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Brazilian Asset Pricing Puzzles*

Abstract

We evaluate how an intertemporal equilibrium asset pricing model fares in reproducing the return moments. We estimate a Markov switching model for aggregate consumption and look for parameters of both expected utility and Kreps-Porteus preferences that best match first and second moments of asset returns. Although the equity premium is much higher in Brazil than in US, there is no equity premium puzzle. The risk-free rate puzzle is reversed in Brazil: the overnight rates are too high in Brazil to be matched by reasonable preference parameters. Our attempt to solve this puzzle by introducing probability of default on Brazilian bonds worsened the results.

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1 Introduction

Asset markets in developed countries have presented some puzzles to rational pricing. Equity premium and volatility of asset prices are considered to high, and interest rates are considered too low to be justified by an efficient model with reasonable preferences. Brazil has been particularly prominent among emergent asset markets in the last decade. However, research on Brazilian stock market has lagged its development. This paper intends to contribute to reduce this gap by trying to rationalize several aspects of the Brazilian asset markets using a benchmark intertemporal representative agent model.

.Our assessment of the Brazilian asset markets is based on a CCAPM framework. We follow Cecchetti, Lam, and Mark (1990) and Bonomo and Garcia (1994), in estimating a Markov Switching Model (MSM) for the constructed consumption growth series. Then, we search for reasonable preference parameters that make the moments of returns generated by the calibrated model match respective sample moments of equity and risk-free rate proxies in the Brazilian market. Expected utility and Kreps-Porteus models of the preferences are used. However, there is no good proxy for a risk-free rate in Brazil. Since assessments of Brazilian government bonds risk put a non-negligible probability of default, we model it explicitly, and reevaluate our results.

Some sample statistics of quarterly asset returns in Brazil are presented in Table 1. First, we note that the equity premium is about 9% per year, higher than for the US, which at first sight evokes that we should also have an equity premium puzzle in Brazil. The standard deviation of equity returns is about 60% a year, more than three times that of the U.S., suggesting that the volatility puzzle should be aggravated. The mean return for the risk-free rate proxy is about 13% a year, contrasting with the low U.S. rates, indicating that there should not be a risk-free rate puzzle similar to the American one.

Since our endeavour is to explain the asset returns with a fundamental model, a first look at the Brazilian fundamentals in Table 2 suggests that we should have very different results from the

U.S. Consumption growth is less than 1% a year in our sample period, and much more volatile than for U.S.

In view of the high volatility of the aggregate consumption series, it is not surprising that we did not find an equity premium puzzle for Brazil. Also in constrast with the US, we are able to replicate the volatility of equity returns with our model, despite its much large magnitude in Brazil. In fact, our results show that we can rationalize the equity premium and volatility of equity returns with reasonable parameters for preferences. However, given the lower growth of consumption and the high level of asset returns, we are unable to explain the level for the risk-free rate proxy without an implausibly low time-discount factor. The attempt to solve this puzzle by introducing explicitly the probability of default was.not fruitful, worsening the results.

The remaining part of the paper is organized as follows. Section 2 describes the model. Section 3 explains the construction of the consumption series, the endowment process calibration, and reports the results. In the fourth section, the exercise of matching return moments is performed under the simpler version of the model with expected utility. Section 5 tries to resolve the puzzles of section 4 by generalizing the preference model to allow for Kreps-Porteus preferences, and introducing the possibility of default in an otherwise risk-free rate. Section 6 concludes.

2 The Asset Pricing Model

Many identical infinitely lived agents maximize their lifetime utility and receive each period an endowment of a single nonstorable good. Following Epstein and Zin (1989), we specify a recursive utility function of the form:

$$U_t = W(C_t; \mu_t) \quad (1)$$

where W is an aggregator function that combines current consumption C_t with $\mu_t = \mu(\tilde{U}_{t+1} \mid I_t)$, a certainty equivalent of random future utility $\tilde{U}_{t+1}$; given the information available to the agents at time t, to obtain the current-period lifetime utility U_t. Epstein and Zin (1989) propose the CES function as the aggregator function, i.e.:

$$U_t = [C_t^{\rho} + \beta \mu_t^{\rho}]^{\frac{1}{\rho}}$$

We normalize the utility in such a way that the utilility level of a sure wealth value is equal to this value of wealth. The parameters β and ρ govern the preference among deterministic paths of consumption, since the intertemporal elasticity of substitution is given by $\sigma = \frac{1}{1-\rho}$ and the rate of time preference is given by $d = \frac{1}{\beta} - 1$.

The way the agents form the certainty equivalent of random future utility is based on their risk preferences, which are assumed to be of the expected utility type. The certainty equivalent function μ_{KP} is defined by:

$$\mu_{KP} = [E(x^{\alpha})]^{\frac{1}{\alpha}}$$

where α is a risk aversion parameter. The certainty equivalent function defined above corresponds to CRRA expected utility preferences. Substituting the expected utility certainty equivalent function defined above into the aggregator function we obtain preferences that generalizes expected utility ($\alpha = \rho$). When α is different from ρ we have Kreps-Porteus (1978) preferences, where the risk-aversion parameter, α, is disentagled from the elasticity substitution parameter, ρ, but where preferences towards timeless gambles are of the expected utility type.

Below are the asset return restrictions implied by the first-order conditions for an interior maximum of the consumption and portfolio decisions as derived in Epstein and Zin (1989 and 1991):

$$E_t \left[z_{t+1}^{\alpha} \frac{\tilde{R}_{t+1}}{\tilde{M}_{t+1}} \right] = 1 \qquad i = 1, \ldots, N \tag{2}$$

where $z_{t+1} = \beta^{1/\rho} \left(\frac{C_{t+1}}{C_t} \right)^{\frac{\rho - 1}{\rho}} \tilde{M}_{t+1}^{1/\rho}$ (for $\rho \neq 0$), $\tilde{M}_{t+1}$ being the return on the market portfolio, which pays off C_t in period t, where $\tilde{R}_{t+1}$ is any portfolio return. Observe that this equation has the form:

$$E_t\left[\psi_{t;t+1}\tilde{R}^{e}_{t+1}\right] = 1 \qquad i = 1;\ldots;N \tag{3}$$

where

$$\psi_{t;t+1} = \beta^{\frac{\alpha}{\rho}}\left(\frac{C_{t+1}}{C_t}\right)^{\frac{\alpha(\rho-1)}{\rho}}\tilde{M}_{t+1}^{\left(\frac{\alpha}{\rho}-1\right)}$$

is an stochastic discount factor that could be interpreted as the intertemporal marginal rate of substitution between t and $t+1$. This Euler equation depends on consumption growth as well as on the market portfolio return.

A risk-free asset in time t is defined as a claim to one unit of consumption in time $t+1$. In this economy, the equity pays off a dividend stream $\{D_t\}$ which is different from the aggregate payoff $\{C_t\}$ of the market portfolio. The restrictions for the returns of the market portfolio, equity and the risk-free asset can be found by replacing $\tilde{R}$ equation ?? by the appropriate return. We follow empirical approach pioneered by Mehra and Prescott (1985) by specifying and estimating an stochastic processes for the endowment process and calculating market portfolio, equity and risk-free asset returns in the economy. Since consumption and dividends are different in our model (see the discussion below), we have different return formulas for the market portfolio and the equity returns. Although the market porfolio is not observed, we are able to evaluate its return, since it is implicitly defined in the model as a claim to the consumption stream. When the alternative approach of using directly the Euler equation for estimating by GMM the preference parameters is taken, market portfolio return data is needed, even in the equations involving other asset returns. This is a feature of recursive utility. The usual choice for the market portfolio return is an equity index return (Epstein and Zin 1991a,b, Jorion and Giovanini 1993), which is in fact a claim to the aggregate dividend stream. This should add to the existing difficulties in diagnosing the causes for the potential success or failure of the model. The approach we follow, which was the one chosen by Kandel and Stambaugh (1991), Hung(1994) and Weil (1989), circumvents this issue.

We postulate that the logarithms of consumption growth follow a process where both the mean and the variance change according to a Markov variable S_t which takes the values $0, 1, \ldots, K-1$ (if K states of nature are assumed for the economy). The sequence $\{S_t\}$ of Markov variables evolves according to the following transition probability matrix P:

$$P = \begin{bmatrix} p_{00} & p_{01} & \cdots & p_{0(k-1)} \\ p_{10} & p_{11} & \cdots & p_{1(k-1)} \\ \vdots & \vdots & \vdots & \vdots \\ p_{(k-1)0} & p_{(k-1)1} & \cdots & p_{(k-1)(k-1)} \end{bmatrix} \tag{4}$$

The consumption process can then be written as:

$$c_t - c_{t-1} = \alpha_0^c + \alpha_1^c S_{1,t} + \cdots + \alpha_{k-1}^c S_{k-1,t} + (\omega_0^c + \omega_1^c S_{1,t} + \cdots + \omega_{k-1}^c S_{k-1,t})\varepsilon_t^c \tag{5}$$

where $S_{i,t}$ is a function of the state of the economy, S_t, taking the value 1 whenever $S_t = i$ and 0 otherwise; c_t is $\ln C_t$; ε_t^c is a $\mathcal{N}(0,1)$ error term. Therefore, in state i, the mean and standard deviation of the growth rate of consumption will be given by $(\alpha_0^c + \alpha_i^c; \omega_0^c + \omega_i^c)$.

Given the Markov processes defined above, the market portfolio price-consumption ratio, λ, the equity price-dividend ratio, φ, and the price of the risk-free asset, P^f, are all functions of the state of the economy. In the Appendix we derive the folllowing return formulas for the market portfolio and the safe asset:

$$M_{t+1} = \frac{\lambda(S_{t+1})+1}{\lambda(S_t)} \exp(\alpha_0^c + \cdots + \alpha_{k-1}^c S_{k-1,t+1} + (\omega_0^c + \cdots + \omega_{k-1}^c S_{k-1,t+1})\varepsilon_{t+1}^c \tag{6}$$

$$R_{t+1}^f = \frac{1}{P_t^f(S_t)} \tag{7}$$

In the next section, we estimate the parameters for the joint consumption-dividend process by maximum likelihood.

3 Data construction and model estimation

3.1 Data construction

There are no series for aggregate consumption in Brazil. For this reason we had to construct a proxy for aggregate consumption of services and non-durable goods.

A proxy for the quarterly aggregate consumption of non-durable goods and services was constructed in the following way. The proxy for non-durable consumption is constructed by lagging the production of non-durable by one month, adding imports and subtracting exports both of non-durable goods. The resulting monthly series are summed for each quarter. Then the resulting non-durable consumption series and service quarterly series taken from the National Accounts are aggregated according to those sectors weights in the National Accounts. The aggregate consumption proxy is divided by the population to obtain the consumption per capita proxy[1].

3.2 Endowment Process Calibration

We estimate an endowment process using the consumption series. A Markov Switching Processes was estimated by maximum likelihood, following the methodology developed by Hamilton (1989). We report and comment our estimation results below. Given the limited number of observations, we do not perform any test for the number of states, neither consider what we do a serious estimation process. In fact, we consider the estimation by maximum likelihood a nice way to calibrate the process.

Table 3 reports the estimates for a two-regime heteroskedastic Markov Switching Process. The state zero is transient, since p_{00} is zero. It captures the seasonal negative growth rate at the first quarter of the year. In figure 4 the consumption growth series is drawed in a figure where each state mean is showed by continuous lines and one standarde deviation confidence intervals are shown in by dotted lines.

[1] Since the population is a yearly series, and its most recent observation is 1996, we had to interpolate geometrically in order to obtain quarterly numbers and extrapolate for the year 1997 and 1998. We assumed population growth rates of 1.28% and 1.24% for the years of 1997 and 1998, respectively.

4 Characterizing the Puzzles with the Basic Model

In this section we report the results for the model with univarite endowment and expected utility. It is possible to reproduce the equity premium and the mean equity and risk-free rate returns with reasonable preference parameters: $\beta = 0.95$ and coefficient of relative risk aversion of 3.23. This is in contrast with the Mehra and Prescott (1985) equity premium puzzle for the US economy. Our first conclusion is that there is no equity premium puzzle for the Brazilian economy.

A second puzzle related to first moments for the US economy was that when we set a large relative risk aversion to reproduce the equity premium, the risk-free rate return increases, becoming too high. To get closer with the observed mean returns it is necessary to increase β to a value greater than 1 (Kocherlakota ....). This was what Weill (1989) dubbed as the risk-free rate puzzle, which refers to the fact that the risk-free rate is too low to be reproduced by a reasonable empirical model.

Here this risk-free rate puzzle does not appear in the same direction and magnitude. However, the annualized value of β is 0.81 (remember that we are working with quarterly data), which is relatively low. If we had used values of annualized beta in a range considered reasonable (say between 0.9 and 1) we would have found a lower risk-free rate than observed risk-free rate mean. Thus, we conclude that the risk-free rate in Brazil is too high to be matched by an intertemporal model with reasonable parameters. Therefore we can say that we have a risk-free rate puzzle which reverses the one found in the US.

A third asset pricing puzzle for the US is the excess volatility of equity prices. As first pointed out by Shiller (1981.), equity prices seem to volatile to reflect fundamentals. This empirical aspect can be examined in the current setting by asking if it is possible to replicate the second moments of equity returns with an asset pricing model calibrated to fundamentals. Using the basic model we find for Brazil a puzzle similar to the US. Equity prices seem too volatile to be justified by fundamentals (table 4). As for the variability of the risk-free rate, the model seems to match it well.

One could object to the basic model we used on various grounds. First, expected utility is a poor setting for intertemporal asset pricing since it constrains the intertemporal substitution elasticity to be the reciprocal of the relative risk aversion coefficient (Epstein and Zin (1989), Weill (1989)). Thus, we should use Kreps-Porteus preferences, where we can set one coefficient independently of the number we chose for the other. Second, an equity is a claim to a dividend stream and not to the consumption stream. As a consequence a more appropriate setting would include a bivariate endowment process disentangling consumption and dividend, where consumption is used in the SDF and the equity payoff is composed of a dividend stream. Third, since there was a stabilization plan in Brazil which confiscated all liquid assets in 1990, one could argue that no interest rate is perceived to be a good proxy to the risk-free rate. In the next subsection we try to resolve the current puzzles by extending the basic model in the mentioned directions.

5 Model Extensions and Remaining Puzzles

5.1 Kreps-Porteus Preferences

In table 5 we report the results we get for the univariate model using Kreps-Porteus preferences. With one more parameter, we are able to match one more moment, the risk-free rate standard deviation. However, a great part of the equity return volatility continue unexplained. Furthermore, the discount rate we had to use is still lower than the one used before, accentuating the reverse risk-free puzzle.(Excess volatility continues).

In our best matching both the risk-aversion and elasticity of substitution coefficients increased, and the discount factor has decreased with respect to the best choice of coefficients in the expected utility setting. To understand the change in coefficients, first recall that with expected utility our choice of coefficients produced to much variability of the risk-free rate. To reduce this variability we had to increase the elasticity of intertemporal substitution. However, if we do only that and keep the other coefficients constant, as in the third column of results, we tend to increase the risk-free rate, reflecting the effect of increased demand for precautionary savings. This reduction in risk-free rate is not accompanied by a reduction in similar magnitude of the mean equity return, reducing the equity premium. To restore the equity premium, we needed to increase risk-aversion, as we have done in the second level. However, the mean level of returns became a little bit smaller than the actual level, requiring us to decrease a little bit the discount factor to reproduce the four moments.

5.2 Introducing a Small Default Probability on the Fixed Income Security

In March 1990, the Brazilian Government froze all money market and savings accounts. As a consequence, the default risk on any Brazilian security is an undeniable reality. Therefore one may be commiting a serious mistake by assuming that a Brazilian asset return is a good proxy for a riskfree asset return. One can also believe that the riskfree rate puzzle we found above is due to this mispecification.

In this session we model a fixed income security with a small probability of default. We then compare the moments generated by the model with those found on the Selic (overnigh rate on Treasury bonds) data.

We assume that there is a small probability of default, $1 - \theta$ in the bad state for consumption growth. Then the formula for the bond price when the present state is k becomes:

$$p_{kg}\left\{\beta^{\frac{\alpha}{\rho}}\exp[(\alpha-1)m_g^c+\frac{(\alpha-1)^2}{2}\sigma_g^{c2}]\left(\frac{\lambda(g)+1}{\lambda(k)}\right)^{\frac{\alpha}{\rho}-1}(P^f(g))^{-1}\right\}+$$
$$p_{kb}\left\{\beta^{\frac{\alpha}{\rho}}\exp[(\alpha-1)m_b^c+\frac{(\alpha-1)^2}{2}\sigma_b^{c2}]\left(\frac{\lambda(b)+1}{\lambda(k)}\right)^{\frac{\alpha}{\rho}-1}\theta(P^f(b))^{-1}\right\}$$

where the subscripts g and b refer to good and bad states for consumption growth, respectively.

We then repeat the matching exercise done in section 4, replacing the riskfree rate by a bond with a small probability of default. The exercise is performed using 5% default probability in the bad state, implying a default probability of 1.13% (the probability of the bad state is about 0.23).

The results are reported in Tables 6 for expected utility. In the first column of those tables we used the best set of preference parameters found for the reference model. In the second column we change the risk-aversion parameter to restablish the equity premium. Finally, we change the discount factor in the third column to restablish the first moments levels.

When a small probability of default is included, the mean bond return is increased, reducing the equity premium. Observe that the standard deviation of the bond return is also increased. Then to match the equity premim we need to increase the risk-aversion parameter. However, this has the effect of decreasing the bond rate to a level lower than the actual one. A further reduction of the discount factor is necessary to achieve the first moments matching. Therefore, the Brazilian riskfree rate puzzle is worsened.

Notice that this paradoxical result came out because the higher risk-aversion reduced the bonds rate. In the US the riskfree rate puzzle exists exact because the opposite effect happens. When one increases the risk-aversion parameter to match the equity premium, the return levels are increased. The difference between the Brazilian and American effects is explained by the difference between the consumption growth series. In the US, the main action comes from the lower elasticity of substitution, which requires a higher return level to make consumers satisfied with the consumption growth rate. In Brazil the mean consumption growth is much smaller, while the volatility of consumption growth is much larger. As a consequence precautionary demand becomes more important. When the degree of risk aversion is increased, the higher precautionary demands for saving leads to a decrease of return rates in equilibrium.

The results for Kreps-Porteus preferences are reported in Table 7. They are qualitatively similar to those with expected utility. The difference is that with one more parameter, we are able to match the bond variance.

6 Conclusion

In examining the asset markets in Brazil with a basic intertemporal asset pricing model we arrived at the following conclusions:

1. There is no equity premium puzzle

2. There is a reverse risk-free puzzle: interest rates are too high.

3. The risk-free puzzle cannot be solved by allowing a probability of default on an otherwise riskfree asset. In fact it is worsened.

4. We can match risk-free rate volatility, but there is an excess volatility of equity returns.

This fourth finding is likely to be reversed when model the equity index as a claim to aggregate dividend instead of aggregate consumption, since dividend growth standard deviation in Brazil is about 400 times that of consumption growth. In fact, given the volatility of dividend series, we believe that we have in Brazil an excess fundamental volatility, reversing the volatility puzzle found in U.S. markets.

7 References

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Table 1: First and Second Moments of Returns (quarterly data)

	Mean (%)	Standard Deviation
Selic Rate (R^f)	3.32	6.28
Equity Return (R^a)	5.57	31.12
Excess Return (R^e)	2.247	30.69
Correlation (R^f,R^a)	0.2136	
Correlation (R^f,R^e)	0.0168	

Table 2: Consumption Growth Series (quarterly data)

Mean	Standard Deviation	Autocorrelation	Skewness	Curtosis
0.002	0.068	-0.075	-0.562	2.429

Table 3: Estimated Coefficients for the Univariated Markov Switching Model

	a_0^c	$a_0^c + a_1^c$	w_0^c	$w_0^c + w_1^c$	P_{00}	P_{11}
Estimated Coefficients	-.1111	0.0362	.0252	.0393	0	.6939
t Statistics	14.91	5.66	4.82	8.37	0	2.80

Table 4: Population Moments for the Risk Free Return and the Equity Premium Implied by the Univariate Model with Expected Utility

		Expected Utility (a=r, d=0)				Actual
Relative Risk Aversion	$1-a$	3,226	2,695	2,695	2,696	
Discount Factor	b	0,9507	0,9507	0,9519	0,9519	
Elasticity of Intertemporal Substitution	$1/(1-r)$	0,310	0,371	0,371	0,371	
Mean Equity Return (Re)		**5,57**	5,71	**5,57**	**5,57**	**5,57**
Standard Deviation Re		11,16	9,91	9,9	9,9	**31,85**
Mean Risk Free Asset (Rf)		**3,32**	3,95	3,82	3,82	**3,32**
Standard Deviaton Rf		7,71	**6,28**	6,27	**6,28**	**6,28**
Mean Risk Premium		**2,25**	1,76	1,75	1,75	**2,25**
Standard Deviation Risk Premium		8,91	8,25	8,08	9,08	**31,12**
Correlation(Re,Rf)		0,6083	0,5627	0,5626	0,5627	**0,2136**
Correlation(Rf, Risk Premium)		-0,1035	-0,0853	-0,0867	-0,0781	**0,01681**

Table 5: Population Moments Implied by the Univariate Model With Kreps-Porteus Utility

		Kreps-Porteus (d=0)			Actual
Relative Risk Aversion	$1-a$	3,685	3,685	3,226	
Discount Factor	b	0,9494	0,9507	0,9507	
Elasticity of Intertemporal Substitution	$1/(1-r)$	0,388	0,388	0,388	
Mean Equity Return (Re)		**5,57**	5,43	5,55	**5,57**
Standard Deviation Re		9,72	9,71	9,68	**31,85**
Mean Risk Free Asset (Rf)		**3,32**	3,19	3,55	**3,32**
Standard Deviaton Rf		**6,28**	6,27	6,15	**6,28**
Mean Risk Premium		**2,25**	2,24	2	**2,25**
Standard Deviation Risk Premium		8,13	8,12	8,10	**31,12**
Correlation(Re,Rf)		0,5552	0,5551	0,5535	**0,2136**
Correlation(Rf, Risk Premium)		-0,1086	-0,1083	-0,0978	**0,01681**

Table 6

Univariate Model with Default Probability=1.13%

		Expected Utility (a=r)			Actual
Relative Risk Aversion	$1-\alpha$	3,226	4,800	4,800	
Discount Factor	β	0,9507	0,9507	0,9431	
Elasticity of Intertemporal Substitution	$1/(1-\rho)$	0,310	0,208	0,208	
Default Probability	$1-\delta$	0,05	0,05	0,05	
Mean Equity Return (Re)		**5,57**	4,74	**5,57**	**5,57**
Standard Deviation Re		11,16	15,11	15,22	**31,85**
Mean Risk Free Rate Return		4,92	2,49	**3,32**	**3,32**
Standard Deviation Rf		6,82	11,3	11,39	**6,28**
Mean Risk Premium Return		0,65	**2,25**	**2,25**	**2,25**
Standard Deviation Risk Premium		8,91	8,25	8,08	**31,12**
Correlation(Re,Rf)		0,6083	0,699	0,7002	**0,2136**
Correlation(Rf, Risk Premium)		-0,0035	-0,0895	-0,0907	**0,01681**

Table 7

Univariate Model with Default Probability=1.13%

		Kreps-Porteus (d=0)		**Actual**
Relative Risk Aversion	$1-a$	3,685	7,400	
Discount Factor	b	0,9494	0,9406	
Elasticity of Intertemporal Substitution	$1/(1-r)$	0,388	0,384	
Default Probability	$1-d$	0,05	0,05	
Mean Equity Return (Re)		**5,57**	**5,57**	**5,57**
Standard Deviation Re		9,72	10,09	**31,85**
Mean Risk Free Rate Return		4,97	**3,32**	**3,32**
Standard Deviation Rf		5,37	**6,28**	**6,28**
Mean Risk Premium Return		0,6	**2,25**	**2,25**
Standard Deviation Risk Premium		8,08	8,30	**31,12**
Correlation(Re,Rf)		0,5552	0,5705	**0,2136**
Correlation(Rf, Risk Premium)		0,0032834	-0,06306	**0,01681**