier1). At a given SEF of 10.8 percent the cost of capital for the nonfinancial firms rises by 1.25 bps above its current cost $P_{K,t}$ of 1200 bps. This is an increase of 0.104 percent (1.25/1200 = 0.104%) and translates into a permanent fall in output of 3.2 bps given the elasticity $E_{Y,PK,t}$ of 0.31 (0.31*0.104% = 3.2 bps).

Given equations (9) and (15) the GDP cost of higher leverage ratios, LR_{Basel_III} are:

$$GDP\ Cost(LR_{Basel\_III}) = \left(R_f + \left(\frac{\hat{a} \cdot LR_{Basel\_III}}{C_{con}} + \hat{b}\right) \cdot R_p\right) \cdot \frac{E_{Y,PK,t} \cdot SEF}{P_{K,t}} \tag{16}$$

After defining a base level of $LR_{Basel\_III\_0}$ as point of departure for the increases of the leverage ratio, LR_{Basel_III} , the equation can be further simplified.

$$GDP\ Cost\ Line\ (LR_{Basel\_III}) = R_p\ \frac{E_{Y,PK,t} \cdot SEF}{P_{K,t}} \left(\frac{\hat{a} \cdot LR_{Basel\_III}}{C_{con}} - \frac{\hat{a} \cdot LR_{Basel\_III\_0}}{C_{con}}\right) \tag{17}$$

Equation (17) is a linear, upward-sloping function of the leverage ratio and measures the GDP cost of additional capital in comparison to a given base level of LR. We use this equation to calculate the GDP impact of higher capital requirements.

For the base level for $LR_{Basel\_III\_0}$ here and for the GDP benefit curve developed in the next section we select 3.3 percent, which is approximately the mean value of the Basel III converted leverage ratio for Tier1 over the period 2013 to 2015. Inserting the already mentioned values of the parameters (see Annex 3, Tables A.3 and A3.2 for a detailed presentation of the parameters and their values) into equation (17) allows us to calculate the social economic cost resulting from a 1 percentage point increase in the leverage ratio. Table 4 presents the results.

Table 4: Impact on real GDP resulting from a 1 percentage point increase in the Basel III leverage ratio

Leverage Ratio	Linear regression		No M-M effect	
	Impact on GDP (RP =5%)	Impact on GDP (RP =10%)	Impact on GDP (RP =5%)	Impact on GDP (RP =10%)
Basel III Tier 1 Look-through	0.030%	0.032%	0.055%	0.060%
Basel III CET1 Look-through	0.038%	0.042%	0.071%	0.077%

Perusal of the results in Table 4 reveals that the social economic costs related to higher capital requirements for the Swiss G-SIBs are very small. The estimates suggest permanent annual output losses of 0.03 percent of GDP for a 1 percentage point increase in the TBTF leverage ratio for Basel III Tier1 capital. For CET1: a 1 percentage point increase in the Basel III CET1 leverage ratio leads to a permanent fall in the level of real GDP by 0.04 percent. Using an annual discount rate of 5 percent, the estimates imply a fall in the present value of all future GDP in the range between 0.6 percent to 0.8 percent.[24] Thus, the recent decision of Switzerland to lift the TBTF Basel III Tier1 LR from 3.12 percent to 5 percent implies a social economic cost of about 0.06 percent per annum whose present value is equal to 1 percent of current output. Note from Table 4 that the size of the market risk premium does not matter very much. It influences the economy as a whole (both the banking and the corporate sector simultaneously) leaving the relative cost between the banking and the corporate sector largely unaffected.[25]

Finally, the last two columns of Table 4 report the social economic costs of higher capital requirements if there were no M-M offset. They are nearly twice as high than the results including the M-M effect, which once more emphasizes that the M-M effect matters.

It is worthwhile to note that the above findings are consistent with a very different investigation. In a recent time series analysis Kugler and Junge (2016) estimate a vector autoregressive model and find little support for the view that higher capital requirements for banks imply widening credit spreads and lower real GDP growth. In line with our calculations here the vector autoregressions show that strengthening bank capital has no sizeable negative impact on Swiss GDP as one would expect it in the case of a sizeable M-M offset.

4. Social benefits of additional capital requirements

The model used to evaluate social benefits of higher capital requirements is based on our earlier analysis (Junge/Kugler, 2013). First we estimated the permanent effect of banking crises on the growth path of GDP. Second, the dependence of the annual probability of banking crises on trend leverage of large banks was estimated. Finally, multiplying the probability function by the estimated permanent drop in the growth path of GDP provided the expected GDP loss as a function of trend leverage of large banks. Short and medium term dynamics during the crisis were ignored. This is in line with our cost estimates discussed in the previous section taking into account only the long run effects of higher capital requirements.

To estimate the impact of banking crises on economic output we used annual Swiss GDP data from 1881 to 2010 and identified the major severe and long-lasting recessions since then. Switzerland experienced four fully fledged banking crises since 1881, namely in 1911, 1931, 1991 and 2007. In addition, we accounted for the two world wars (1917 and 1942) as well as the oil price shock of 1974.

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[24] We use the discount rate of 5 percent only in order to facilitate the comparison of our results with the results from other studies. In particular, the BCBS tends to present estimates of social economic cost using a discount rate of 5 percent. The appropriate social discount factor for Switzerland should be much lower.

[25] In equation (16) the market risk premium enters the numerator through the change in the banks' funding cost (equation 9) and the denominator through P_K (equation 15) with little overall impact on real GDP growth.

In order to estimate the long run impact of these crises we used a deterministic time trend model for log GDP taking into account the effects of major shocks by including level shift dummy-variables (being equal to 0 before the event and 1 after) for all major adverse shocks.

$$\log(GDP) = \gamma_0 + \gamma_1 t + \delta_1 D1911_t + \delta_2 D1931_t + \delta_3 D1991_t + \delta_4 D2007_t \\ + \delta_5 D1917_t + \delta_{16} D1942_t + \delta_7 D1974_t + \varepsilon_t \quad (18)$$

The dummies did not capture the short-run effect of a crisis but only its permanent effects on GDP. The transitory cyclical deviations from trend were captured by the residual of equation (18), which we expect to be strongly auto-correlated but stationary. This assumption is confirmed by the corresponding econometric tests.

The empirical results for this model and annual Swiss data from 1881-2010 are as follows: First of all, consider the coefficient estimate for the time trend γ_1: It is 0.039, which implied a potential GDP growth of nearly 4 percent instead of the historical average of 2.7 percent. This reduction of measured GDP growth was brought about by permanent shifts of the GDP growth path by the crises reflected in our dummy variables. The data enabled us to adopt a more restricted model assuming the same effects for all four banking crises and the three non-banking crises, respectively. This allowed us to get the estimated average impact of a banking and non-banking crisis. The estimates indicated that a severe banking crisis leads to a permanent and highly statistically significant decrease in the growth path of real GDP of 28.5 percent, whereas the other adverse shocks let “only” to an approximately 11 percent permanent reduction of GDP which was only marginally significant at the 10 percent level. The difference between these two estimates represented the additional negative GDP effect of a crisis with severe banking problems. This was -17.7 percent with a standard error around 6 percent. The value was therefore statistically significant at the 1 percent level.[26] This estimate will be used in our calculations of the benefits of avoiding banking crises presented below.

We should mention here that our approach to estimating the GDP loss of a banking crisis differs from that used by BCBS (2010) or more recently Cline (2016). These authors use a kind of event study approach and compare the actual GDP path with a hypothetical GDP path with no banking crisis: these differences are then discounted resulting in a measure for the overall (short and long run) GDP loss triggered by a banking crisis. The assumptions on the potential growth path are crucial in this framework. Is there a permanent effect of the crisis on GDP or is it a transitory phenomenon? Not surprisingly, the results depend strongly on the classification of the losses as permanent or transitory. By contrast, our approach does not consider the short run GDP loss but exclusively the permanent impact of a banking crisis on the growth path of GDP. At least for Switzerland this model, which passes all the relevant econometric tests, clearly tells us that we have a strong permanent impact of banking crises on the growth path of GDP.

Having estimated the impact of banking crises on Swiss GDP we then considered the annual probability of the occurrence of a banking crisis and its relationship to leverage. To this end we estimated a probit model for the occurrence of banking crises in Switzerland with the explanatory

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[26] These observations are in line with the research of the IMF (2009) on recessions and Carmen Reinhart and Kenneth Rogoff’s (2009) investigations of banking-crisis recessions. Accordingly, recessions resulting from banking crises tend to differ from recessions generally. They are more severe and drawn out and according to C. Reinhard and K. Rogoff are “associated with profound declines in output and employment”

variables being leverage of the Swiss large banks, interest rate spread (mortgage/savings rate), real GDP growth and inflation.[27] For this purpose we decomposed the first three variables into a transitory or cyclical and a permanent or trend component using the HP filter. Inflation was decomposed into an expected (using an AR(2) model to predict inflation) and an unexpected inflation rate (the residual of the AR(2) model). All regressors were lagged one year in order to avoid simultaneity problems. We have to mention that leverage is defined as total assets divided by total book equity. This approach was chosen for data reasons, since it was only for this definition of leverage that we had the long-time series we need for our analysis.

For leverage and the interest rate spread only the cyclical component was statistically significant. An increase in cyclical leverage (interest rate spread) leads to an increase (decrease) in the probability of a banking crisis. The findings appear reasonable: A strong short-run increase in leverage and a cyclical decline in the interest rate spread are indicators for overexpansion, with fierce competition in the banking sector, and are typical of the euphoria paving the way to a bubble. The change in trend GDP (10 percent significance) and in expected inflation (5 percent significance) reduce the probability of a banking crisis. These results were in line with our a priori expectations. An increase in trend growth indicates that loans become less risky and the incomplete adjustment of bank (sight) deposit rates to inflation.

The higher equity capital requirements under Basel III and the Swiss TBTF legislation do not primarily target the cyclical variability of the leverage but are designed to reduce leverage permanently, i. e., a reduction of the trend component is intended. Even if there is no direct significant effect of the trend component of leverage on the probability of a banking crisis there is an indirect impact resulting from the relationship between the variability of the cyclical component and the trend component of leverage. Indeed, the application of an EGARCH model provided a statistically highly significant effect of trend leverage on the variance of the cyclical leverage component.

Figure 1 shows the probability of a banking crisis as function of the trend component of the leverage of large banks. This function was estimated as the mean of 50,000 Monte Carlo replications simulating the effect of the variability of the cyclical component of leverage on the probability of a banking crisis. That is, we calculated the conditional variance as a function of trend leverage ranging from 5 to 28 and used these values to create the 50,000 Monte Carlo replications for the cyclical component of leverage for all values of trend leverage. These values were then used to arrive at the probability according to the probit model described above. For these calculations, all other variables except leverage were kept at their long-run equilibrium level.

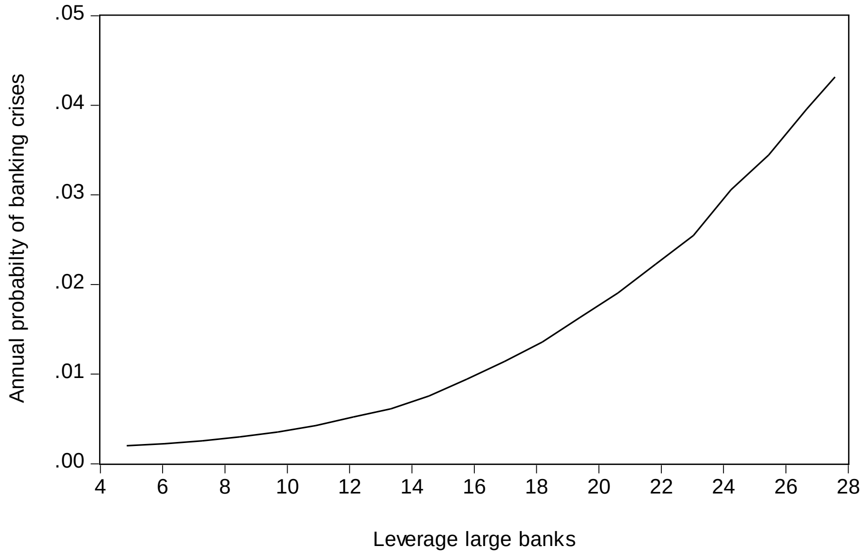
This exercise showed, as expected, that reduced leverage (higher capital levels) is associated with lower probabilities of banking crises. Reducing the leverage from 28 to 14 leads to a decrease of 3.6 percent[28] in the annual probability of a crisis (see Figure 1 below). Note also that the slope between crisis probability and leverage declines with lower levels of leverage. At high levels of leverage (low levels of capital) reductions in leverage (increases in capital) yield larger decreases in the probability

[27] The sample period runs from 1906 to 2010.

[28] The BIS (August 2010) survey shows that an increase of CET1 capital ratio by 100 percent (i.e. halving of leverage) leads to a reduction of the probability of banking crisis by 4.2 percent; see Table 3. The two estimates are not far from each other and one could expect that the crisis probability of Switzerland is lower than the experience of a panel of countries over a period of nearly 30 years (1980-2008).

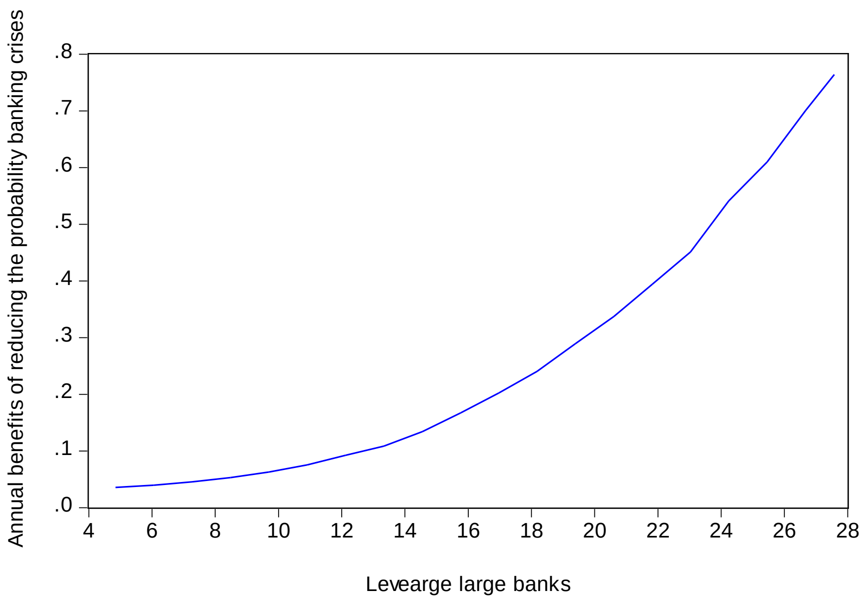
of crisis than at low levels of leverage (high capital levels). This pattern is consistent with our expectations that the marginal benefits of higher capital levels decline with further capital increases.

Figure 1: Estimated annual probability of banking crises and leverage of large banks



The expected GDP benefits (in the sense of avoided costs of crises) were obtained by multiplying the probability of Figure 7 by 17.7 percent (the estimated GDP loss produced by a banking crisis) and displayed in Figure 2. For instance, a reduction of the leverage from 28 to 14 leads to a decrease in expected costs of banking crises by 0.64 percent of GDP. Note that this effect is permanent and that the discounted future GDP loss, at a discount rate of 5 percent (2.5 percent), is 13 percent (26 percent).

Figure 2: Expected annual GDP benefits and trend leverage of large banks.



For further analysis, we follow the approach of Cline (2016) and approximate the function displayed in Figure 2 by an exponential expression:

$$Expected\ GDP\ Benefit\ (L_{Basel\_III}) = A \cdot (B_{con} \cdot L_{Basel_{III}})^{\rho} \tag{19}$$

This function provides a very close fit (R-squared = 0.998) to the data of Figure 2 and the exponent ρ is estimated as 2.54 and the constant A is 1.56E-04. The exponent describes the concave slope of the function and the constant A reflects the expected GDP loss when the leverage is zero, i.e. the asset/capital ratio is 1.[29] Moreover, the function is now expressed in terms of the Basel III leverage. The conversion factor is $B_{con} = 0.676$ (= 0.73/1.08, see Annex 1 and Table A3.2 in Annex 3) and turns the accounting-based leverage multiple of balance sheet assets/book equity used in the estimation of the probability function into a Basel III compliant expression.

This function is transformed in terms of the leverage ratio LR = 1/L:

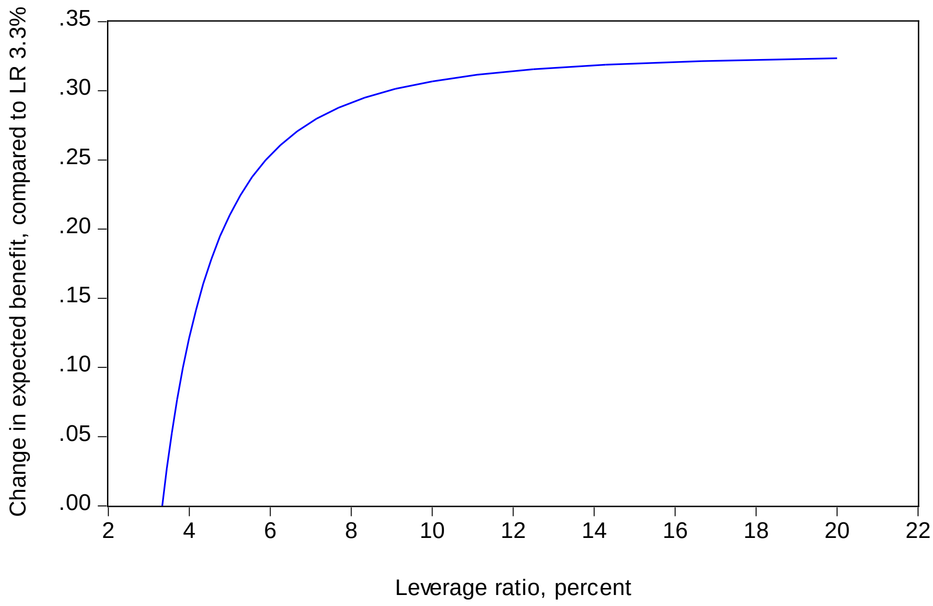
$$Expected\ GDP\ Benefit(LR_{Basel\_III}) = A \cdot (B_{con} \cdot \frac{1}{LR_{Basel\_III}})^{\rho} = A \cdot (\frac{B_{con}}{LR_{Basel\_III}})^{\rho} \tag{20}$$

The change in Expected benefits compared to a base leverage ratio $LR_{Basel\_III\_0}$ is therefore given by the following equation:

$$Change\ in\ GDP\ Benefit(LR_{Basel\_III}) = A \cdot {B_{con}}^{\rho} \cdot \left(\frac{1}{LR^{\rho}_{Basel\_III}} - \frac{1}{LR^{\rho}_{Basel\_III\_0}}\right) \tag{21}$$

This function is displayed in Figure 3 where the starting value of the leverage ratio is set to 3.3 percent, with the approximate mean value of the Basel III converted leverage ratio expressed in terms of Basel III Tier1 over the period 2013 to 2015.

Figure 3: Change in expected annual GDP benefits and leverage ratio of large banks in percent.



[29] Ln (1) = 0, Note the constant A = 1.56E-04 refers to expected loss (crises probability * 17.7%).

A 1 percentage point increase of the leverage ratio from 3.3 percent to 4.3 percent yields a GDP benefit of 0.16 percent. This is clearly above the impact on GDP Cost of 0.03 percent (see Table 4) and in line with the conclusion of our 2013 paper that the benefits exceed long-run costs by a substantial multiple. However, after a certain level the marginal benefit of additional capital turns modest and falls short of marginal cost. For example, a 1 percentage point increase of the leverage ratio from 7 percent to 8 percent amounts to only 0.01 percent GDP benefit and hence is below GDP cost. This behavior stems directly from our estimation of the annual crisis probability and reflects the fact that extreme crisis events are rare and require significantly more capital.

The sharply shaped benefit curve is an observation that has also been made in other studies. We have already mentioned Cline (2016). But also Miles (2012), another Bank of England study (2015) and a recent IMF paper (Dagher et al 2016) estimate similar shapes of benefit curves. The common feature is that the marginal benefits of additional capital are material at first, but rapidly turn modest after a certain level of bank capitalization.

5. Comparing social cost and benefits and the determination of the optimal leverage ratio

Using the Cost Line equation (17) and the Benefit Curve equation (21) we calculate the social marginal cost (MC) and benefit (MB) and determine the optimal leverage ratio for the Swiss G-SIBs. The optimal leverage ratio will occur where the two marginal effects are equal (MC=MB).

The derivative of the social Cost Line equation (17) with respect to the required Basel III leverage ratio is:

$$MC = R_p \cdot GDPM \cdot \frac{\hat{a}}{C_{con}} \tag{22}$$

All terms in equation (22) are constants and hence the derivative with respect to the leverage ratio is a constant.

The derivative of the benefit equation (21) is:

$$MB = \gamma \cdot \ A \ \cdot B_{con}^{\rho} \cdot LR^{-\rho-1} \tag{23}$$

Equation (23) states that increases of the leverage ratio reduce the marginal benefit. The shape of the function is concave and reflects the diminishing benefit to increases in the leverage ratio.

Solving for the optimal LR* yields:

$$LR^* = \left(\frac{\rho \cdot \ A \ \cdot B_{con}^{\rho}}{R_p \cdot GDPM \cdot \frac{\hat{a}}{C_{con}}} \right)^{\frac{1}{1+\rho}} \tag{24}$$

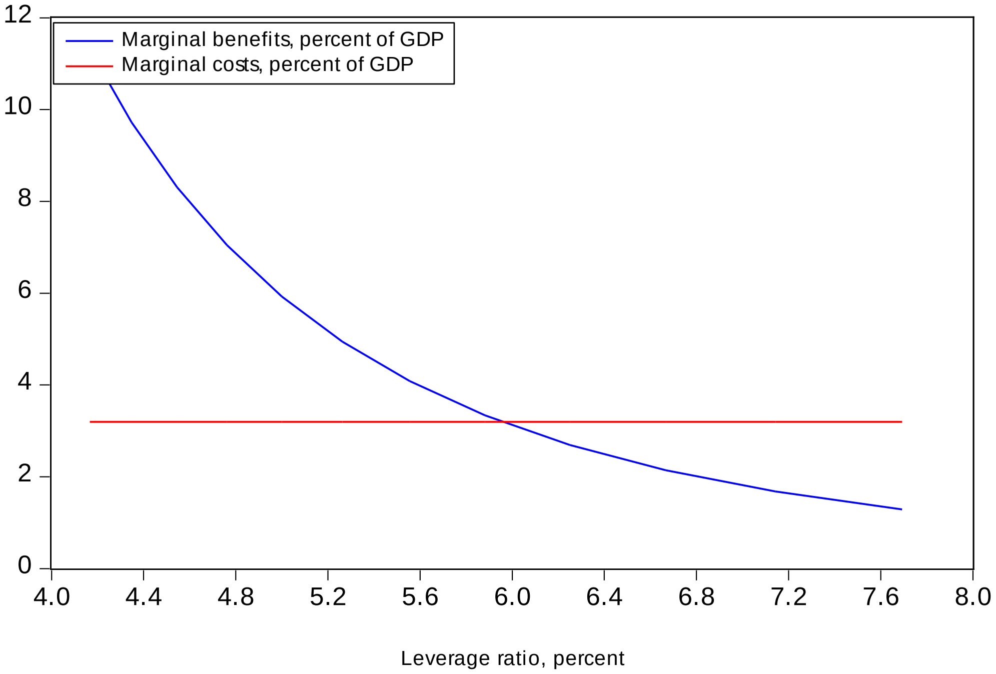
Table 5 reports the base case for the optimal LR* for Swiss G-SIBs in terms of the Basel III Tier1 and CET1 leverage ratios and Figure 4 provides an example of a graphical presentation. The base case varies with respect to two parameters: the capital definition (Basel III Tier1 or CET1) and the Risk Premium (5 percent or 10 percent).[30]

[30] A complete list of the parameters and variants is shown in Annex 3, Table A3.1.

Table 5: Base case: Optimal TBTF leverage ratios for Swiss G-SIBs

Optimum and minimum required LR	Basel III Tier 1	Basel III CET1
LR* (RP=5%)	6.07%	4.43%
LR* (RP=10%)	5.93%	4.33%
Minimum required LR	5.00%	3.50%

Figure 4: Optimal Leverage Ratio LR*, Basel III Tier1.



The base case suggests that the optimal leverage ratio for Basel Tier 1 capital requirements is about 6 percent and for CET1 capital requirements about 4.4 percent. Thus, the Swiss regulatory TBTF minimum leverage ratios fall short of the optimal level by about 1 percentage point. This result can be translated into risk-weighted capital ratios. Since the Swiss TBTF framework establishes a fixed linear relationship between the leverage ratio and the capital ratio for Swiss G-SIBs,[31] capital ratios are easily calculated and compared to other studies of optimal capital ratios (see Table 6).

[31] The link between the leverage ratio and the capital ratios for Swiss G-SIBs is the RWA density, which is the average risk weight per unit of exposure for any given bank $(\frac{RWA}{LRD})$. In order to ensure a coherent interaction between the leverage and the capital ratios the Swiss TBTF framework requires for G-SIBs an RWA density of 35 percent. Hence, capital ratio (CR) is easily determined from the leverage ratio and the RWA density: $CR = \frac{LR}{RWA\ Density}$.

Table 6: Optimal capital ratios and Minimum equity requirements				
Mainly large systemically important banks		**Source**	**Basel III Tier1**	**Basel III CET1**
Optimal Capital Ratios	**Switzerland**	**Junge/Kugler**	**17%**	**12.5%**
	United Kingdom	**Miles et al (2011)**	**20%**	
		Bank of England (2015)	**10-14%**	
	Sweden	**Sveriges Riksbank (2011)**		**14-17%**
	Norway	**Norges Bank (2012)**		**16-23%**
	Industrial countries	**BCBS (August 2010)**		**12.5%**
		Dagher et al (2016, IMF)	**15-23%**	
		Cline, W.R. (2016)		**11.7-14.1%**
Minimum equity requirements		**Switzerland**	**14.3%**	**10.0%**
		BCBS	**9.5-11.0%**	**8.0-9.5%**

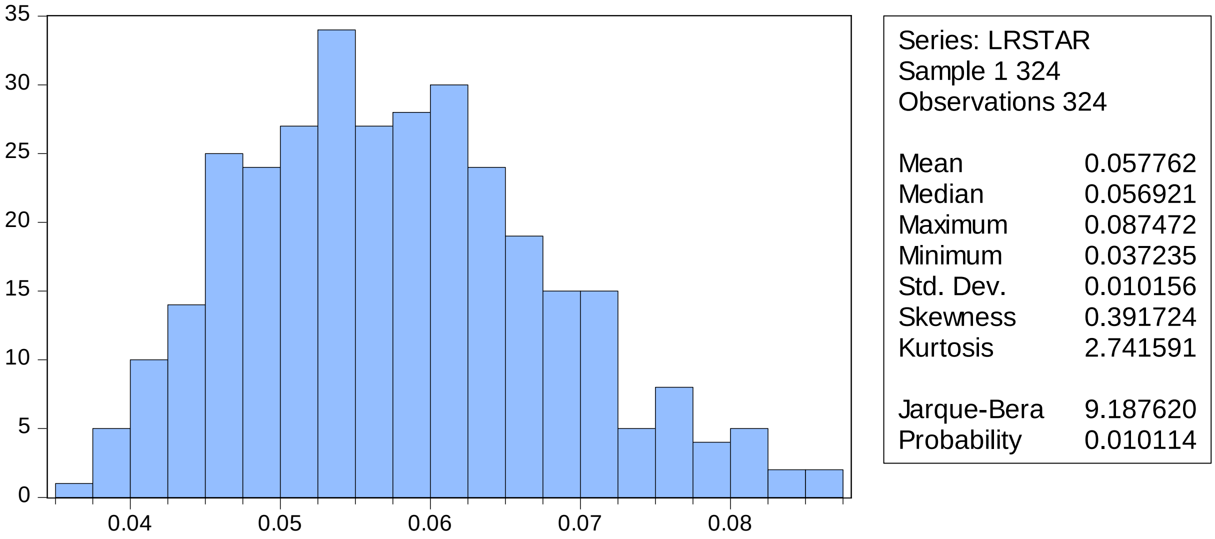
Going over Table 6 leads to three conclusions: First, the optimal capital ratios for Swiss G-SIBs are about 2.5 percentage points higher than the required Swiss TBTF capital ratios of 14.3 percent (Basel III Tier1) and 10 percent (CET1). Second, a similar picture emerges for the large banks of other countries. The optimal capital ratios are always above the minimum equity requirements of the BCBS. Third, results vary widely across the studies, which is not surprising given the uncertainty attached to the estimations and the differences in applied methods and assumptions. Key parameters with significant impacts on the optimal capital ratio are: the size of the M-M offset, the share of business finances by banks and the GDP loss experience of countries in banking crises.

In order to assess the uncertainty attached to the estimations and the choice of parameters we follow a methodology of Cline (2016) and provide alternative parameter values for key variables and calculate optimal LRs* for all possible 324 combinations[32] of the parameter values shown in Table A3.1. Figure 5 presents a histogram of the calculations. The lowest optimal LR* is 3.72 percent which is obtained by assuming a zero M-M offset (â =1), the higher risk premium (10 percent), a larger share of external financing of firms affected by capital cost increase (18.5 percent), a high elasticity of GDP with respect to capital costs (0.34), a lower GDP Loss severity (10 percent) and a downward adjusted exponent of the benefit curve (minus 2 standard errors). The median of the optimal LR* is 5.69 percent which is above the minimum requirement and close to our benchmark case discussed above. The maximum LR* is equal to 8.75 percent which is accomplished by assuming an M-M offset of 67 percent (â =0.506), a low risk premium (5 percent), the base case share of non-financial corporates' financing provided by G-SIBs (10.8% percent), a low elasticity of GDP with respect to capital costs (0.27), a high GDP Loss severity (28.5 percent) and an adjusted exponent of the benefit curve (plus 2 standard errors). It is worth mentioning that the asymmetry of the frequency distribution is mainly driven by the M-M effect. The econometric estimate of the intercept (=â-2 standard errors) corresponds to a 67 percent M-M offset. However, compared to the no M-M validity (â =1), a larger M-M offset than 67 percent may be justified. When we increase the M-M offset to 75

[32] We have 4 parameters with three values and 2 with 2 resulting in 3^4 times 2^2 combinations.

or even 90 percent we get a high optimal leverage ratio of over 10 percent and the median increases to ca. 6 percent in the distribution for the outcome of all the parameter combinations.

Figure 5: Histogram of Basel III Tier1 Optimal Leverage Ratio LR*.



Finally, the CET1 histogram exhibits a similar pattern as shown for Basel III Tier1 in Figure 3. Its median is equal to 4.13 percent, which is above the minimum TBTF standard of 3.5 percent and somewhat below the optimal base case LR*of 4.43 percent of the CET1 base case. When we vary the parameter values we arrive at a minimum optimal CET1 leverage ratio of 2.72 and a maximum of 6.39 percent, respectively.

6. Conclusions

This paper extends the analysis of Junge and Kugler (2013) on the effects of increased equity capital requirements on Swiss GDP in three respects. First, we present updated estimates of the M-M offset for Swiss G-SIBs extending the data base from 2001-2010 to 2001-2015. Second, we replace the CES production function applied for the estimation of the impact of capital costs on GDP by a flexible Translog form which was estimated using newly released capital stock data for Switzerland. Thirdly, we calculate the socially optimal leverage and capital ratios for the Swiss G-SIBs equating the marginal costs and marginal benefits of higher equity capital requirements. Our main results are: First the M-M effect is robust with respect to the substantial extension of the data base and yields an offset of capital cost of 46 percent. Second, the Translog production function estimate results in a time-varying elasticity of production with respect to the price of capital between 0.34 and 0.27, which is substantially lower than the value of 0.43 found in the CES framework. Third, and most important, the optimal leverage ratios for Swiss G-SIBs are approximately 6 percent in terms of Basel III Tier1 and 4.5 percent in terms of CET1. The corresponding optimal risk-weighted capital ratios range are 17 percent and 13 percent, respectively. Thus, our estimates of optimal leverage and capital ratios are about 20 percent higher than the recently revised minimum TBTF requirements for the Swiss G-SIBs.

The paper also addresses the large range of uncertainty around the estimates. Although variations in the key parameters can result in big changes in the estimated optimal capital requirements ranging from 3.7 to 8.8 percent, the median of the distribution is close to our benchmark estimate of 6.1 percent.

Our estimates of optimal equity requirements are considerably smaller than the Admati and Hellwig (2013) proposition of 20 to 30 percent. Their argument is based on the M-M theorem that higher equity capital requirements would not increase the banks` overall funding cost and hence do not impact GDP. They do not consider the impact of GDP benefits nor the intersection of marginal cost and benefits. In line with a partial M-M offset, our estimates show that the M-M theorem matters and that GDP costs are rather small as presumed by Admati and Hellwig (2013). But the limiting factor for additional increases in capital requirements stems mainly from the GDP benefit curve. Its shape implies that the marginal benefits of additional capital turn modest at leverage ratios clearly below 20-30 percent.

Finally, given the uncertainty around our estimates, we are the first to caution against a too-literal interpretation of the "optimal" equity capital requirements. Rather, our investigation of the trade-off between social cost and social benefit of higher equity capital requirements should be taken as an important complementary alternative to other approaches to bank capital determination. At any rate, our investigation addresses the central question of the optimal level of bank equity capital. The issue, however, is far too complex to be treated by one approach alone. Instead, different approaches - including international benchmarking exercises and competitiveness considerations as applied by the Swiss Group of Experts - should be used to determine the appropriate level of bank equity.

Annex 1: Regulatory capital definitions and conversion methods

This Annex presents the various definitions of leverage ratios used to calculate the economic costs and benefits of higher equity capital requirements and explains how they can be converted into a common leverage ratio in line with the definitions of the Basel III Accord. Based on this conversion we are able to express our results in terms of the Basel III definition of the leverage ratio.

The estimation of the M-M offset and *WACC* before any conversion applies the Basel II BIS Tier1 capital definition as numerator and the banks' Balance Sheet Asset as denominator of the leverage ratio. The estimation of the annual probability of banking crises occurring, and the economic benefit before conversion, are estimated using Book Equity as capital definition and Balance Sheet Assets as denominator of the leverage ratio.

$$Simple\ Leverage\ Ratio = \frac{\text{Basel II BIS Tier1 Capital (Cost) resp. Book Equity (Benefit)}}{Balance\ Sheet\ Assets}$$

In order to compare the results of various definitions of the leverage ratio they must be made compatible with a common Basel III basis.

The new Basel III definition requires that the numerator consists of loss absorbing equity capital, i.e. dominantly CET1 and a proportion of AT1. This is a markedly stricter definition than the Basel II BIS Tier1 capital definition. In particular, the Basel III definition excludes any hybrid capital items, which were found in the financial crisis to be poor in absorbing losses. Also the definition of the denominator of the Basel III leverage ratio goes beyond the definition of balance sheet assets. It additionally includes off-balance sheet items and treats the calculation of Securities Financing Transactions and Derivatives in its own way.[33]

In order to convert the different capital and asset definitions to the Basel III standards, we used the leverage ratios reported by CS and UBS under both a Basel II and Basel III approach for a common reporting period.

Tables A1.1 to A1.5 present the results. All conversion factors refer in each case to the Look-through or Fully applied equity capital definition of Basel III. They capture the equity capital position of the banks assuming the full application of Basel III, excluding the phase-in adjustment of the transition period from 2014 up to 2018. The conversion factors related to CET1 and Basel II BIS Tier1 respectively between CET1 and Book Equity are shown in Table A1.1 and A1.2 and were calculated on the basis of a common (pre-phasing-in) reporting period from Q4 2011 to Q4 2013.

$$Basel\ III\ CET1_{Look-through} = 0.60 * Basel\ II\ BIS\ TIER1$$

$$Basel\ III\ CET1_{Look-through} = 0.52 * Book\ Equity$$

In the same way we calculated the conversion factors between Basel III Tier1 Look-through and BIS Basel II Tier1 respectively Book Equity (see Tables A1.3 and A1.4). The following conversion factors were determined:

$$Basel\ III\ Tier\ 1_{Look-through} = 0.77 * BIS\ Basel\ II\ TIER\ 1$$

$$Basel\ III\ Tier\ 1_{Look-through} = 0.73 * Book\ Equity$$

Again the calculations are based on the quarterly Financial Reports of CS and UBS. However, for the relationship Basel III Tier1 Look-through versus Basel II Tier1 and Book Equity we used the data between 2013 Q4 and 2015 Q3 because the banks did not disclose Basel III Tier1 Look-through calculations prior to Q4 2013.

[33] The calculation of the Basel III leverage ratio and in particular its denominator is described in detail in: "Basel III Leverage Ratio Framework and Disclosure Requirements", January 2014 and the FINMA Circular 2015/3 Leverage Ratio".

Finally, we determined the conversion factor between Balance Sheet Assets and the Basel III LRD over the period from Q4 2014 to Q3 2015 (Table A1.5). This is the earliest period available where the two big banks recorded simultaneously LRD and Balance Sheet Assets. The individual conversion factors of the two banks are rather different and reflect to a great deal the differences in the accounting standards of the two banks. CS balance sheet calculations follow US-GAAP while the UBS calculations are based on IFRS standards. Given the differences in the treatment of derivatives and SFTs between US-GAAP and IFRS accounting rules, it is no surprise that the conversion factor of CS is considerably larger than the UBS conversion factor.[34]

The combined CS and UBS conversion factor is:

$$Basel\ III\ LRD = 1.08 * Balance\ Sheet\ Assets$$

It may be objected that the observation period is too short to calculate reliable conversion factors. However, there are reasons to believe that the calculated conversion factors are robust. First, a great proportion of on-balance sheet items are treated in the same way across US-GAAP, IFRS and LRD and hence, limit the scope for unfounded measurement deviations. Second, thanks to pro-forma LRD calculations of UBS back to Q4 2012 we can calculate the conversion factor for this period. It typically hovered in a small corridor slightly below 1 with an average conversion factor of 0.98. This suggests that the sampled conversion ratios between LRD and the accounting measurements IFRS respectively US-GAAP are reliable.

Table A1.1: Conversion Factor: Basel III CET1 Look-through to BIS Basel II Tier1

Basel III CET1_Look-through = 0.60* BIS Basel II Tier1					
Period	CS		UBS		Combined
	Basel II BIS Tier1 Mio CHF	Basel III CET1 Look-through Mio CHF	Basel II BIS Tier1 Mio CHF	Basel III CET1 Look-through Mio CHF	Conversion Factor Basel III CET1/Basel II Tier1
2011Q4 - 2013Q4	43'730	23'895	40'406	26'902	0.60

Sources:

BIS Tier1 Quarterly observations gathered via Bloomberg and Quarterly Financial Reports of CS and UBS.

CET1 Look-through respectively CET1 Fully applied: Quarterly Financial Reports of CS and UBS.

The pro-forma CET1 Look-through figures of CS for Q2 2012 and 2013 and for Q4 2012 were collected from CS Investor Day Presentations, in particular: Barclays Global Financial Services Conference, September 12, 2012 and September 11, 2013.

[34] The quarterly financial reports of CS and UBS in 2015 provide an impression of the different treatments of derivatives in SFTs between US accounting rules and IFRS. For example, in case of CS (US-GAAP) leads the adjustments of derivatives to LRD to a significant increase of the LRD exposure (CHF 124bn, Q3 2015), and UBS (under IFRS) shows a sharp reduction of LRD (CHF 137bn, Q3 2015).

Table A1.2: Conversion Factor: Basel III CET1 Look-through to Book Equity

Basel III CET1_Look-through = 0.52 * Book Equity					
Period	CS		UBS		Combined
	Book equity Mio CHF	Basel III CET1 Look-through Mio CHF	Book equity Mio CHF	Basel III CET1 Look-through Mio CHF	Conversion Factor Basel III CET1/Book Equity
2011Q4 - 2013Q4	45'241	23'895	51'802	26'902	0.52

Sources:

Book Equity: Quarterly observations gathered via Bloomberg.

CET1 Look-through respectively CET1 Fully applied: Quarterly Financial Reports of CS and UBS.

The pro-forma CET1 Look-through figures of CS for Q2 2012 and 2013 and for Q4 2012 were collected from CS Investor Day Presentations, in particular: Barclays Global Financial Services Conference, September 12, 2012 and September 11, 2013.

Table A1.3: Conversion Factor: Basel III Tier1 Look-through to Basel II Tier1

Basel III Tier1_Look-through = 0.77* BIS Basel II Tier1					
Period	CS		UBS		Combined
	Basel II BIS Tier1 Mio CHF	Basel III Tier1 Look-through Mio CHF	Basel II BIS Tier1 Mio CHF	Basel III Tier1 Look-through Mio CHF	Conversion Factor Basel III Tier1/Basel II Tier1
2013Q4 - 2015Q3	46'864	38'207	42'115	31'622	0.77

Sources:

BIS Basel II Tier1: Quarterly observations gathered via Bloomberg.

Basel III Tier1 Look through respectively CET1 Fully applied: Quarterly Financial Reports of CS and UBS.

Table A1.4: Conversion Factor: Basel III Tier1 Look-through to Book Equity

Basel III Tier1_Look-through =0.73* Book Equity					
Period	CS		UBS		Combined
	Book equity Mio CHF	Basel III Tier1 Look-through Mio CHF	Book equity Mio CHF	Basel III Tier1 Look-through Mio CHF	Conversion Factor Basel III Tier1/Book Equity
2013Q4 - 2015Q3	44'584	38'207	53'032	31'622	0.73

Sources:

Book Equity: Quarterly observations gathered via Bloomberg.

Basel III Tier1 Look through respectively CET1 Fully applied: Quarterly Financial Reports of CS and UBS.

Table A1.3: Conversion Factor: Ratio LRD to Balance Sheet Assets

Basel III LRD_Look-through = 1.08* Balance Sheet Assets					
Period	CS		UBS		
	Balance Sheet Assets US GAAP in Mio CHF	Basel III LRD Look-through in Mio CHF	Balance Sheet Assets IFRS in Mio CHF	Basel III LRD Look-through in Mio CHF	Conversion Factor LRD/Balance Sheet Assets
2014Q4 - 2015Q3	890'899	1'089'770	1'010'311	966'414	1.08

Sources:

UBS: Quarterly Reports 2014 and 2015, Section: Capital Management.

CS: Quarterly Reports 2014 and 2015, Section: Treasury, Risk, Balance Sheet and Off-Balance Sheet.

Annex 2: Estimation of the Translog production function, Switzerland 1995-2014

The Translog analysis is usually done in the dual framework of cost-share equations. The term dual means in this context that all the information needed to obtain the relevant parameters of the production function is contained in the corresponding cost function and vice versa. In a model with two production factors K and L their corresponding shares in total production costs (S_K and S_K) are represented as linear function of factor prices (P_K and P_L):

$$S_{K,t} = \delta_K + \gamma_{KK}\log(P_{K,t}) + \gamma_{KL}\log(P_{L,t}) + \gamma_{Kt}t \qquad (A2.1)$$

$$S_{L,t} = \delta_L + \gamma_{LK}\log(P_{K,t}) + \gamma_{LL}\log(P_{L,t}) + \gamma_{Lt}t \qquad (A2.2)$$

For theoretical reasons the γ – matrix is symmetric ($\gamma_{KL} = \gamma_{LK}$) as substitution of capital by labour is symmetric. As the left-hand variables are shares the slope coefficients add up to zero ($\gamma_{KK} + \gamma_{KL} = 0$; $\gamma_{KL} + \gamma_{LL} = 0$; $\gamma_{Kt} + \gamma_{Lt} = 0$), whereas the intercepts add up to 1 ($\delta_K + \delta_L = 1$). Given these restrictions, we only have to estimate one equation. Using the restriction $\gamma_{KK} = -\gamma_{KL}$ we can write the first equation of the system above as:

$$S_{K,t} = \delta_K + \gamma_{KK}(\log(P_{K,t}) - \log(P_{L,t})) + \gamma_{Kt}t \qquad (A2.3)$$

Note that this model collapses to the Cobb Douglas case if both γ coefficients are zero and we arrive at a constant cost share of capital which is independent of factor price and equal to the intercept term δ_K. Correspondingly the labour cost share is constant and equal to $\delta_L = 1 - \delta_K$. If the elasticity of substitution is below 1 then we have a positive γ_{KK} coefficient and if technical progress is biased in favour of capital γ_{Kt} is positive.

The elasticity of substitution is calculated as

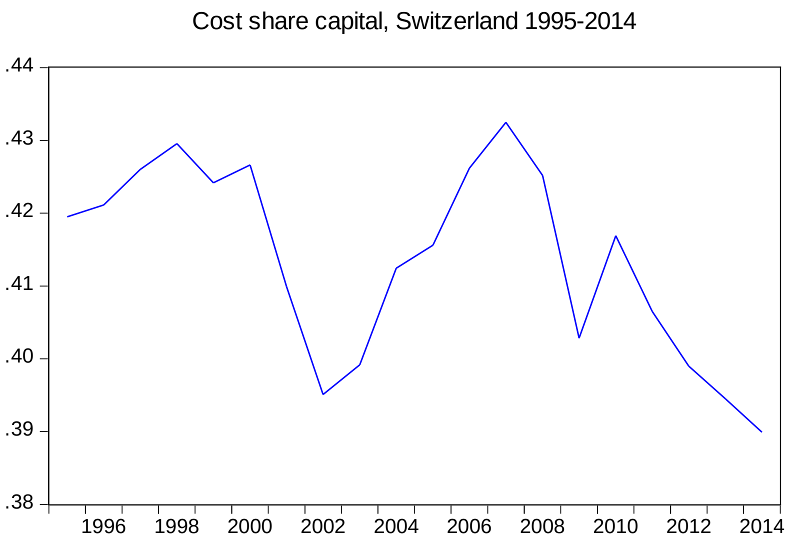
$$\sigma_{KL,t} = \frac{\gamma_{KL} + S_{K,t}S_{L,t}}{S_{K,t}S_{L,t}} = \frac{-\gamma_{KK} + S_{K,t}S_{L,t}}{S_{K,t}S_{L,t}} \qquad (A2.4)$$

which is, of course, 1 for the Cobb Douglas function. As we can see from the equation above the opposite case of a zero elasticity of substitution implies a maximum positive parameter value of $\gamma_{KK} = S_K S_L$.

Figure 6 and 7 display the data used in our estimation. Figure 6 shows the development of the cost share of capital defined as net operating surplus + depreciation (or capital consumption) divided by the sum of capital costs and compensation of employees (labour costs). The factor prices were calculated by dividing capital income by the capital stock and total labour income by the number of hours worked.

The estimation results for the capital share equation $(A2.3)$ are given in Table A2.1. In order to avoid simultaneity problems we estimated the model with a lag of one for factor prices.

Figure 6: Cost share of capital, Switzerland 1995-2014.



Data source: Capital and Labour income, employment and hours worked, https://data.snb.ch/de/topics/uvo#!/cu.

Capital stock, https://www.bfs.admin.ch/bfs/de/home/statistiken/volkswirtschaft/kapitalstock.html

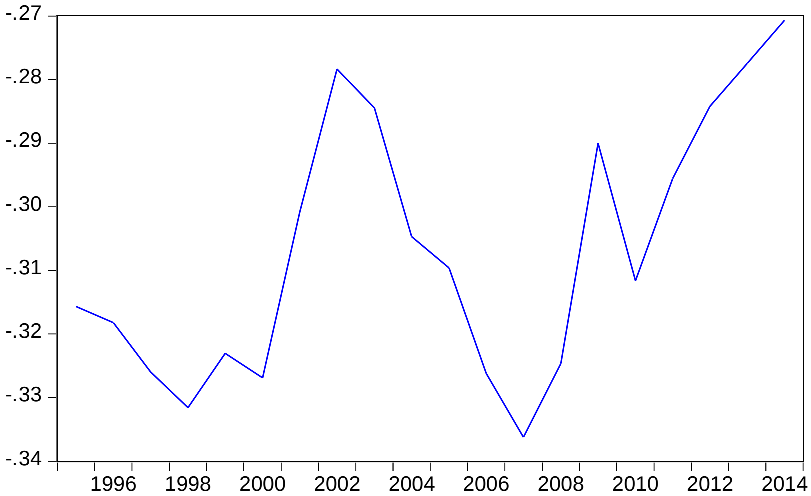
Table A2.1: Estimation results for the Translog production function, Switzerland 1995-2014

Standard errors in parentheses.

Parameter	Estimate	Restricted estimate
γ_{KK}	0.1028 (0.04217)	0.1371 (0.03618)
γ_{Kt}	-0.000554 (0.000513)	–
Adj. R^2	0.3557	0.3637
S.E	0.01084	0.01077
Durbin Watson	1.2435	1.3461

Table A2.1 shows a positive γ_{KK}-estimate which is statistically significantly different from zero and implies a substitution elasticity which is clearly lower than one in absolute value. However, no evidence in favour of a non-neutral technical progress is found, while the deterministic trend coefficient is small and statistically not different from zero. Therefore, we estimated the model without time trend which gives a slightly higher γ_{KK}-estimate in absolute value. Inserting the time varying factor shares displayed in Figure 6 results in an elasticity of substitution estimate varying between 0.42 and 0.44 during the period 1995-2014. Given this time series of the capital cost share (S_{K,t_t}) and the elasticity of substitution ($\sigma_{KL,t}$) we are able to calculate a time-varying estimate for the elasticity of production with respect to the price of capital as given in equation (9). It varies between -0.34 to -0.27 with a mean and median approximately equal to -0.31. As shown in Figure 7, the elasticity of output with respect to price of capital reached its absolute maximum before the financial crisis and decreases in absolute value since 2008 implying a weaker reaction of GDP to capital costs changes in recent years.

Figure 7: Translog estimate of the elasticity of GDP to the price of capital, Switzerland 1995-2014.



Annex 3: Parameter values for calculation of the optimal leverage ratios

Table A3.1 and A3.2 list the parameters and the values used in the calculation of the optimal leverage ratio for Basel III Tier1 and CET1 capital. Table A3.1 shows alternative values for key variables next to the parameter values of the base case.

Table: A3.1: Base case parameter values and alternatives

Parameter	Description	Base Case	Low opt. LR	High opt. LR
M-M offset: $\hat{a}$	Intercept of $\hat{a}$ of the M-M regression. If $\hat{a}$ = 1 there is no M-M offset, if $\hat{a}$ = 0 M-M holds fully	0.826987	1	0.5059
R_p	Equity Risk Premium	5% / 10%	10%	5%
SEF	Share of non-financial corporates' financing provided by G-SIBs	10.8%	18.5%	10.8%
$E_{Y,PK}$	Elasticity of production with respect to the price of capital	0.31	0.34	0.27
A	Constant of GDP benefit curve and varies with GDP losses of 17.7% (base case), 10% (low LR*) and 28.5% (high LR*)	1.56E-04	8.81E-05	2.51E-04
ρ	Exponent of GDP benefit curve	2.541	2.463	2.619

Explanation of the alternative parameter values:

- M-M offset variation of $\hat{a}$ = 1 (no M-M), $\hat{a}$ - 2 standard errors 0.5059 (M-M offset is 67%)
- Risk Premium: lower (5%) bound and upper (10%) bound to take care of the variations of equity risk premiums
- SEF: The lower bound of SEF (10.8 percent) is the share of G-SIBs in external financing of the Swiss corporate sector. The upper bound includes in addition the Swiss D-SIBs Raiffeisenbank and ZKB.[35] The market share of Raiffeisenbank in Swiss domestic credits is 13.5 percent[36] for period 2012 to 2015 and that of ZKB is 8 percent.[37] These shares must be multiplied with the share of external financing of the corporate sector (35 percent) and added to 10.8 percent in order determine the upper bound of SEF of 18.5 percent.
- Production elasticity with respect to the price of capital: The estimations of the Translog framework showed that the elasticity varies between 0.27 and 0.34 with a mean and median of 0.31.
- *A* is the constant of the benefit curve and defined as crises probability * GDP Loss. The base case GDP Loss (17.7 percent of GDP) and the upper GDP Loss (28.5 percent of GDP) are derived from our historical regression analysis (equation 18). The lower GDP Loss of 10% is the ratio of the bank losses of CS and UBS (nearly CHF 60 bn.) to GDP in the financial crisis from 2007/8.

[35] The PostFinance, also a D-SIB, is not allowed to provide credits.

[36] See SNB Statistik: Bankenstatistisches Monatsheft, Kreditvolumenstatistik.

[37] See ZKB: https://www.zkb.ch/media/dok/corporate/medien/praesentation-rudolf-sigg.pdf

- Exponent ρ: estimate +/- 2 standard errors, 2.463 and 2.619

Table: A3.1: Other parameters used to calculate GDP cost and benefit

Parameter	Description	Value
$\boldsymbol{R_f}$	Risk-free money market rate	1%
$\boldsymbol{\hat{b}}$	Slope coefficient of M-M regression (2001Q2-2015Q2)	0.01754
$\boldsymbol{\beta_t^{Corp}}$	Swiss corporate companies	1.1
Tier1, $\boldsymbol{C_{con}}$	Leverage Ratio: Basel III Tier1 Look-through to Basel II Tier1	0.713
Tier1, $\boldsymbol{B_{con}}$	Leverage Ratio: Basel III Tier1 Look-through to Book Equity	0.676
CET1, $\boldsymbol{C_{con}}$	Leverage Ratio: Basel III CET1 Look-through to Basel II Tier1	0.556
CET1, $\boldsymbol{B_{con}}$	Leverage Ratio: Basel III CET1 Look-through to Book Equity	0.481

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