Economic Stability under Alternative Banking Systems:

Theory and Policy

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Abstract

In this paper we show in a thought experiment that in an economy where i) investors hold rational expectations, ii) output is generated by a linear homogeneous production function, and iii) real investment is allocated across sectors according to the CAPM, a fractional reserve banking system is not Pareto efficient and amplifies the business cycle. In developing these results we show that these three well known propositions in economics also imply a new view of the business cycle, one where the business cycle is described in terms of the dispersion of an *ex-ante* probability distribution. The policy implication of this analysis is that bank regulation should go further than the Volcker rule or the Vickers commission proposal by restricting bank investments to currency and deposit accounts on the central bank. Nonbank financial institutions should then carry out the financial intermediation function now carried out by banks. The paper proposes that post office banking perhaps augmented with blockchain technology sometime in the future is one way to implement the transition from fractional reserve banking to full reserve banking. While little academic work has been done on full reserve banking in the aftermath of the Great Crisis, it is interesting to note that it is part of banking reform proposals now (July, 2016) before the parliament in Iceland and a special national referendum in Switzerland.

Key Words: Economic Stability, full reserve versus fractional reserve banking, CAPM, Business Cycles, Pareto Optimality

JEL classification: E32, E44, E52, G1, G18, G21

"It is well enough that people of the nation do not understand our banking and monetary system, for if they did, I believe there would be a revolution before tomorrow morning." Henry Ford

I. INTRODUCTION

The world-wide crisis that began in 2007 raised a number of fundamental questions regarding the role of bank and non-bank financial institutions within the financial systems and their effect on the real economies of financially developed countries. Before the crisis most financial economists and policymakers favored deregulating banks in order to promote one-stop shopping for financial products and encourage competition and innovation in the financial services industry. The prevailing view then was to let the innovative human capital in lightly regulated financial institutions operating in relatively efficient financial markets guide the savings of society into productive real investment. The end result was supposed to be an efficient allocation of resources and optimal economic growth. Since the crisis this view of financial institutions and markets is now being questioned. It has been argued (eg., Stiglitz, 2011 and many others) that some financial products invented by this innovative human capital have contributed to the severity of the financial crisis in that they have proven to be opaque and difficult to assess their underlying risk. Moreover large financial service companies have proven to be too unwieldy to manage efficiently and some are now in the process of being partially dismantled. They along with other large financial institutions unleashed a significant moral hazard problem in that some financial supermarkets became too big and interconnected to fail. Repeal of parts of the Glass-Steagall Act and the Investment Company Act that occurred in the Gramm-Leach-Bliley Act in 1999 is now viewed by many economists and even some former bankers as a regulatory mistake. In response to the crisis

Europe and the U.S. are now in the process of re-regulating the markets and institutions of their financial systems.

One very fundamental regulatory question that has received relatively little attention from academics and policymakers during the most recent financial crisis is the following: Why should privately owned banks whose checking account deposits constitute an important component of the medium of exchange be allowed to accept and facilitate the creation of checking account money and engage in risky financial intermediation in the first place? This paper is concerned with that fundamental question. Economists pretty much agree that a fractional reserve banking system is volatile, and that volatility in the banking system could adversely affect the real economy. What they disagree on is whether the cost in terms of foregone liquidity provision and maturity transformation is worth the benefits of banking stability in the form of 100 percent reserve banking. In section II we begin the discussion by considering the traditional economic argument favoring the present banking system that combines deposit-taking and lending in the form of loan commitments within a single financial institution. This analysis abstracts from the problems of inflation, real investment allocation, and business cycles, and focuses on the provision of liquidity services to depositors and borrowers. The conclusion of this analysis is that present day fractional reserve banks are the most efficient liquidity providers. The economists that hold this view oppose a regulatory framework that would include 100 percent reserve banking. Their opposition is based on the view that lightly regulated shadow banks that would replace present day banks in the intermediation process would be inferior liquidity providers and more vulnerable to runs and instability than present day banks. That is because the funding of shadow banks is not credibly insured like the demand deposits of present day banks. In section III the above question is examined from the perspective of efficient real investment allocation abstracting from liquidity considerations and inflation. In this section we pose a thought experiment in the sense of Gilboa et al. (2014) and especially Maki (2005, 2009) for a hypothetical model economy that is considering two types of banking systems: i) a

100 percent reserve banking system and ii) a fractional reserve banking system. We then compare the investment allocations for the two systems. We find that a fractional reserve banking system that combines deposit-creation with risky investing in firms results in a misallocation of real productive investment. The misallocation we have in mind is one where the marginal rate of transformation of expected return for risk generated on the real investments of firms does not equal the marginal rate of substitution of expected return for risk in the preferences of household savers at the optimal level of savings. This misallocation takes the form of overinvestment that produces too much risk per unit of expected return consistent with the preferences of household savers. We also find that this overinvestment financed by deposit creation within a fractional reserve banking system amplifies the volatility of the real economy. Section IV concludes with a summary and some thoughts about how the financial system might transition from fractional reserve banking to full reserve banking.

II. THE CASE FOR A DEPOSIT-TAKING AND LENDING BANKING SYSTEM

Until recently the strongest argument for combining deposit creation and risky lending/investing in banks is that it has always been so for many hundreds of years and over many different countries. The conventional view is that those goldsmiths and money-changers who provided safety deposit box and foreign exchange services to merchants eventually realized that only a fraction of the coins deposited with them for safe-keeping would be withdrawn at any one point in time. It would therefore be relatively safe and profitable to lend/invest a certain proportion of "other people's money" although it probably took much skill and experience to determine what that proportion for a specific money-changer might safely be. This quest for profit of money-changers and modern day banks is aptly summed up in an interview with Professor Raghuram Rajan at the Minneapolis Federal Reserve Bank by Ron Feldman (2009, p.22) when Rajan asks: "…what business are the banks in? They're not in the business of being plain-vanilla entities, because they *can't make any money that way."* While trying to

avoid making money (literally as we will argue below) in a plain-vanilla way is the argument of the money-changer/banker as to why banking evolved in the way it did, economists also want to know whether the way banks make money is socially optimal.

Kashyap, Rajan, and Stein (2002) extending Diamond and Dybvig (1983)(1986) provide an important economic argument for the social usefulness of present day banking that combines deposit-taking and loan commitments to borrowers. Their general argument is that the main economic function of banks is one of providing liquidity by maturity transformation, namely, converting illiquid debt obligations of borrowers into liquid checking account deposits. Wallace (1996) presents a similar argument but his deposits are savings deposits and money market shares, and not checking account deposits that serve as the medium of exchange. The specific argument offered by Kashyap et al. is based on the notion that deposit-taking and loan commitments represent demands for liquidity by owners of demand deposits and borrowers. Both of these demands for liquidity require the providing institution to hold a stock of liquid assets themselves that in turn can be used to service these demands from both sides of the bank's balance sheet as they occur through time. From this observation they conclude that if these two demands for liquidity are not perfectly correlated, it makes economic sense to combine deposit-taking and loan commitments in the same financial institution, namely, present day banks. The reason is that a smaller quantity of liquid assets can service both demands for liquidity when they are provided by the same financial intermediary compared to the case when they are provided by separate intermediaries as proposed by 100 percent reserve banking. Liquid assets (eg., cash, reserve accounts with the central bank, Treasury securities, high grade commercial paper, etc.) in their model represent "costly overhead" that is required to service the normal demands for liquidity by depositors and lending commitments to borrowers. They argue this overhead is costly for three reasons: i) cash and until recently reserve accounts yield a zero nominal return; ii) short-term riskless and near riskless securities yield a nominal return but this return is subject to double taxation since banks are required to use the

corporate form of business organization; and iii) borrowing ideas from the corporate finance literature they argue that large stocks of liquid assets create agency costs in that they can quickly be transformed into perks and empire building. For these reasons it is desirable that this costly overhead be reduced to a minimum which it will be if deposit-taking and lending are combined in the same institution and if the two demands for liquidity are not perfectly correlated. In other words present day banks are low cost producers of liquidity services precisely because they service both demands.

III. Investment and Business Cycles under Alternative Banking Systems

The argument of Diamond and Dibvig (1983,1986) and Kashyap et al. (2002) that a given stock of liquid assets can support a larger volume of normal liquidity needs when deposit-taking and lending are combined into a single entity is an interesting rationale for present day banking. It does however assume an absence of runs induced by pending bank failure which presumably would affect both sides of the balance sheet of banks at the same time and move the correlation coefficient between the two liquidity needs towards unity. But in any event is minimizing the stock of liquid assets relative to liquidity needs the only criteria for judging the social optimum for a banking system? The most important social function of a *financial* system is the transfer of financial resources from expected utility maximizing household savers to value maximizing investing firms. It would therefore seem that another and perhaps more important criterion is whether a financial system based on 100 percent reserve banking allocates savings to investment better than a fractional reserve universal banking system. By "better" we mean will the level of investments in the economy generate the risk/return trade-off that maximizes the expected utility of household savers who finance the investment with their savings. In

this paper we argue that in a 100 percent reserve banking system it does, whereas it doesn't in a fractional reserve banking system.[1]

To see this we will abstract from the liquidity considerations of Diamond and Dybvig, Wallace, and Kashyap et al. and look for a model that generates a risk/return tradeoff in the capital market. The workhorse model in finance that does this is the well-known 2-paremeter capital asset pricing model, CAPM, and its various extensions to 3-5 factor models. Suppose then a simple version of the CAPM allocates investment in a purely private and closed economy. As originally developed by Sharpe (1964) and Lintner (1965), the CAPM takes the total stock of real capital as fixed and given. The model then derives a set of relative market prices for the financial claims on the individual firms that comprise an efficient market portfolio whose returns are normally distributed that is optimal in the sense that it maximize the excess expected return (over and above the riskless return) on that portfolio for a given amount of portfolio risk. In doing this the model generates the expected return/risk trade-off on the market portfolio. This paper derives an expected return/risk tradeoff in a CAPM type model linked to a Cobb-Douglas production function where the stock of capital is a choice variable and therefore subject to change. Towards this end we assume that the individual productive units or capital assets are components (or divisions) of a single representative firm that underlies the market portfolio. The managers of these individual productive units or divisions are allocated capital by the market portfolio manager in the optimal CAPM way of maximizing excess expected return on the portfolio per unit of

[1] Arguments favoring 100 percent reserve banking are not particularly new. Early English writing proponents of 100 percent reserve banking include Simons (1934) and Fisher (1935); and later Friedman (1959), Tobin (1985), Kareken (1986), and Allais (1987) among others. Their arguments in favor of 100 percent reserve banking were different than ours and focused on preserving the safety of the banking system. These arguments include: i) that it will stabilize the banking system; ii) enable the central bank to more tightly control the M1 stock of money; and iii) when coupled with a fixed percentage money growth rule leads to more stable prices and real economic activity. For a review of the older traditional and non-traditional literature on fractional and 100 percent reserve banking see de Sota (2009) especially chapter 9. Recent advocates and discussion include among others Benes and Kumhof (2012), Kotlikoff (2010), Lucas (2013), and the review by Pennacchi (2012). For different proposals on how to transition from a fractional reserve system to a 100 percent reserve system see Krainer (2013) along with Benes and Krumhof (2012) and Kotlikoff (2010).

portfolio risk. The question is how much financial capital should that representative firm get from saver/investors to allocate to its separate productive units or divisions. We then ask the question whether the stock of this productive capital underlying the market portfolio is Pareto efficient in a financial system with fractional reserve banking versus 100 percent reserve banking.

Consider then the following thought experiment where a privately owned deposit-taking narrow bank is only allowed to invest in a risk-free reserve asset yielding a zero return. We also hold constant the size of the balance sheet of the central bank. Assume also that households can only hold risk-free deposit money with a zero return and invest long in the representative firm/market portfolio. In this set-up there is complete separation between deposit banking and financial intermediation which in turn is carried out within the market portfolio/shadow banking system. The manager of the market portfolio/shadow banking system accepts financial savings from the representative household. For any given level of savings the market manager then allocates the financial resources among the separate productive units or divisions of the representative firm to buy real capital in the CAPM way that generates the highest expected return on the portfolio for a given level of portfolio risk measured as the standard deviation of the return on this portfolio. The problem solved by the market portfolio manager for each and every level of household financial saving is to allocate capital to the various divisions, j, of the representative firm so as to maximize:

$$\frac{E(R_M)}{\sigma(R_M)} = \sum_j x_j \, E(R_j) \, [\sum_j x_j^2 \, \sigma^2(R_j) + 2 \sum_j \sum_k x_j \, x_k \, \sigma(R_j R_k)]^{-1/2} \qquad 1)$$

Subject to

$\sum_j x_j = 1.0$

Where

X_j = the proportionate share of capital allocated to division j within the representative firm.

$E(R_j)$ = The expected rate of return on division j.

σ^2 (R_j) = The variance of the rate of return on division j.

$\sigma(R_j\ R_k)$ = the covariance of the rate of return between division j and division k.

$E(R_M)$ = the expected rate of return on all divisions j that make-up the firm.

$\sigma(R_M)$ = the standard deviation of the rate of return on the representative firm/market portfolio.

In maximizing (1) the market portfolio manager adjusts the proportionate allocations of capital, x_j, to each division j so that:

$$\partial[\tfrac{E(R_M)}{\sigma_{(R_M)}}]/\partial x_j = E(R_j) - \tfrac{E(R_M)}{\sigma^2(R_M)}\,[x_j\,\sigma^2(R_j) + \textstyle\sum_k x_k\,\sigma(R_j\ R_k)] = 0 \qquad 2)$$

The second order conditions for a maximum are satisfied since:

$$\partial^2[\tfrac{E(R_M)}{\sigma(R_M)}]/\partial x_j^2 = -\ \tfrac{E(R_M)}{\sigma^2(R_M)}\,\sigma^2(R_j) < 0 \qquad 3)$$

This is for a fixed K. We next consider the case for a variable K. The return generating process of the linear homogeneous production technology of the representative firm that describes the expansion path for the efficient market portfolio is known to the market portfolio manager and its general form is assumed to be the following[2].

$E(Y) = f(K)$ $\quad f'(K) > 0$ $\quad f''(K) < 0$ 4)

and

$\sigma(Y) = g(K)$ $\quad g'(K) > 0$ $\quad g''(K) \geqslant 0$ 5)

where

K = Physical productive capital.

[2] See Stiglitz (1972, p.39) for this set of assumptions on the production of risk and return in the CAPM. Stiglitz provided no evidence or economic rationale on why risk should be increasing in the level of real investments. Theoretical reasons and empirical evidence for this assumption can be found in Krainer (2009,pp. 6-7).

E(Y) = Expected income on the productive capital underlying the market portfolio.

σ (Y) = Standard deviation of income generated on the productive capital of the market portfolio.

Together equations (4) and (5) reflect the fact that real capital investment generates a probability distribution around an expected diminishing returns income, and the spread of this distribution increases with capital investment. This result is consistent with the "low risk anomaly "in finance that stocks with higher volatility earn lower rates of returns (Baker and Wurgler, 2015). Risk is endogenous in this model and is a choice variable of household savers and the CAPM market portfolio manager. Equation (4) taken separately is well established in the literature. However, economic theory is silent on equation (5) which has risk going up as capital investment goes up. Nature is stingy in this model economy in that the investment attributes of expected income and risk both deteriorate at the margin as capital investment increases.

Since economic theory is silent on equation (5) and the fact that it plays an important role in the analysis, some justification is necessary in order to pass a "real world filter." To begin with there is statistical evidence that *future* earnings variability is an increasing function of *current* capital investment (Kothari et al.2002 and Suurmeijer et al. 2013). In this connection, Kothari et al. (2002) with a sample in excess of 50,000 firm-year observations for Compustat industrial firms over the period 1972-1997 provide regression evidence that increases in current investments in year t in plant and equipment, R&D, and advertising are associated with an increase in the standard deviation (and variance) of future corporate earnings both before and after corporate taxes. We supplement the Kothari et al. micro evidence with some macro evidence from the nonfinancial corporate business sector in the U.S. Towards this end we regress the standard deviation of future corporate profits before tax on current capital expenditures for the U.S. nonfinancial corporate sector. Since financial leverage in principal can also increase the volatility of before tax earnings, we also include a leverage variable measured as the

change in the ratio of total liabilities to total assets. Finally, a Cochrane-Orcutt procedure is implemented to correct for auto-correlated residuals in the regression. The results for the period 1977-2010 are as follows.

$$\text{Log (Stdev Profits,BT)}_{t-t+4} = -4.86 + 1.38 \log(\text{Cap Expend})_t + 9.85\ \Delta(\text{Liab/A})_t \qquad 6)$$

(-2.17/.00) (4.07/.00) (1.74/.09) $\overline{R}^2$=.80 AR(1) = .67

Where

Log (Stdev Profits,BT) = the log of the standard deviation of before tax corporate profits in the nonfinancial corporate sector computed over the 5 year period from t to t+4.

Log (Cap Expend) = the log of capital expenditures (fixed investment, change in inventories, and nonproduced nonfinancial assets) for the nonfinancial corporate sector.

Δ(Liab/A) = The change in the ratio of total liabilities to assets in the nonfinancial corporate sector.

$\bar{R}^2$ = Adjusted coefficient of determination.

AR(1) = Estimated autoregressive coefficient.

Newey-West t-scores/P-values are given beneath the estimated coefficients.

All variables obtained from the Federal Reserve Financial Accounts (Table F102) of the United States at www.federalreserve.gov/releases/z1...b102

The regression says that a 1 percent change in capital expenditures is associated with a 1.38 percent change in the standard deviation of future before tax corporate profits. Do capital expenditures cause future earnings volatility as equations (5) and (6) suggests, or is the causation reversed? To answer this we carry out a pairwise Granger causality test. The Granger Causality test for lags of 2 years indicates that we can reject the hypothesis that log(CapExpend) does not Granger cause log(StdevProfits,BT) at the 1 percent level of significance since the F-statistic is 5.49 with a Prob of .01; but we cannot reject the hypothesis at the 5 percent significance level that log(StdevProfits,BT) does not Granger cause log(CapExpend) since the F-statistic is only 2.20 with a Prob. of .12. Finally the leverage effect on future profit volatility is positive as predicted by finance theory and statistically significant at the 10 percent

level. Both the micro and macro evidence is consistent with the assumption that increases in current investment are associated with increases in the volatility of future investment returns as indicated by the derivatives in (5).

Further evidence on the derivatives in equation 5 comes from bank financing of investment projects. This evidence indicates that credit standards for bank lending vary cyclically (see Cunningham and Rose (1994), Weinburg 1995, and Keeton (1999) for the U.S.; Hoggarth et al. 2002 for 47 developing and developed countries; Berger and Udell 2003; Jimenez and Saurina (2006 for Spain); Drehmann et al. (2011); and Caporale et al. 2013 and Rodan et al. 2015 for Italy). In periods of rapid capital accumulation and economic expansion financed in part by bank lending, the true risk on the underlying investment projects is underestimated as bankers think the good times will continue into the indefinite future. As a famous former Wall Street banker once said: "As long as the music is playing, you have got to get up and dance." This well-documented phenomenon in the bank loan market has led to a regulatory capital response that takes the form of Section 616 of the Dodd-Frank Act where it states "…the amount of capital required to be maintained by an insured depository institution increases in times of economic expansion and decreases in times of economic contraction,…". Further evidence comes from financial markets (reflecting the real economy) and the cyclical movement of the Sharpe ratio, $E(R_M)/\sigma(R_M)$. Brandt and Kang (2003) find that in and around NBER troughs of recessions (when bank financing and real investment is low), the mean returns on stocks, $E(R_M)$, are rising and the volatility of stock returns, $\sigma(R_M)$ is falling. Conversely in NBER peaks of expansion (when bank financing and real investment is high), mean returns are falling and the volatility of returns are rising. The end result is that the Sharpe ratio is countercyclical.[3] This empirical evidence on the Sharpe ratio is

[3] Other empirical studies finding a countercyclical movement in the Sharpe ratio include Harrison and Zhang (1999), Campbell and Diebold (2009,Ludvigson and Ng (2007), and Lustig and Verdelhan (2012) among others.

consistent with the return generating process in equations (4) and (5). In addition to this empirical evidence several economic arguments support our assumptions on the return generating process in (4) and (5). One argument is that new investment typically involves implementing new technologies and new technologies often require unforeseen costs in their implementation. A second argument is that a large increase in K will increase supply relative to demand. To which sectors will the demand go with this increased supply? Each individual productive unit will then experience an increase in risk just as adding more players to the game of musical chairs increases the risk for each individual player finding a chair when the music stops. For every Amazon that succeeds, many dot coms failed which resulted in the 2001 recession. A third argument is that when the capacity-increasing investment is allocated unevenly across the separate productive units by the market portfolio manager in response to changes in taste and technology, relative prices of output in those sectors will become more variable. An increase in the variability of relative prices, according to the New Classical theory (Lucas, 1973), makes it more difficult for the managers of the separate divisions to estimate profits and plan production thereby increasing the underlying operating risk of the representative firm. A fourth argument is that with a fixed supply of experienced managers/skilled workers, an increase in capital investment that expands capacity will require the firm to use less experienced managers and workers and/or spread the experienced human capital more thinly across the different divisions within the firm. How these relatively new and inexperienced managers/workers will perform is uncertain, and this uncertainty contributes to the increased operating risk associated with the new investment. Alternatively spreading the experienced managers more thinly throughout the firms will also contribute to an increase in operating risk. "Too big and too complicated to manage" is becoming an increasing reality for financial as well as nonfinancial enterprises in the industrial advanced countries as the recent break-ups of Hewlett-Packard, Kraft, Wendy's, Ingersoll-Rand, and ITT among many others testify to. A fifth and related argument is that a rapid expansion in productive capacity that comes with increased real

investment may make it more difficult to maintain the quality of the firm's product thereby creating a new but lower quality product. Will the firm/division be able to profitably sell this new but lower quality product in the market place at a profitable price? Will the lower quality product result in expensive suits and government fines? Recent examples of the problems associated with rapid capacity expansion and maintaining product quality is the automobile manufacturers Toyota, GM, Honda, and more recently Volkswagen. Perceived quality changes that often accompany a rapid expansion in real investment pose an additional risk confronting the representative firm. This evidence would also be consistent with the assumptions on the derivatives in equation (5).

With these assumptions and the above evidence on the derivatives of (4) and (5) we can now derive a CAPM return/risk frontier for different levels of K between E(Y) and σ(Y) based on their separate relationships to K in the production function. In this connection note that as K varies, [σ(y), E(Y)] describes a locus of points with equations (4) and (5) constituting a parametric representation of the locus. Eliminating K between equations (4) and (5) defines E(Y) implicitly in terms of σ(Y) as in the CAPM. On the assumption that f and g are continuously differentiable functions of K we can then express the derivatives of E(Y) wrt σ(Y). Begin by noting that the total differentials of (4) and (5) are:

$$d[E(Y)] = f'(K)dK \qquad \text{and} \qquad 7)$$

$$d[\sigma(Y)] = g'(K)dK \qquad 8)$$

Dividing (7) by (8) the derivative of E(Y) wrt σ(Y) is thus

$$\frac{dE(Y)}{d\sigma(Y)} = \frac{f'(K)}{g'(K)} > 0 \qquad 9)$$

indicating that E(Y) is a positive function of σ(Y) as K increases. To compute the second derivative to test for concavity we have:

$$\frac{d^2E(Y)}{d\sigma(Y)^2} = \frac{d}{d\sigma(\mathrm{Y})} * \frac{dE(Y)}{d\sigma(\mathrm{Y})} = \frac{dE(Y)'}{d\sigma(\mathrm{Y})} \qquad 10a)$$

where $E(Y)' = \frac{dE(Y)}{d\sigma(\mathrm{Y})}$. Taking the total differential of E(Y') and σ(y) and then dividing as above we get

$$\frac{d}{d\sigma(Y)} * \frac{dE(Y)}{d\sigma(\mathrm{Y})} = \frac{d}{dK} * \frac{dE(Y)}{d\sigma(\mathrm{Y})} * \frac{dK}{d\sigma(\mathrm{Y})} \leq 0 \qquad 10b)$$

Equation (10b) is negative since d/dK • dE(Y)/dσ(Y) contains f''(K) which according to diminishing returns is assumed to be negative in (4) above. E(Y) is therefore a concave function of σ(Y) implying that the marginal rate of transformation of expected income for risk on real capital investment is diminishing[4].

The relationship between E(Y) and σ(Y) from the above equations is visually presented in Figure 1. The curve TC describes the varying amounts of E(Y) and σ(Y) generated on varying amounts of capital investment K when the market portfolio manager allocates capital amongst the different divisions so as to maximize the ratio of E(Y)/σ(Y) for the underlying representative firm as in equations (2) and (3).

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[4] An alternative derivation based on the Inverse Function Theorem is to write:

i) E(Y) = f (K)

ii) σ(Y) = g (K)→ K=g^{-1}[σ(Y)]
That is, the inverse function g^{-1}(σ(Y)) exists on any interval where g is monotonic with either g'(σ(Y)>0 or g'[σ(Y)]<0.
Since g'(K) >0, g^{-1}[σ(Y)] exists, and
It is then the case that:

iii) E(Y) = f(K) = f[g^{-1} σ(Y)] and

iv) $\frac{dE(Y)}{d\sigma(\mathrm{Y})} = f'[\mathrm{g}^{-1}\sigma(\mathrm{Y})] * \frac{d}{d\sigma(\mathrm{Y})} g^{-1}\sigma(\mathrm{Y})$ or

v) $f'[g^{-1}\sigma(\mathrm{Y})] * \frac{1}{g'(K)} > 0$

vi) Using the quotient rule the second derivative is

$$\frac{d^2E(Y)}{d\sigma(Y)^2} = f''[g^{-1}\sigma(\mathrm{Y})] * \frac{1}{[\mathrm{g}'(\mathrm{K})]^2} + \mathrm{f}'[\mathrm{g}^{-1}\sigma(\mathrm{Y})] * \frac{-1}{[\mathrm{g}'(\mathrm{K})]^2} * \mathrm{g}''(\mathrm{K}) < 0$$

Since both terms on the rhs are negative, vi) is negative. Thus the relationship between E(Y) and σ(Y) is concave just as it is in the CAPM. My thanks to Katherine Kovarik and Donald Schuette for pointing out this inverse function proof of concavity. Stiglitz (1972, p.39) shows that all that is needed for concavity is [g''(K)g(k)]/[g'(K)]^2 + 1.0 ≥ 0.

(Put Figure 1 here)

Next we describe the representative saver/investor in this economy. Capitalist saver/investors are endowed in the beginning of some hypothetical time period t=0 with a given stock of wealth (claims on the market portfolio) along with money, the result of providing capital services to the representative firm in the previous period t=-1. With this money they pay for the pre-ordered consumption goods in t=-1 to be consumed in the current period t=0, and reinvest the remainder in the market portfolio at the beginning of the current period. Transaction and precautionary needs are the motivations for households and the representative firm for holding money in this economy. The manager of the representative firm/market portfolio will then use the money obtained from households to invest in real capital and money balances spread across the separate divisions of the representative firm underlying the market portfolio where it will become part of the capital stock in the next period.[5] Our focus will be on the representative agent's savings decision in the market portfolio and set aside their consumption decision. The assumption that consumption goods are pre-ordered at the end of t=-1 closes the consumption goods factory and store for new orders during period t=0 as they are in the standard CAPM. The investment goods store and factory (with available capacity) are now open and ready to do business.[6] To complete the model it is necessary to describe the preferences of the representative

[5] Think of households as receiving money from the representative firm at the end of t-1 for capital services provided during the period t=-1. At the beginning of t=0 they use this money income (and money held in precautionary balances) to pay for the food consumption goods planned and pre-ordered at the beginning of t=-1 that will be consumed during t=0. The remaining money is saved/invested in precautionary balances and the CAPM market portfolio so as to maximize their expected utility over risk and return. Money is held by household in the beginning and end of a period, and by the representative firm and government during the period. They also pre-order the consumption goods to be produced in t=0 but paid for at the end of t=0 and consumed over period t=1. Precautionary money balances are held by households at the beginning of a period to absorb shocks in income and attain the planned consumption and saving/investment for the future.

[6] These assumptions are made to facilitate a comparison of a 100 percent reserve banking system and a fractional reserve banking system on the allocation of productive investment without the added complications of inflation. We show below that even in the absence of inflation, money creation results in a suboptimal allocation of investment. With consumption predetermined and the investment goods factory (with available capacity) open, we eliminate any inflation associated with a transition to a fractional reserve banking system and restrict the analysis to emphasizing the increased volatility in future output that is set in motion when banks facilitate the

household saver/investor in terms of expected income, E(Y), and risk, σ(Y), on their savings. The standard expected utility function for the representative risk averse saver/investor (assuming non-satiation) is then given by:

$$E(U) = U[\, E(Y), \sigma(Y)] \qquad U'[E(Y)] > 0 \quad U''[E(Y)] \leq 0 \quad U'[\sigma(Y)] < 0 \quad U''[\sigma(Y)] \leq 0 \qquad 11)$$

Taking the total differential of expected utility in (7) and setting it equal to zero yields an indifference curve in terms of E(Y) and σ(Y); namely,

$$dE(U) = U'E(Y)*dE(Y) + U'[\sigma(Y)]d\sigma(Y) = 0 \qquad 12)$$

The slope of this indifference is positive since

$$\frac{dE(Y)}{d\sigma(Y)} = -\frac{U'[\sigma(Y)]}{U'[E(Y)]} > 0 \qquad 13)$$

It is traditional to assume that indifference curves in [σ(Y), E(Y)] space is convex as displayed by IC in Figure1. Convexity implies that savers/investors require ever higher amounts of expected income in compensation for incremental increases in risk in order to keep their expected utility constant.[7]

financing of risky investment with newly created money. This point is graphically illustrated in Figures 2 and 4 below. If the investment goods factory were closed (i.e., no available capacity) then money creation by banks would obviously result in inflation in the store selling investment goods. This would then result in a redistribution of the ownership shares on the market portfolio towards banks and away from household saver/investors reducing the latter's expected utility even further.

[7] An intuitive demonstration of convexity of indifference curves is the following. Consider a point A on an upward sloping indifference curve involving relatively small amounts of σ(Y) and E(Y). Since E(U) is assumed to be a negative function of σ(Y) with a negative second derivative while E(U) is a positive function of E(Y) with a negative second derivative, the derivative dE(Y)/dσ(Y) at point A follows - U'σ(Y)/U'E(Y) ~ "small"/"large" ~ "small". In other words, dE(Y)/dσ(Y) is relatively small at point A and the indifference curve while upward sloping is relatively flat. Next consider a point B further up the positive sloped indifference curve involving large amounts of σ(Y) and E(Y). Again we have dE(Y)/dσ(Y) = -U'σ(Y)/U'E(Y) but now -U'σ(Y)/U'E(Y) ~ "large"/"small" ~"large" and the indifference curve is relatively steep. Thus as we move along an upward-sloping indifference curve from A to B in a northeast direction the value of d(EY)/dσ(Y) increases indicating that investors require ever increasing amounts of E(Y) for every unit increase in σ(Y) to keep their expected utility constant. For the standard proof on convexity see Fama and Miller (1972, pp. 226-227).

With these assumptions on tastes and technology consider first in this thought experiment a financial system where banks are initially required to maintain 100 percent reserves against their deposit obligations and households alone through their saving/ investment in the market portfolio provide the financing for the risky capital investment in the economy. With the return generating process of the firm given by (4) and (5) and household preferences given by (13), the initial level of real investment generates the expected income $E(Y)_0'$ and risk $\sigma(Y)_0'$ for the beginning of the period t=0 in Figure 1. This equilibrium stock of private risky capital K_0' of firms is seen to generate a trade-off of volatility for expected income growth underlying the market portfolio that is equal to the marginal rate of substitution (given by the slope of IC) of risk for expected income in the indifference curve of the representative saver/investor at M'.

Does this version of the CAPM have anything to say about future economic growth and the business cycle? To answer this question observe that the beginning of the period capital stock K_0' generates a normal probability distribution (a sufficient condition for deriving the CAPM) with mean $E(Y)_0$ and standard deviation $\sigma(Y)_0$. On the assumption of rational expectations, it will be from this probability distribution that the actual next period income Y_1' to saver/investors will be drawn. The spread of this probability distribution describes both the utility maximizing potential future fluctuations of capitalist income Y_1', and future total output Q_1' when Q is generated by a linear homogeneous production function with constant factor income shares α and $(1-\alpha)$. In this model economy saver/investors in maximizing their expected utility freely choose the expected level, (Q_1), and volatility, $[\sigma(Q)]$, of future economic activity when they choose the level of current savings to finance the capital investment, K_0', of the firm/economy. This is graphically described in Figure 2. In part A of the figure we reproduce Figure 1 with the normal distribution drawn in at the initial equilibrium of M' generating $E(Y)_0'$ and $\sigma(Y)_0'$ in period t=0. In part B we plot the possible realized Y_1 and Q_1 when Q_1 is generated by a Cobb-Douglas

production function, $Q_1 = AK_0^{\alpha} N_0^{1-\alpha}$, where N is fixed (at full utilization) and A>0 represents random factor productivity. The slope of the line translating Y_1 into Q_1 is α, or, capital's share in total output. The horizontal dashed lines represent kσ(Y) standard deviations on both sides of the mean $E(Y_0)$ which when reflected back to Q_1 via the construction line with slope α represents the magnitude of future variations in total output Q_1. Thus the distance between Q_1' and ${}^{r}Q'_1$ represents the varying magnitudes of future recession outcomes associated with K'_0 while the distance between Q_1' and ${}^{e}Q'_1$ represents the future cyclical expansions within the kσ(Y) bands. Since the transformation curve TC in Figure 2 is concave, increasing amounts of K_0 results in both lower growth of Q_1 and increases in economic volatility σ(Q). The tradeoff between growth and economic volatility is becoming worse. Finally, a rotation of the saver/investor indifference curve reflecting changes in risk aversion in this static model will change these bands and the associated probability distributions describing business cycles.

(Put Figure 2 here)

From this initial efficient equilibrium now consider in this thought experiment an artificial parallel economy where the privately owned banks obtain a reduction in their legal reserve requirement from 100 percent to something less; for example, 10 percent of deposit obligations. We still assume the size of the central bank's balance sheet is fixed and ignore for the time being the costs of implementing a government deposit insurance scheme and regulatory structure. The private profit maximizing banks now have money in the form of excess reserves which in this CAPM model they will fully invest in the market portfolio since the other asset (money/reserves) in the system yields a zero nominal return. Total capital investment, K_0^*, of the representative firm underlying the market portfolio will now be financed with the money income saved, S, by capitalist and new deposit money, ΔM, created by banks; i.e., $S+\Delta M= K_0^*$. The main difference between the banks and saver/investors is that the latter generated their savings by providing capital services to the firm in some previous period and deferred

consumption whereas bank deposit creation was not the result of a prior expenditure of any prior factor services but instead a change in regulation. With a lower return to risk ratio the representative firm in Figure 1 will now increase their capital investment. The effect on the financial system of this additional financing that allows risky capital accumulation to grow from K_0' to K_0^* is described in Figure 3. There it can be seen that the additional productive investment generates an increase in expected income to $E(Y)_0^*$ and an even greater increase in risk to $\sigma(Y)_0^*$. Since the additional risky investment generates more growth in the form of expected income and output (both Y and Q) but even more risk (σ(Y) and σ(Q)), the economy moves further along the efficient concave expansion path/ transformation curve TC to some point like M* in the figure. At point M* the indifference curve of the representative saver/investor will no longer be tangent to the efficient transformation curve but will lie everywhere below the indifference curve that is tangent to TC at point M'. In other words, when investment is $K_0^* > K_0'$ the representative firm is generating too little expected income (and output) per unit of risk in their productive investment decisions than saver/investors require in their personal trade-off between expected income and risk in their indifference curve. The trade-off between growth and economic volatility has deteriorated.

(Put Figure 3 here)

Could the representative saver/investor undo this excessive risky capital investment financed by new deposit money created by banks at M* by simply reducing their personal investment in the market portfolio and get back to their expected utility maximum at M'? It would depend on the extent to which they owned and controlled the deposit creating banks. If they completely owned and controlled the deposit creating banks, there would be no incentive in the first place to become fractional reserve banks and invest ΔK with created money in the market portfolio. Moreover if unlike the stylized economy described here we considered the real world expenses associated with deposit insurance and

government regulation that would be necessary in a fractional reserve banking system, the answer would be a decidedly No. On the other hand if banks were privately owned and outside the market portfolio (which they originally were and to a certain extent continue to be), or, more likely management controlled due to agency problems associated with the separation of ownership and control, the answer would still be a decidedly No.[8] That is because at the new market portfolio M* household savers and bankers would share the E(Y) and σ(Y) in the same proportion as their relative share of investment in the market portfolio. To see this let γ (for $0 < \gamma \leq 1.0$) be the proportionate share of investment in the market portfolio put up by household savers and $(1-\gamma)$ be the share put up by the privately owned banks. On the assumption that risk increases linearly with investment, this sharing is then represented by a point somewhere along a ray emanating from the origin of quadrant 1 of Figure 3 to the new M*> M' on curve TC. This sharing of E(Y) and σ(Y) is illustrated in Figure 3A. Points on the ray 0A in the figure lying closer to the origin would represent a relatively smaller share of investment in the market portfolio (ie., small γ) owned by the representative saver/investor while points closer to M* would represent a relatively larger share of the market portfolio. In the figure $\gamma E(Y)_0$ and $\gamma[\sigma(Y)_0]$ would then be the shares of expected income and risk belonging to the representative household saver/investor with indifference curve IC*. The indifference curve IC* touching or going through the sharing point lying on ray 0A is everywhere below the curve IC'.

(Put Figure 3A here)

[8] Management control that included the granting of excessive compensation agreements linked to risky investments has been well-documented in the Great Crisis literature; see Stiglitz (2011) and Prager (2012). Bonus plans in some banks take up as much as one-half the after-tax profits of the bank making manager's implicitly large equity holders. Moreover under "hustle" programs bankers were compensated in terms of the number and dollar amounts of mortgage deals they arranged with little regard for the quality of the credit extended.

In any event the larger amount of capital investment while increasing the expected income and output of firms in the economy, also increases the amplitude of future fluctuations in income and output even more. This can be seen in parts A and B of Figure 4. In part A of the figure the probability distribution at point M* associated with K_0^* capital investment is now more spread out than the distribution at point M' associated with $the\ K_0'$ level of investment. Through the Cobb-Douglas production function this greater variability in expected income going to household saver/investors and banks as owners of the capital underlying the market portfolio is reflected in greater variability of realized output Q_1 at the end of the period. This can be seen in part B of the figure where the distance between ${}^{r}Q^*_1$ (or ${}^{e}Q^*_1$) and Q_1^* associated with K_0^* is greater in magnitude than the fluctuations in Q associated with the Pareto efficient capital investment of K'_0 described in Figure 2.

(Put Figure 4 here)

This non-optimal and excessive level of capital investment by firms in t=0 is not the result of herding by bankers, Basle-type capital regulations for banks, or changes in the risk perceptions and risk aversion of the banks, or changes in the value of collateral and/or net worth by borrowing firms, or changes in bank stock valuations, or mark to market accounting; arguments in the literature that link present day bank lending to increased amplitude of the business cycle. The problem in a financial system with fractional reserve banking is more fundamental. It is the ability of fractional reserve banks to finance productive investment in the market portfolio with newly created deposit money that causes a negative externality for household savers/investors in this economy. In this CAPM world saver/investors draw up a saving- investment plan in t=0 that maximizes their expected utility over risk and expected return. Embedded in that plan is a probability distribution from which under rational expectations future investor income and aggregate output is drawn in period t=1, 2, 3,… . Rational expectations in this model is the link between the present and future. In this sense the future growth and fluctuations in

income and output are the natural result of saving and investment in a risky economic environment where productive investment is efficiently allocated across sectors according to the 2-parameter CAPM. In other words, economic growth and business cycles are a freely chosen and natural outcome of a private utility maximizing saving/investment decision when the risky capital investments of firms are financed with the saving of households. Households generate an income from the sweat of their abstinence. Out of this income they save and invest in the market portfolio. In maximizing profits banks generate new deposit money with a stroke of a pen when they invest in the market portfolio, our proxy for the shadow banking system. When financing is provided by the savings of capitalists and the money creation of banks, the real capital investment underlying the market portfolio creates a probability distribution around future expected income and output that has a greater variability than the utility maximizing distribution chosen by saver/investors alone when banks are subject to a 100 percent reserve requirement. In this sense fractional reserve banks financing risky productive investments create excessive risk in the form of business cycles with greater amplitude. Of course introducing a government subsidized deposit insurance scheme would provide a well-known additional incentive for banks to invest in the risky market portfolio that in turn would further amplify business fluctuations because of the put option embedded in the deposit insurance. Our argument is that even in the absence of deposit insurance fractional reserve banks create excessive risk per unit of expected return for household savers whenever they finance risky capital with newly created deposit money.

Banks in a fractional reserve system are not the only vehicles for excessive risk creation and volatile fluctuations in an open economy. Countries with large trade surpluses (the so-called global savings glut) that in turn invest their surpluses in the risky sector of deficit countries can create the same externality for domestic saver/investors in the deficit countries. Trade deficits can amplify domestic business cycles. Indirectly domestic saver/investors in the deficit countries choose this increased amplitude in the business cycle when they freely choose to consume foreign produced products. Moreover the

foreign saver/investors of surplus countries bear part of the cost of exporting business fluctuations to the deficit countries due to the repercussion effect of the greater volatility of their future exports and GDP. The U.S. has been somewhat lucky in this regard in that many Asian countries with substantial trade surpluses in the past have chosen to invest their surpluses in the risk-free sector[9].

IV. Summary and a Proposal for the Transition to Full Reserve Banking

To conclude, it has long been known that the maturity transformation and liquidity provision that is the business of present day fractional reserve banks exposes the system to potential financial and economic instability. In good times optimistic banks fund too many marginal projects, and in bad times their flight to safety precludes the funding of projects that in more normal times they would fund. Many economists attribute this cyclical amplification of bank lending and economic activity to a number of factors including: herding, procyclical changes in monetary policy, countercyclical changes in risk perceptions and risk aversion, procyclical changes in the value of collateral and borrower net worth, procyclicity in lending induced by various Basle Accord capital requirements, and procyclical changes in bank share valuations that amplify changes in the cost of capital for banks. These factors can and do amplify fluctuations in bank lending and economic activity. Those economists that favor fractional reserve banking implicitly argue that the benefits of liquidity provision via maturity transformation outweigh the cost of a more volatile banking system and economy. That cost was high in the 2007-2009 recession and was estimated by Atkinson et al. (2013) to be somewhere between $6 -14 trillion in lost

[9] There were some indirect effects of Asian and OPEC trade surpluses that contributed to the recent U.S. crisis even though these countries primarily invested their surpluses in Treasury securities. There is evidence that Asian and OPEC surpluses were partly invested in European bank deposits. These deposits provided the financing for European investments (particularly in asset backed securities) in the U.S. in the run-up to the crisis. A second indirect effect was that the massive inflows of capital into Treasury securities by Asian and OPEC countries lowered interest rates which in turn spread throughout the U.S. economy stimulating investment in housing. For an excellent review and discussion of the role capital imports from various groups of countries played in the run-up to the U.S. crisis see Bertaut et al. (2011).

GDP (depending on assumptions regarding trend GDP) up to 2012 and still counting, or, $50,000 - $120,000 per family. The question that must be asked is whether liquidity provision is worth this much in terms foregone GDP. At present we do not have a measure of what liquidity provision is worth in terms of GDP and this question should be high on the agenda of future research. Our criticism of fractional reserve banking, based on the importance of the coordination of savings and investment along with its effects on economic growth and the volatility of future real economic activity, broadens the debate. The coordination of savings and investment is the raison d'etre of financial intermediation. We have argued that **any** bank lending/investing with created money whether it be abnormally large or abnormally small, or, anywhere in-between in magnitude with created deposit money is suboptimal. In this stylized world we show in a thought experiment how changes in the institutional arrangements of going from a 100 percent reserve banking system to a fractional reserve banking system with or without government deposit insurance will increase the available funding for increasingly risky productive investments. These investments will increase output on average but they will even more increase the volatility of output.[10] Economic growth does not come free. To the best of our knowledge this is the first time a chain of standard economic models made up of: i) a CAPM description of real investment allocation; ii) saver/investors hold rational expectation; and iii) a linear homogeneous production function like the Cobb-Douglas have been brought together to describe a parallel (to reality) economic

[10] There is some evidence that both economists and non-economists in the U.S. are prepared to give up cyclical expansions in order to eliminate recessions. In this connection a survey study of economists and non-economists by Shiller (1996, pp.22-23) found that 83 percent of non-economist endorsed a counter-cyclical policy that would eliminate recessions but also eliminate expansions. For professional economists 84 percent favored a counter-cyclical policy that equally eliminated recessions and expansions. This is a high degree of agreement for both groups and one of the few questions in the survey where economists and non-economists were in very close agreement. What is also interesting is that the survey was not taken in a recessionary period with high unemployment rates as we have had in the crisis of 2007-2010; but instead taken in a period of good times when the U.S. economy was experiencing better than average real GDP growth of 3.7 percent, an unemployment rate of 5.4 percent and falling, and a labor participation rate of 66.9 percent and rising (all data taken from the Economic Report of the President). Wolfers (2003) finds the same result in a microeconometric study of "well-being" and unemployment. His results indicate that eliminating unemployment volatility is equivalent to lowering the average level of unemployment by .25%. The life satisfaction index he uses is from the Eurobarometer Survey.

system of an expected utility maximizing business cycle. Ex-ante business fluctuations are described in this parallel economy by the spread of a probability distribution. Describing business cycles in terms of the spread of a probability distribution is non-traditional. Business cycles are typically defined as the deviation of actual output from long-term trend output. In our model actual output in some period t is the result of real capital investment decisions made in a sequence of prior time periods just as the given position of a large ocean-going vessel at any point in time period t is determined by the decisions of the helmsman in prior time periods. The only difference is that the helmsman using physics knows precisely where the boat will be in period t as a result of his/her decisions in prior time periods. Business decision makers and investors are not so lucky and the best they can hope for is that their analysis gives them the right probability distribution from which the actual outcome in period t is drawn. Consequently when households choose to invest their savings in the market portfolio/shadow banking system, they choose the expected return/risk combination that maximizes their expected utility and the probability distribution from which future output will be drawn. To highlight this result in the strongest possible way we (along with Diamond and Dibvig and Kashyap et al.) assumed that prices are fixed when fractional reserve banks create money and invest in the market portfolio. The idea behind this assumption is to isolate the causally significant relationships between bank credit creation, real investment, economic growth, and future economic volatility that we emphasize in this paper, from the many other relationships (eg, the relationship between money and prices) that characterize a complex real economy. Moreover, introducing price inflation would only make the misallocation worse for households by capriciously redistributing financial wealth towards banks and away from household saver/investors. Productive investment generates a “good” (expected return) and a “bad” (variability of return). The excessive productive investment associated with fractional reserve banking generates a lower “good” to “bad” ratio than the ratio associated with the maximum expected utility of

saver/investors when banks are subject to 100 percent reserves. In other words, excessive productive investment today will sow the seeds of greater variability in income and output tomorrow.

The goal of 100 percent reserve banking presented in this paper is the same as it was in the original "Chicago Plan"*;* namely, to safeguard deposit money at a relatively lower cost than current regulation (eg., FDIC deposit insurance and various regulatory agencies) but even more importantly, *moderate* the amplifying effect of the banking system on the real economy. Whether or not the policy of dampening expansions as well as recessions by separating deposit banking from financial intermediation is one that will be supported by the legislative branches of government in the EU, North America, and developed Asia remains to be seen. And yet there is cause for some optimism. While academic work on full reserve banking has been minimal in the aftermath of the Great Crisis, full reserve banking is currently being discussed and considered as part of banking reform proposals recently before the Dutch, Icelandic, and U.K. parliaments and in a national referendum in Switzerland.

Yet most countries have not looked to full reserve banking as a regulatory response to the Great Crisis. The prevailing view seems to be that fractional reserve banking with "appropriate" regulation would be a better solution to financial crises than full reserve banking. It is true that compared to unregulated fractional reserve banks, appropriate regulation that reduces fractional reserve banks ability to finance real investments would have the effect of reducing the spread of the probability distributions describing business cycles in this paper. This type of regulation would also reduce growth. In this case regulation has the effect of raising the effective required reserve ratio above the legal reserve ratio thereby reducing money creation. However, it might be asked whether regulation can ever be a permanent solution to financial and economic instability? Regulation evolves out of the political process and not any immutable laws of economics. One political group puts in a set of regulations in response to a crisis. Then with the passage of time and the lobbying efforts of the regulated, another

political group repeals the earlier regulation. This certainly was the case in the U.S. with the Glass-Steagall Act and threatens to be the case with the Dodd-Frank Act. It is not clear (at least to me) how banks will react to on again, off again regulation.

What would full reserve banking and its transition look like if adopted by those countries presently studying full reserve banking? There are many possible answers. Most likely it would take some form of ring fencing the checking account business of existing banks since that would be the easiest to implement in the U.S. given the large volume of excess reserves. Other less conventional proposals include: cash mutual funds and limited purpose financial intermediation proposed by Kotlikoff (2010), digital cash accounts managed by the government as proposed by van Egmond and de Vries (2016), and the Treasury credit and private debt forgiveness plan proposed by Benes and Kumhof (2012) during the transition just to name but a few. Digital cash accounts with blockchain technology managed by a central bank is an interesting possibility for the future and is discussed in Raskin and Yermack, (2016). The idea is that individuals and firms would hold digital accounts at the central bank thereby bypassing commercial banks and achieving much of the advantages of full reserve banking discussed above. The advantages would include lower cost of processing of money transactions using the blockchain technology. Another advantage is that it would help reduce money laundering and tax evasion since the central bank would be in a better position to monitor these illegal activities. Finally, monetary policy could be implemented by merely changing the interest rate paid on private accounts at the central bank either generally or selectively. Disadvantages include: i) absence of privacy; ii) vulnerability to hacking (e.g., the loss of $450 million worth of bitcoins and the bankruptcy of the Mt Gox exchange in Tokyo and more recently the $65 million theft of 120,000 bitcoins at bitfinex in Hong Kong); iii) potential cyber-attacks that could destabilize the financial system; and finally iv) the current inability of citizens to use this technology. Further development of the blockchain technology to enhance its acceptance, reliability, and safety would eventually pave the way for the widespread use of a digital currency.

Our own view at present is that full reserve banking should first be introduced with existing transactions money including checking account money. One way to achieve this is through a system of post office banks or government created banks. Moreover, according to Baradaran (2014) postal banks would also have the added advantage of providing banking services to the unbanked and underbanked low income groups because they are located in both high income and low income areas. Post office banking would be easier for Europe and Asia to achieve than the U.S. since they already have a well-developed system of post office banks. Conversion to full reserve banking would be a major regulatory change in the financial system, but probably no more difficult to achieve than the conversion to the Euro, Brexit, and much easier to achieve than metrication in the U.K. Therefore any transitions to full reserve banking would have to be spread out in a series of stages over time. The first stage (more relevant for the U.S.) would be to create a system of post office banks that are required to hold full reserves in a special interest bearing account at the central bank. The central bank would pay interest on this reserve account during this transition period sufficient to make postal deposits competitive with deposits at present day lending and investing fractional reserve banks. In the second stage, after suitable notification and an adjustment period, government would remove insurance on deposits other than checkable deposits at fractional reserve banks. In the third stage government deposit insurance would be withdrawn from the remaining demand deposits of fractional reserve banks. In the fourth and final stage deposits accessible with debit cards at post office banks would be declared legal tender. In this way checking account money (accessible by check writing and electronic transfers) or government digital money would become national money rather than private local money which it now is. Advanced polymer currency money and checkable deposits at post office banks would both be liabilities of the government. What would become of present day traditional banks? They would become shadow banks of their own choosing.

Why implement full reserve banking through post offices/government banks rather than existing privately owned banks and why make postal deposits legal tender? The answer to these two questions are interrelated. The primary reason is that privately owned banks have a powerful incentive to remain fractional reserve banks because as Rajan has noted (in section II above) "…they can't make any money …" being plain vanilla full reserve banks. Historically private banks have been very successful in shaping legislation that effects their profitability. There is no reason not to believe that with the passage of time private full reserve banks would successfully lobby for legislation that would eventually undo the full reserve requirement. Implementing full reserve banking through postal banks would be more difficult to undo. Moreover making postal deposits legal tender would reinforce the distinction between the non-insured claims on shadow banks and checking account money as claims against the government.

What problems might be encountered in transitioning from a fractional reserve banking system to a full reserve system through post office banking? One possible problem for the U.S. would be whether there are enough post offices to replicate the present day banking system. According to FDIC data (http://www5.fdic.gov/hsob/HSOBRpt.asp) there were roughly 5,300 banks with roughly 82,000 branches (both falling) at the end of 2015. Post Office statistics put the number of post offices at roughly 32,000. Moreover to better accommodate customers, convenience kiosks and ATM's could easily be installed in high traffic office buildings and shopping centers. Another possible criticism of full reserve banking is that present day fractional reserve banks perform useful evaluation and monitoring services for consumer and business borrowers, especially small business borrowers. The human capital that performs the evaluation and monitoring function for present day fractional reserve banks would not be lost. That human capital could easily be transferred to a shadow bank. In fact the entire lending department of a bank could be set-up as a separate non-bank financial institution(s) financed with non-insured shares. In this connection it must be remembered that finance companies and insurance companies presently compete with banks for lending to individuals and to small, medium, and large

firms (Cary et al., 1998). If these shadow banks could compete in a financial system with fractional reserve banks protected by deposit insurance, then the newly emerging non-banks resulting from the break-up of present day fractional reserve banks should be viable financial institution.

Another criticism sometimes made is that with full reserve banking the "near money" claims created by shadow banks would eventually take over many if not most of the functions (eg.,liquidity provision via maturity transformation) now provided by present day fractional reserve banks. The argument goes on to assert that shadow banks and their near money claims would probably be more vulnerable to instability than the fractional reserve banks they would replace since the latter are protected by a credible deposit insurance program while the former is not. However we did not need to go to a full reserve banking system to experience shadow bank instability. The repo run on the shadow banking system that destroyed the large investment banks and helped trigger the Great Crisis of 2007-2009 occurred within a fractional reserve banking system. Moreover going over to a full reserve banking system does not imply that the shadow banks would escape government regulation. Capital and liquidity requirements along with stress tests and living wills could easily be imposed on systemically important shadow banks. Furthermore Dodd-Frank gives the Financial Stability Oversight Council the extraordinary authority to dissolve a financial company (including shadow banks) before actual bankruptcy occurs if in the opinion of a 2/3rds majority of the Council such dissolution will preserve financial stability. The present regulatory framework seems adequate to respond to financial instability arising from the shadow banks. With full reserve banking more financial intermediation will be equity-based in the sense that the claims on shadow banks for the most part will be equity sharing rules that float with the value of their underlying assets. This will be good. No one argued that government should bail out equity mutual funds, hedge funds, or private equity funds when their valuations fell 40 percent between October 2007 and April 2009. No one argued that government should bail out bond

mutual funds when they lost much of their value during the crisis. Why then should money market mutual funds or other shadow banks be treated any differently?

What about monetary policy and liquidity provision in a full reserve banking system? We address the question of monetary policy in general within a full reserve banking system and not within the context of our limited purpose model presented in section III. To begin with liquidity provision via open market operations in a full reserve banking system would more or less remain the same in that central banks would still buy and sell securities in the market place as they now do. Discounts and advances would change. Under the current system fractional reserve banks lend to firms and households and then borrow if necessary from the central bank to satisfy their reserve requirement. In a full reserve banking system the central bank would no longer lend to private or public depository institutions whose liabilities were demand deposit money. The central bank would instead invest in the variable-priced shares of shadow banks who in turn invest in firms and lend to households. In effect the distinction between open market operations (the purchase/sale of marketable securities) and discounts and advances (the purchase/redemption of shadow bank shares) would tend to disappear. Moreover this would have the advantage of the central bank initiating the investment in shadow bank shares compared to the present system where fractional reserve banks initiate the borrowing under discounts and advances. A further advantage is that the central bank could direct their investment in shares of shadow banks across the board, or, towards those sectors that historically have posed systemic risks for the entire real economy such as commercial and residential real estate, certain commodities, and the stock market. In this way the central bank could broadly or selectively provide or withdraw liquidity to or from the households and firms in the economy.

It might be argued that central banks should not be in the business of allocating finance to the real economy by investing/lending in privately owned shadow banks as they would in a full reserve banking

system. But is it so different in the present day fractional reserve banking system? When the central bank buys a Treasury security from a life insurance company they provide the life insurance company with the funding necessary to supply debt and/or equity finance to a firm or household for purposes of making a real investment. Reserves coming to private fractional reserve banks enable banks to allocate finance to households and firms. Why would banks be better allocators of finance than shadow banks? In fact the lending and investing by shadow banks in a full reserve banking system would in part be done by the same human capital that previously lent and invested for fractional reserve banks. Finally, the European Central bank has now taken to buying private debt securities as part of their monetary policy. Nevertheless this is a controversial policy issue that merits much more analysis than we are able to provide in this paper.

Finally, is liquidity provision by the central bank any better when provided to fractional reserve banks compared to non-bank financial intermediaries? One difference is that fractional reserve banks as a system can magnify the liquidity provision from the central bank by the deposit multiplier thereby making liquidity cheaper. Liquidity is a scarce resource. Should that resource be made artificially cheaper through fractional reserve banks backed up with government guarantees in the form of deposit insurance particularly when the volatility of the supply of liquidity leads to economic instability?

Financial intermediation is all about matching the preferences of household saver/investors for risk and return, and the generation of risk and return by real investing firms. The saving/investment process is also the generator of business cycles and growth. We like growth and dislike business cycles. Unfortunately we can't get the one we like without getting the other we dislike. In a market economy with free choice the combination of growth and business cycles should be decided by the preferences of households and not artificial entities like fractional reserve banks. For that reason we advocate for a 100 percent reserve banking system since it enables the tastes of households to determine the growth

and economic fluctuations that evolve in a market economy. Of course moving to a full reserve banking system in the real world would not *eliminate* the financial amplification of the business cycle. Individual saver/investors and their proxies (shadow banks) investing in risky asset markets are subject to the same changing risk aversion and perceptions of risk as today's fractional reserve banks. This is represented by a clockwise or counter-clockwise change in the indifference curve IC of household saver/investors in figures 1, 3, and 3A above. The only difference is that with 100 percent reserve banking household savers freely choose with their savings and portfolio decisions the volatility in future real economic activity that maximizes their current expected utility. That is how a market-based financial system is supposed to work.

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Figure 1

Pareto Efficient Investment in a CAPM Model

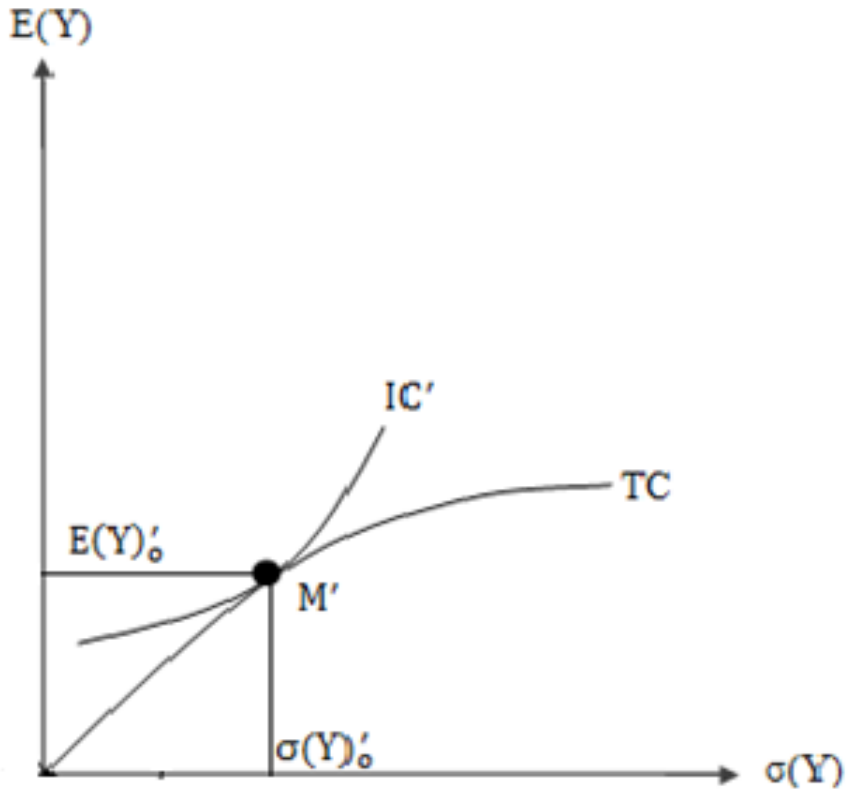
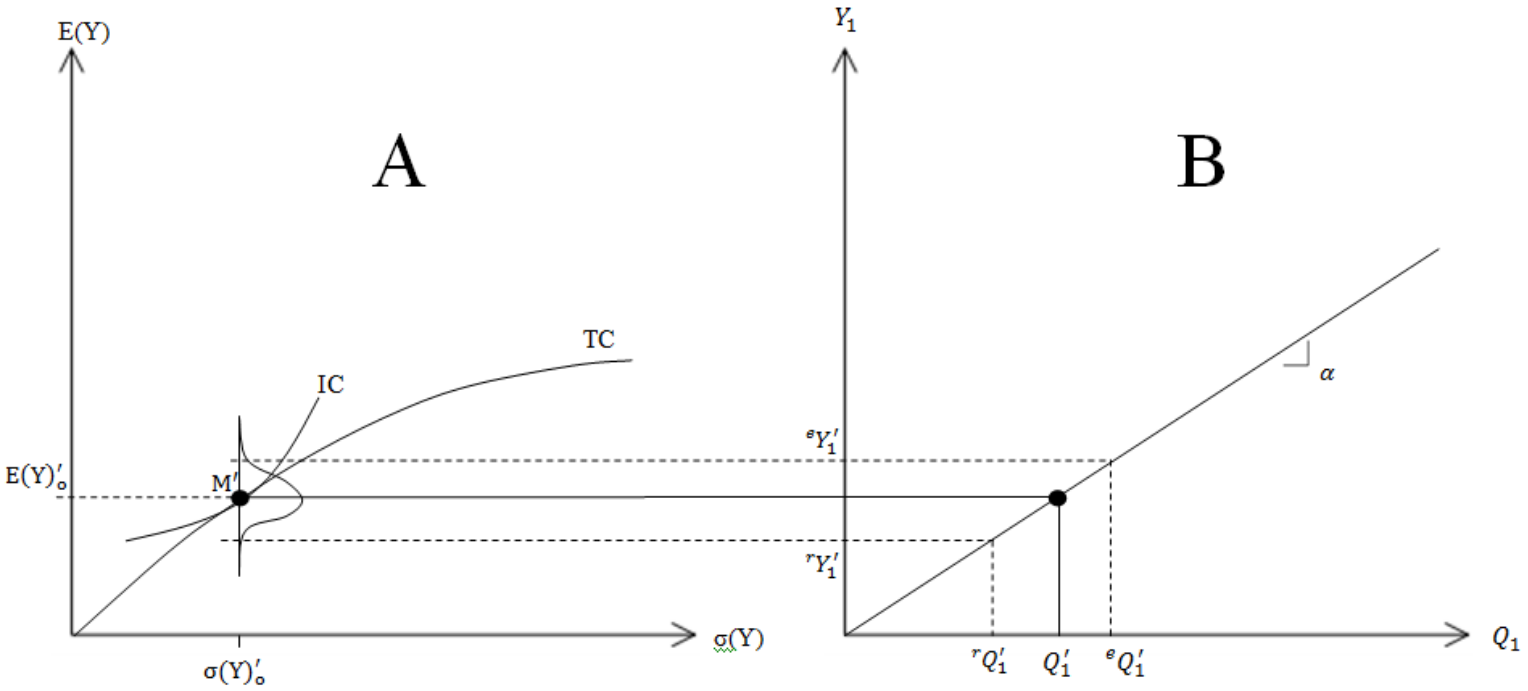


Figure 2

Business Cycles in a CAPM Model



$Q_1 = A\ K_0^{\alpha}\ N_0^{1-\alpha}$

Figure 3

Pareto Efficiency in a Fractional Reserve Banking System

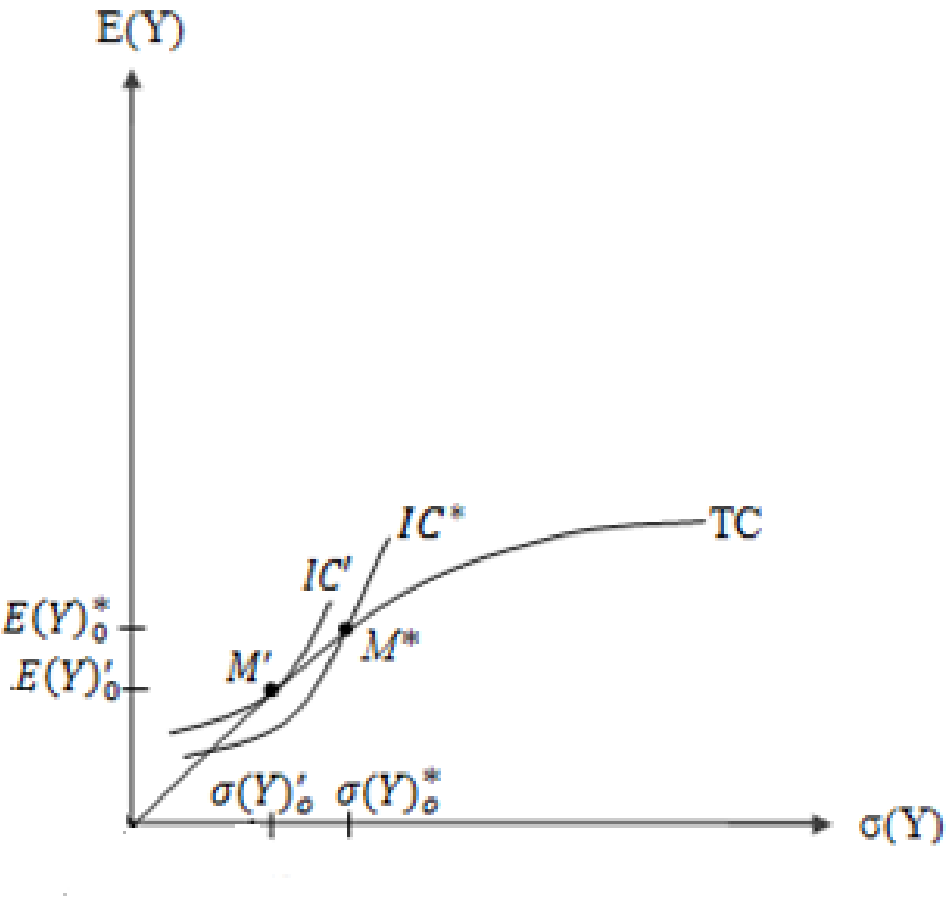


Figure 3A

Pareto Efficiency under a Fractional Reserve Banking System

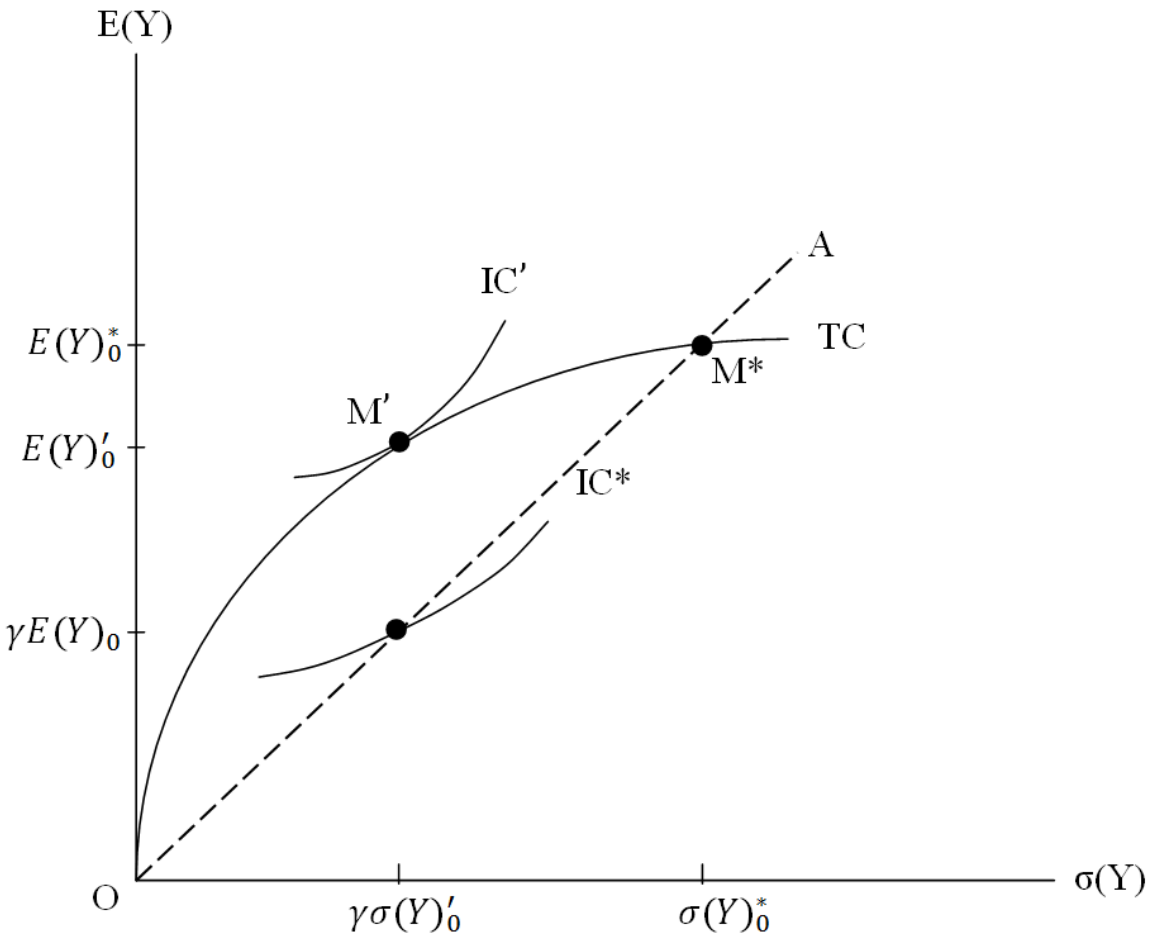
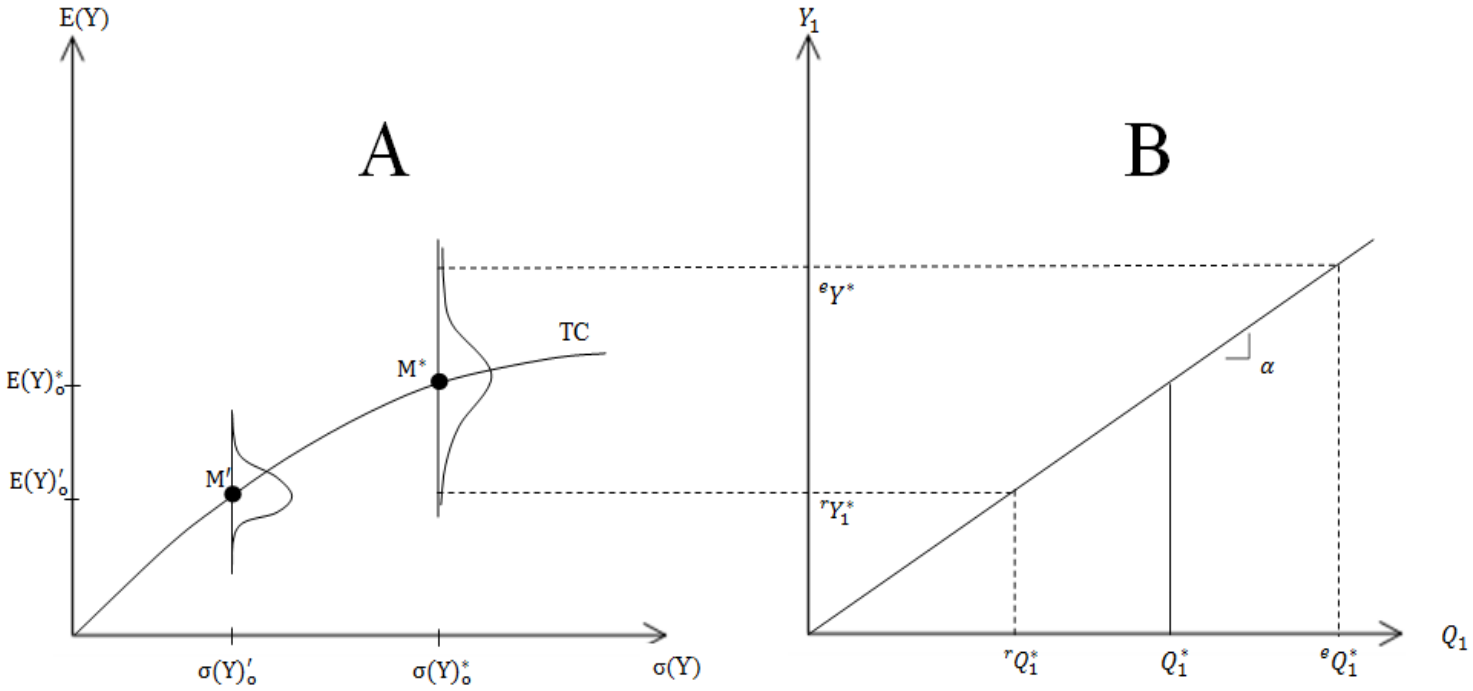


Figure 4

Business Cycles under Alternative Banking Systems in a CAPM Model



$$Q_1 = AK_0^{\alpha} N_0^{1-\alpha}$$