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CALENDAR EFFECTS IN DAILY ATM WITHDRAWALS

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Calendar effects in daily ATM withdrawals*

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Abstract

This paper analyses the calendar effects present in Automated Teller Machines (ATM) withdrawals of residents, using daily data for Portugal for the period from January 1st 2001 to December 31st 2008. The results presented may allow for a better understanding of consumer habits and for adjusting the original series for calendar effects. Considering the Quarterly National Accounts' procedure of adjusting data for seasonality and working days effects, this correction is important to ensure the use of the ATM series as an instrument to nowcast private consumption.

Keywords: Calendar effects, ATM, POS.
JEL codes: C32, C51

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1. Introduction

Payment cards allowing for transactions in Automated Teller Machines (ATM) became an indispensable tool in everyday life. Nevertheless, this phenomenon is far from being well understood, probably reflecting its minor importance in the past, before the strong increase in ATM usage in the early 80s.[1]

Research on payment systems has attracted increased academic attention over the last 15 years, merging monetary economics and banking theory with the study of mechanisms of exchange.[2] At the empirical front, information on ATM transactions is far from being completely explored. These databases have typically a large coverage and are timely, as they become typically available just a few days after the reference period. However, this information is at present not being taken into account by statistics producers, such as Central Banks and National Statistics Institutes.

The objective of this paper is to study the daily evolution of ATM withdrawals, using information available at the Payment Systems Department of the Banco de Portugal, for the period from January 1st 2001 to December 31st 2008. A better understanding of consumer's habits is crucial for the logistic management of this type of services and may help other studies on the topic. In addition, the correction for calendar effects - in accordance with the procedure typically used for the Quarterly National Accounts - may help bring this information to be used as input to improve the performance of short-term macroeconomic forecasts (Galbraith and Tkacz, 2007), as a tool for nowcasting private consumption (Esteves, 2009) or as a timely indicator of retail trade statistics (Carlsen and Storgaard, 2010).

Calendar effects are an important feature of economic data, given that most economic time series are directly or indirectly linked, to a daily activity which is usually

[1] Developments in payments media are easily followed from an individual country's publications. For instance, the ECB Blue Book presents updated information for European countries. Katala and Viren (2007) present a summary of the recent evolution in Europe, while Humphrey *et al.* (2000) and Gerdes *et al.* (2005) provide an overview of the development of these payment systems in the US economy.

[2] This is illustrated by the special issues of the Journal Money, Credit and Banking (1999, vol. 31(3) Part 2) and of the Journal of Monetary Economics (2003, 50(2)) dedicated to this topic. More recently, Schmitz and Wood (2006) contribute to the research on the interdependence of institutional changes in payment systems and monetary policy and Snellman and Viren (2009) study the relationship between the structure of banking systems and the number of ATM networks and ATM posts.

recorded on a daily, monthly, quarterly or some other periodicity. Thus, economic variables may be influenced by daily calendar effects, as started to be noted since the late seventies; see *inter alia* Cleveland and Devlin (1980) and Liu (1980). The number of working days and its relation with seasonal effects are noticeable examples, because they are almost *quasi* predetermined effects which affect the short-term movements of time series. These periodic fluctuations must be adequately detected and modeled in order to better analyze other non-periodic properties. This explains why the Quarterly National Accounts that are used to analyze economic developments are adjusted for seasonal and working days effects.

Apart from the number of working days, the day of the week, the week of the month and other calendar effects such as public holidays or religious events may also affect time series.[3] For the specific series under analysis, calendar effects are of particular importance given that cash withdrawals vary over time and are often overlaid with additional factors such as paydays, holidays and seasonal demand, and are subject to trends and generally follow weekly, monthly and annual cycles. This type of calendar effects is mentioned in papers related with the logistic management of the ATM system; see Simutis *et al.* (2008).

Calendar effects are typically masked by strong seasonal patterns, because they are generally second-order effects only observed after other sources of variation have been accounted for. Furthermore, regular seasonal adjustment methods do not capture these calendar effects adequately because they are not precisely periodic or not so within a useful time frame; see, for instance, Cleveland and Grupe (1983). Proper modeling of trading day and calendar effects are of importance given that this generally leads to better models and better pre-adjusted series; see Findley, Monsell, Bell, Otto and Chen (1998).

The objective of this paper resides in the identification of specific calendar effects in ATM cash withdrawal series. From the analysis, it is observable that withdrawals are different according to the day of the week. Fridays and Saturdays are the days in which the largest amounts are withdrawn and Sundays and Mondays the days with

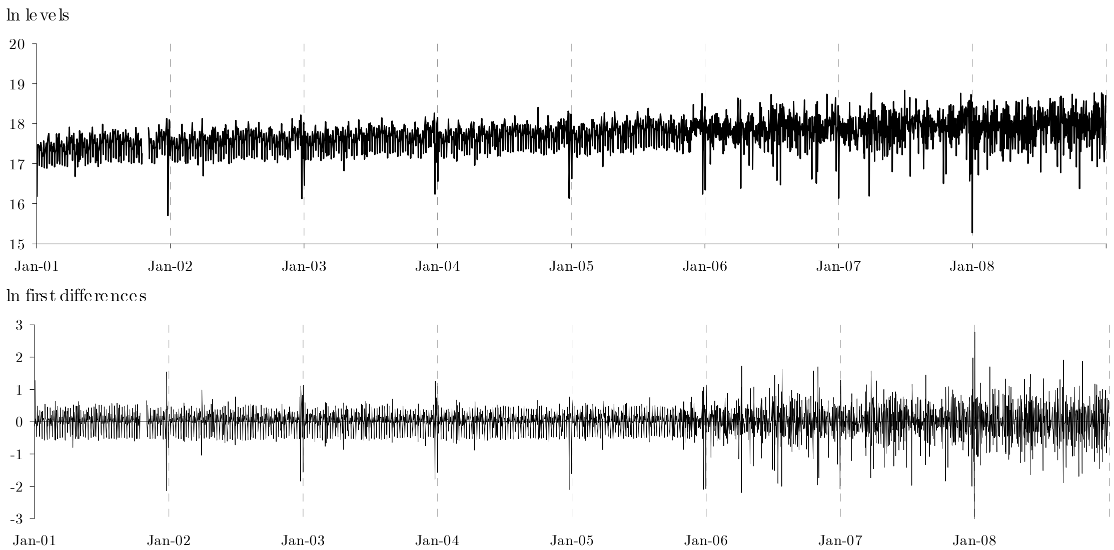
[3] Recently, Findley and Morsel (2009) show the relevance of accounting for different week days. Within the daily activity, there can be patterns of within-week variation that causes the monthly values to change with the day-of-week composition of the month, *e.g.* days that occur five times or the day on which the month ends. Another important effect is the one related with the Easter season, because it is not a fixed holiday varying between March and April, and thus it is not captured by the usual seasonal adjustment procedures and may even affect quarterly year-on-year rates.

the lowest amounts withdrawn. Over the month, cash withdrawals are stronger in the first and in the last weeks of the month, which should be related with the profile of wage payments. In Portugal wages are paid at the beginning of the last week of the month in the case of the public sector and just at the end of the month in the private sector. Concerning seasonality, a strong profile is also observable. In particular July, August and December are the month in which the largest amounts are withdrawn, which are certainly related with the summer holidays and the Christmas season.
The remaining of this paper is organized as follows. Section 2 presents the data that will be analyzed, Section 3 discusses the methodological approach and discusses the empirical results, Section 4 addresses the conditional volatility of the series and Section 5 concludes the paper.

2. Data

The data used in this paper was provided by the Payment Systems Department of the Banco de Portugal, and covers withdrawals made by local residents both in the national territory and in foreign countries over the period from January 1st 2001 to December 31st 2008 (a sample of 2905 daily observations). Figure 1 presents this time series both in levels and first differences.
The series in levels is characterized by a positive trend and strong volatility, which does not allow to visually identify calendar regularities. A notable feature of this data is the structural break in variance observed in the second half of 2005. Considering first differenced data, its standard deviation almost doubles for the period from 2006 onwards (0.61 against 0.33 in the previous period). A possible explanation for this break is the change that took place in November 2005 in the data collecting system of the payments processor in Portugal (SIBS - Forward Payment Solutions).

Figure 1 - Daily ATM withdrawals



3. Methodological approach

Calendar effects are typically considered as anomalies related to the calendar, such as for instance the day-of-the-week, the month-of-the-year or specific holidays. Several methods have been proposed in the literature for their detection, estimation and correction.[4]

In order to measure the importance of the day of the week effect, a model may be considered where the regressors are defined from the number of Mondays, Tuesdays, …., Sundays in a specific month. As on the one hand these regressors are highly correlated and on the other are partly seasonal, some adjustments must be made to

[4] For instance, Cleveland and Devlin (1980) computed the real spectrum of trading days and exhibited the main frequencies for monthly time series. The sample spectrum of the series can then be checked for significant peaks at these frequencies. The efficiency of the sample spectrum to detect trading-day effects has been studied by Findley and Soukup (1999, 2000b) and a nonparametric test for assessing spectral peaks has been proposed by McElroy and Holland (2005).

get a stable estimate of the trading-day effect *per se* (see, for instance, Young, 1965; Bell and Hillmer, 1983; Bell, 1984, 1995; Cleveland and Grupe, 1983).[5]

However, it may not be easy to take into account national or sectoral specificities, as the ones related to moving holidays, such as Easter, Ramadan or Chinese New Year. Moreover, given the cost of not accounting for relevant calendar effects (see Findley and Soukup, 2000) and given that, as suggested by Hansen, Lunde and Nason (2005), the universe of possible calendar effects is not given from theory, the approach used in this paper considers all potential calendar effects.

The identification of calendar effects seems to be particularly important in the current application for daily ATM withdrawals, given that its behavior is far from being well known. The present analysis considers the following calendar effects:

(i) Day-of-the-week: This effect assumes that cash withdrawals are not the same for all weekdays.

(ii) Week-of-the-month: In Portugal, as people are paid monthly, the existence of an intra-month profile for ATM withdrawals should not be disregarded.

(iii) Month-of-the-year: the analysis includes the twelve month-of-the-year effects, in order to account for the usual consumption seasonality.

(iv) Holidays: Christmas, New Year, two moving holidays (Carnival and Easter) and the remaining fixed holidays as a whole. As in Sullivan *et al.* (2001) we also consider pre- and post-holiday. Pre-holidays are those days which directly precede a bank holiday and post-holidays are those that follow the holidays. This adds two calendar effects to our universe per holiday since we only consider one pre- and one post-holiday.

3.1. Modeling calendar day effects in daily ATM withdrawals

Given the observed series $\{y_t\}$, it is considered that

[5] The most popular seasonal adjustment softwares (such as X-12-ARIMA and Tramo-Seats) provide the user with a facility to integrate national calendars and specific public holidays.

$$y_t = z'_t \beta + x_t, \quad t=1,2,...T \tag{1}$$

and

$$\phi(L) x_t = \psi(L) \varepsilon_t \tag{2}$$

where β *is a* $k \times 1$ vector of regression coefficients, $z_t=(z_{1t}, z_{2t},...,z_{kt})'$ is a vector of deterministic variables, x_t is allowed to follow an ARMA model, ε_t is assumed to be white noise, L is the conventional lag operator, and ϕ(L) and ψ(L) are polynomials in L of order p and q, respectively.

Besides the dummies accounting for the calendar effects previously mentioned, the determinist vector z_t also includes a constant and a linear time trend in order to deal with this revealed feature of the data (Figure 1). Given the apparent structural break, two additional estimations were made covering two sub samples: January 1st 2001 to October 31st 2005, and November 1st 2005 to December 31st 2008. Taking into consideration the apparent increase in volatility, all standard errors are adjusted using White's heteroscedasticity-consistent estimators (White, 1980).

3.2. Results

Figures 2 and 3 synthesize the main important calendar effects underlying the daily behavior for ATM withdrawals, while the complete results are presented in the Appendix. As the variables are expressed in logarithms, the results should be read as the percentage deviation relatively to the benchmark day (a non-holiday Sunday of the last week of January).

Figure 2 presents the results concerning some fixed calendar effects: (i) the day of the week; (ii) the week of the month; and (iii) the month of the year. In general, the results point to highly significant calendar effects, which are relatively similar in the two sub-samples considered.

The amount of cash withdrawals increases during the week, reaching its peak on Friday and Saturday. On average, during these two days, cash withdrawals are around 50 per cent higher than on a usual Sunday. This is certainly related with Portuguese consumer's habits. According to Simutis *et al.* (2008), ATMs located in retail centres are most commonly used on Fridays and Saturdays.

Regarding its monthly evolution, cash withdrawals are stronger in the first and in the last week of the month, followed by the second week. In the third week, the amount of transactions is weaker, around 12 per cent less when compared with the daily average of the other weeks. This profile is probably related with the profile of wage payments. In Portugal wages are paid monthly, being concentrated at the beginning of the last week of the month in the case of the public sector and just at the end of the month in the private sector.

A very notable feature emerging from these results is the pronounced seasonal pattern of cash withdrawals, characterized by a large increase during the Christmas season (December) and in the months of the summer holidays (July and August). For instance, on average, cash withdrawals in December are almost 23 per cent higher than in January.

Figure 3 presents this type of calendar effects around holidays: Carnaval, Easter, Christmas, New Year an all the other fixed holidays as an all. In general the results indicate that cash withdrawals are negatively affected the day before the holiday. This effect is even more pronounced during the holiday. Concerning the day after the holiday, the results are less general, pointing on average to a positive effect. This type of profile is clearly stronger and statistically relevant in the Christmas and New Year periods.

Figure 2 - Main calendar effects in ATM withdrawals

in logarithmic terms

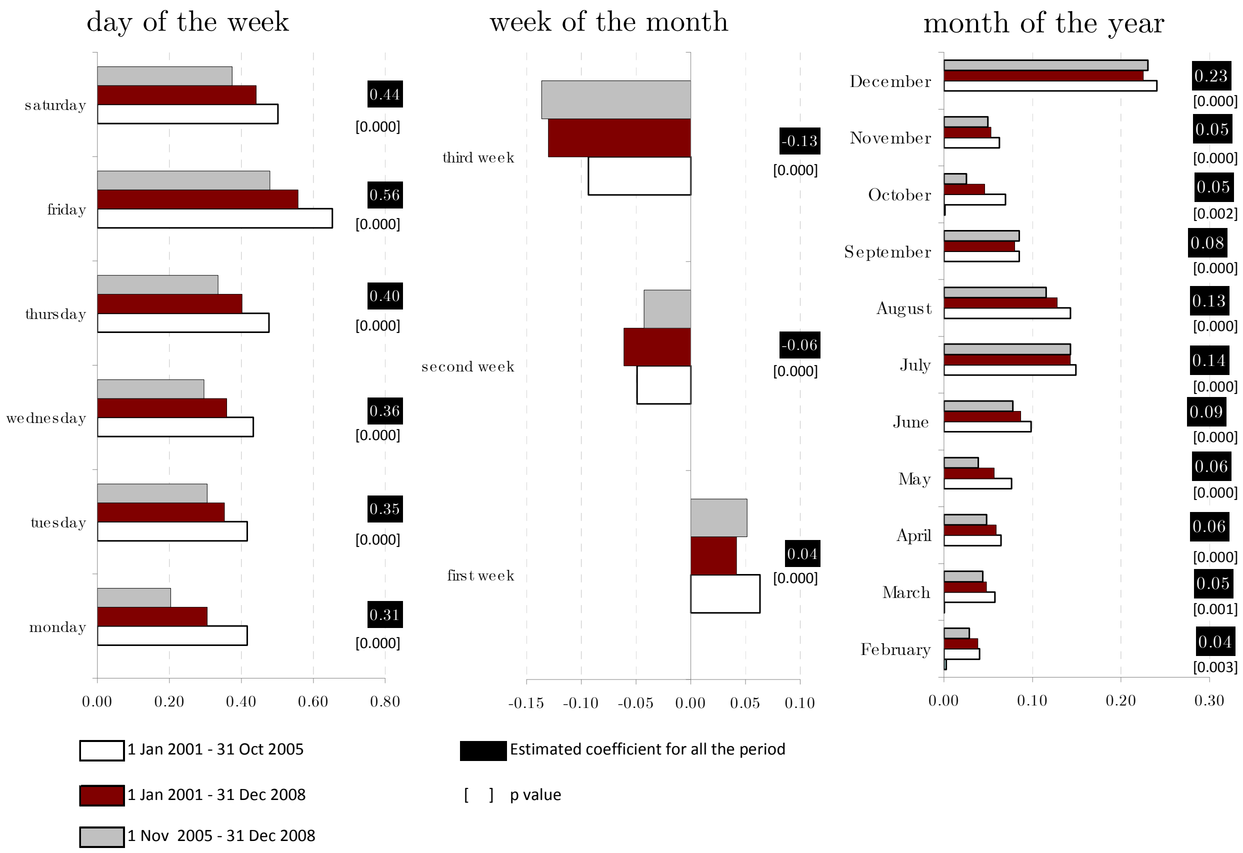


Figure 3 – Holiday effects in ATM withdrawals

in logarithmic terms

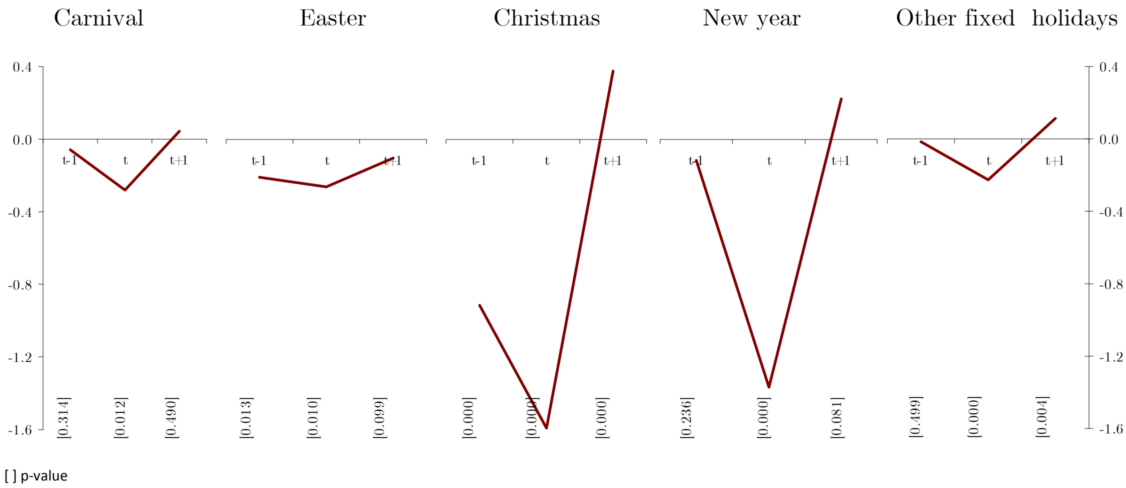


Table 1 compares the original series with the one adjusted for the estimated calendar effects. Some conclusions seem to emerge. As expected volatility of the adjusted data is lower than that of the original series, and these differences are more important in higher frequency data. Finally, as part of the adjustment is related with strong seasonal effects, the differences become lower when series are evaluated in year-on-year rates.

Table 1 - Observed data vs Calendar effects adjusted data

		Observed data variance [(a)]	Corrected data variance [(b)]	difference [(b)-(a)]	Correlation coefficient
daily	chain rate	0.2064	0.1389	-0.0675	0.758
weekly	chain rate	0.0163	0.0071	-0.0092	0.623
	yoy rate	0.0041	0.0039	-0.0002	0.923
monthly	chain rate	0.0054	0.0006	-0.0048	0.221
	yoy rate	0.0012	0.0013	0.0001	0.921
quarterly	chain rate	0.0032	0.0003	-0.0030	0.079
	yoy rate	0.0009	0.0009	0.0000	0.980
annual	chain rate	0.0260	0.0265	0.0005	0.996

4. Volatility

As suggested above, a further important feature of the series is volatility. Figure 4 presents the residuals obtained from the model computed for the whole sample, clearly confirming an increase of the residual standard deviation in the second part of the sample. Furthermore, another indicator of conditional volatility is the degree of autocorrelation in the squared residuals. Table 2 provides the results for the first 20 autocorrelations. The autocorrelations are relatively small in magnitude, but very significant.

Figure 4 – Model residuals

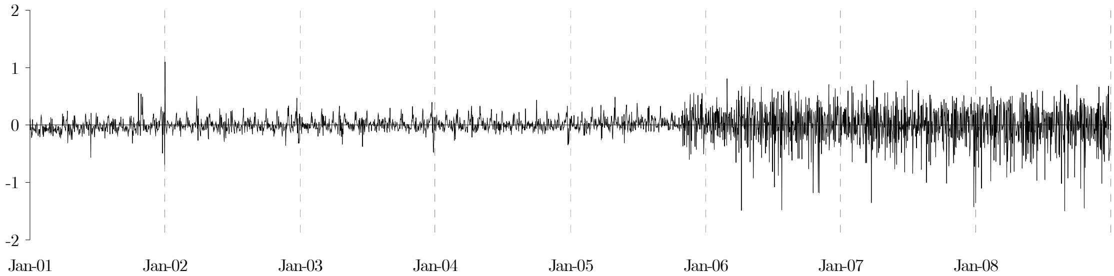


Table 2 - Autocorrelation of squared residuals

	AC	Q-Stat	Prob
1	0.175	89.886	0.000
2	0.089	113.14	0.000
3	0.119	154.64	0.000
4	0.097	182.01	0.000
5	0.106	214.79	0.000
6	0.102	245.03	0.000
7	0.111	281.12	0.000
8	0.145	342.86	0.000
9	0.159	416.82	0.000
10	0.123	460.83	0.000
11	0.098	488.98	0.000
12	0.105	521.13	0.000
13	0.100	550.69	0.000
14	0.116	589.92	0.000
15	0.119	631.71	0.000
16	0.162	708.49	0.000
17	0.081	727.87	0.000
18	0.083	748.04	0.000
19	0.091	772.32	0.000
20	0.127	819.73	0.000

Thus, in the series under analysis, as already stated, heteroscedasticity is an important issue, although White's approach has been used to correct for this problem a closer look may be necessary. In this section we look at the relevance of conditional heteroscedasticity in the data. In a financial context where the dependent variable is

the returns on an asset or portfolio, the variance of the return represents the risk level of those returns. Hence, the expected value of the magnitude of the error terms at some times is greater than at others (*i.e.*, some time periods are riskier than others).
Concerning daily withdrawals, it is noticeable that the amplitude of withdrawals varies over time which can be related to the "volatility clustering" concept in finance. The autoregressive conditional heteroscedasticity (ARCH) and generalised ARCH (GARCH) models proposed by Engle (1982) and Bollerslev (1986), respectively, are designed to deal with this type of features of the data. Computing some descriptive statistics for this series such as skewness and kurtosis we observe that it shows evidence of fat tails (Kurtosis of 6.21) given that it exceeds 3, which is the value of kurtosis of the normal distribution, and presents evidence of negative skewness (-0.56) which indicates that the left tail is particularly extreme.
Therefore, the model above presented is re-estimated considering a GARCH(1,1) model for the variance such as,

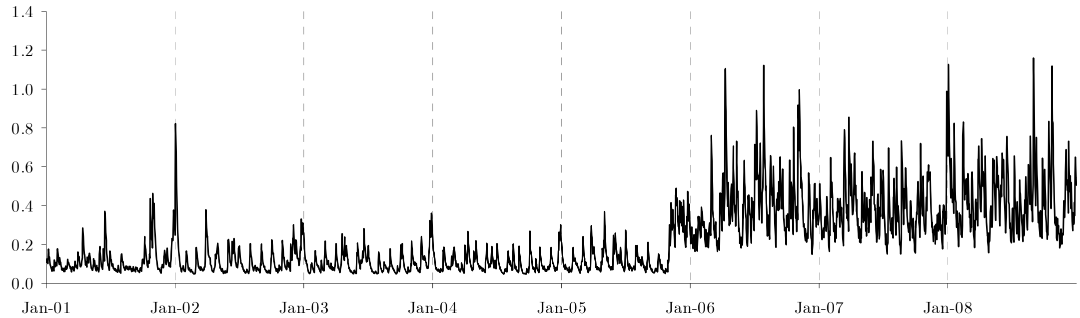
$$\sigma_t^2 = \omega + \beta\sigma_{t-1}^2 + \alpha\varepsilon_{t-1}^2 \quad (3)$$

where $\omega > 0$, $\alpha \geq 0$ and $\beta \geq 0$ are sufficient conditions to ensure that the conditional variance, σ_t^2, is positive. In this model α and β are the parameters of the ARCH and GARCH components, respectively. It is also worthwhile mentioning that α indicates the short-run persistence of the shocks and $(\alpha+\beta)$ the degree of long-run persistence in volatility (for details see Bollerslev, 1986).
A formal ARCH test can also be carried out. Hence, using the LM test proposed by Engle (1982) to test for ARCH effects, we observe that the null hypothesis of no ARCH effects is rejected when an auxiliary first order and an auxiliary seventh order models are considered. Hence, we observe by estimating our model considering a GARCH component for the variance that:

- the three parameter estimates of the variance equation are $\omega = 0.0005$, $\alpha = 0.40$ and $\beta = 0.68$.
- the sum $\alpha + \beta = 0.40 + 0.68 = 1.08$ clearly exceeds 1 indicating that the unconditional variance is nonstationary.

- Graphing the resulting conditional standard deviation (Figure 6) shows that our suspicion initially put forward is confirmed i.e. the series under analysis presents a break in the unconditional variance. The results indicate the occurrence of a structural break in the second half of 2005. From thereafter the unconditional variance seems to become constant again.

Figure 6 – Conditional standard deviation



5. Conclusions

This paper analyzes the daily evolution of ATM withdrawals, using information available at the Payment Systems Department of the Banco de Portugal, for a period from January 2001 to December 2008. The results point to the presence of important calendar effects. The day of the week, the week of the month, the month of the year and the occurrence of holidays are crucial to understand the evolution of ATM withdrawals.

These results may help the logistic management of this type of services. In addition, the correction of these effects is important in order to better analyze other non-periodic developments. Moreover, this type of correction is in line with the procedure typically used for Quarterly National Accounts, and thus can help to bring this type of information to be used as an input in short-term macroeconomic forecasts.

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Appendix

Table A1 - Estimation results

Method: Least Squares

White Heteroskedasticity-Consistent Standard Errors & Covariance

Sample: 1/01/2001 10/31/2005
Included observations: 1765
Convergence achieved after 24 iterations
MA Backcast: 12/31/2000

Sample (adjusted): 1/11/2005 12/30/2008
Included observations: 1450 after adjustments
Convergence achieved after 15 iterations
MA Backcast: 1/10/2005

Sample (adjusted): 1/01/2001 12/30/2008
Included observations: 2921 after adjustments
Convergence achieved after 7 iterations
MA Backcast: 12/31/2000

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.
C	16.940	0.014	1207.055	0.000	17.275	0.030	575.336	0.000	17.069	0.016	1057.496	0.000
@TREND	0.000	0.000	28.714	0.000	0.000	0.000	16.237	0.000	0.000	0.000	43.464	0.000
CARNAVAL(-1)	-0.027	0.035	-0.763	0.445	-0.115	0.115	-0.995	0.320	-0.058	0.058	-1.006	0.314
CARNAVAL	-0.453	0.022	-20.994	0.000	-0.102	0.196	-0.520	0.603	-0.281	0.112	-2.506	0.012
CARNAVAL(1)	0.146	0.024	6.040	0.000	-0.041	0.100	-0.409	0.683	0.043	0.062	0.691	0.490
HOL(-1)	0.020	0.018	1.097	0.273	-0.041	0.042	-0.965	0.335	-0.017	0.024	-0.677	0.499
HOL	-0.185	0.035	-5.248	0.000	-0.273	0.055	-4.921	0.000	-0.227	0.034	-6.708	0.000
HOL(1)	0.069	0.022	3.142	0.002	0.152	0.075	2.032	0.042	0.113	0.039	2.882	0.004
M2	0.040	0.014	2.833	0.005	0.029	0.017	1.737	0.083	0.038	0.013	2.936	0.003
M3	0.057	0.015	3.780	0.000	0.044	0.017	2.584	0.010	0.048	0.014	3.431	0.001
M4	0.065	0.018	3.654	0.000	0.048	0.017	2.888	0.004	0.059	0.014	4.172	0.000
M5	0.076	0.015	4.968	0.000	0.039	0.016	2.430	0.015	0.057	0.013	4.228	0.000
M6	0.098	0.018	5.598	0.000	0.078	0.017	4.655	0.000	0.087	0.014	6.295	0.000
M7	0.149	0.012	12.046	0.000	0.143	0.017	8.583	0.000	0.143	0.014	10.463	0.000
M8	0.143	0.014	10.391	0.000	0.115	0.017	6.857	0.000	0.128	0.014	9.212	0.000
M9	0.085	0.014	6.096	0.000	0.085	0.015	5.580	0.000	0.080	0.013	6.298	0.000
M10	0.070	0.019	3.671	0.000	0.025	0.017	1.489	0.137	0.046	0.015	3.170	0.002
M11	0.063	0.017	3.709	0.000	0.050	0.016	3.119	0.002	0.053	0.014	3.867	0.000
M12	0.240	0.023	10.468	0.000	0.230	0.020	11.636	0.000	0.225	0.016	13.765	0.000
PASCOA(-1)	-0.068	0.047	-1.472	0.141	-0.286	0.143	-1.998	0.046	-0.200	0.080	-2.497	0.013
PASCOA(-2)	-0.295	0.036	-8.308	0.000	-0.142	0.167	-0.850	0.396	-0.252	0.098	-2.575	0.010
PASCOA	0.117	0.026	4.469	0.000	-0.175	0.047	-3.700	0.000	-0.098	0.060	-1.652	0.099
WD2	0.416	0.008	53.980	0.000	0.204	0.038	5.386	0.000	0.305	0.020	15.500	0.000
WD3	0.417	0.009	48.612	0.000	0.305	0.031	9.709	0.000	0.354	0.017	20.756	0.000
WD4	0.434	0.009	50.369	0.000	0.297	0.033	9.049	0.000	0.359	0.017	20.979	0.000
WD5	0.477	0.009	50.297	0.000	0.336	0.033	10.043	0.000	0.402	0.017	23.073	0.000
WD6	0.652	0.009	70.457	0.000	0.479	0.032	15.025	0.000	0.558	0.017	32.919	0.000
WD7	0.502	0.007	67.767	0.000	0.375	0.037	10.202	0.000	0.441	0.019	22.902	0.000
XMAS(-1)	-0.497	0.095	-5.256	0.000	-1.079	0.206	-5.228	0.000	-0.879	0.102	-8.611	0.000
XMAS	-1.804	0.078	-23.222	0.000	-1.249	0.155	-8.042	0.000	-1.529	0.134	-11.403	0.000
XMAS(1)	0.042	0.033	1.264	0.206	0.504	0.075	6.728	0.000	0.362	0.049	7.324	0.000
XMONTHW1	0.063	0.012	5.395	0.000	0.051	0.016	3.252	0.001	0.042	0.009	4.448	0.000
XMONTHW2	-0.049	0.009	-5.174	0.000	-0.043	0.012	-3.471	0.001	-0.061	0.009	-6.975	0.000
XMONTHW3	-0.093	0.009	-10.335	0.000	-0.136	0.014	-9.833	0.000	-0.130	0.009	-14.419	0.000
NEWYEAR(-1)	-0.062	0.073	-0.851	0.395	-0.216	0.182	-1.185	0.236	-0.110	0.093	-1.184	0.236
NEWYEAR	-0.974	0.230	-4.230	0.000	-1.896	0.367	-5.167	0.000	-1.308	0.209	-6.244	0.000
NEWYEAR(1)	-0.029	0.138	-0.207	0.836	0.378	0.073	5.151	0.000	0.216	0.124	1.745	0.081
AR(1)	-0.392	0.131	-2.999	0.003	0.405	0.059	6.880	0.000				
AR(2)	0.288	0.057	5.025	0.000	0.133	0.041	3.243	0.001				
MA(1)	0.745	0.129	5.795	0.000	-0.811	0.050	-16.081	0.000	-0.276	0.024	-11.466	0.000

	Sample 1/01/2001 10/31/2005	Sample 1/11/2005 12/30/2008	Sample 1/01/2001 12/30/2008
R-squared	0.876	0.417	0.591
Adjusted R-squared	0.873	0.401	0.586
S.E. of regression	0.099	0.286	0.226
Sum squared resid	16.946	115.428	147.414
Log likelihood	1595.564	-222.722	216.973
F-statistic	312.588	25.902	112.706
Prob(F-statistic)	0.000	0.000	0.000
Mean dependent var	17.628	17.864	17.729
S.D. dependent var	0.278	0.370	0.351
Akaike info criterion	-1.763	0.362	-0.123
Schwarz criterion	-1.639	0.508	-0.045
Hannan-Quinn criter.	-1.717	0.417	-0.095
Durbin-Watson stat	2.011	2.012	1.999

	Sample 1/01/2001 10/31/2005		Sample 1/11/2005 12/30/2008		Sample 1/01/2001 12/30/2008
Inverted AR Roots	.38	-.77	.62	-.21	
Inverted MA Roots	-.74		.81		.28

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