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2025-29 Document de Travail/ Working Paper

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Fundamental Valuation of Equities under Allocative Rationality

Remzi UCTUM[*], Georges PRAT[□], Fredj JAWADI[+]

June 2025

Abstract – We estimate the fundamental values of individual stocks under the allocative rationality hypothesis, according to which portfolio diversification implies a valuation process in which only non-diversifiable risk is rewarded to investors. This new modeling approach, which departs from the rational expectations hypothesis, is applied to 33 companies selected from the 11 economic sectors of the S&P500 index. For each company, the dividend growth model (DGM) is combined with arbitrage pricing theory (APT), linking the equity risk premium to common factors through specific sensitivities. The estimation of our multivariate DGM-APT model over the period November 1983 to September 2024 leads to the identification of five common factors: the market factor, the default spread of interest rates, the oil price, the inflation rate, and the real GDP growth rate. To this end, we employ a methodology that is robust to parameter instability - marked by a common structural break in August 1995 - and which addresses residual autocorrelation through the use of bootstrap techniques. Our results differ from previous studies, which conclude that the fundamental values of stock indices are smoother than observed indices, a phenomenon known as the volatility puzzle. This puzzle disappears within our firm-level DGM-APT framework, in which fundamental values capture stock price trends and account for a large share of short-term fluctuations. However, consistent with studies based on indices, we highlight a mean-reversion process of stock prices toward their fundamentals.

JEL: C22, G15.
Keywords: equity prices, fundamental values, volatility puzzle, dividend discount model, arbitrage pricing theory

1 Introduction

Fundamental valuation helps investors assess a company's economic value based on expected future cash flows. By contrast, book value-based valuation relies on accounting

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balances, offering little insight into its future performance. Knowledge of a company's fundamental value allows investors to gauge whether its equity is under- or overvalued, thereby creating opportunities for arbitrage and enabling more effective capital allocation across firms.

Measuring the deviation between price and fundamentals necessarily depends on how the fundamental value is estimated, which in turn requires assumptions about the representation of expectations and risk. Any approach in the literature relies on a specification of the standard valuation model (i.e., the dividend discount model) combined with either rational expectations hypotheses or behavioral assumptions regarding expected dividends and the discount rate, which itself includes the risk-free rate and a risk premium. On theoretical grounds, the efficient stock market hypothesis implies that the deviation between equity prices and their fundamental values are white noise (Samuelson, 1965). However, as detailed in Section 2, the vast majority of empirical studies focusing on stock price indices—regardless of the expectation hypothesis—consistently find that estimated fundamental values are smoother than observed market prices, a phenomenon referred to by Shiller (1981) as the "volatility puzzle." The Section also documents that the relevance of this puzzle remains unsettled regarding the few studies estimating fundamental values at the firm level.

In this paper, we aim to estimate fundamental values of equities at the firm level, with the objective of assessing their ability to explain equity price dynamics. To this end, we propose a model that is consistent with the "allocative rationality" hypothesis, according to which portfolio diversification implies equity valuation processes that account only for non-diversifiable risk, since only this type of risk is rewarded by the market. It is worth emphasizing that this allocative rationality represents a substantially weaker assumption than the informational rationality underpinning the rational expectations hypothesis. In this regard, our contribution models expectations using behavioral heuristics.

We determine the fundamental values of firms' equities by combining the Dividend Growth Model (DGM) and the Arbitrage Pricing Theory (APT) (Ross, 1976), according to which equity risk premiums are driven by factors common to all firms, with firm-specific sensitivities indicating how individual companies respond to these risks. Shareholders can thus construct diversified portfolios that reduce risk by combining assets with different exposures to the same economic conditions. Note that the process of building such portfolios is beyond the scope of our study, which focuses on assessing firms' fundamental values. We estimate our DGM-APT model using data from 33 firms across 11 economic sectors of the S&P500 index, employing the Seemingly Unrelated Regression (SUR) method to account for contemporaneous correlations across equations, over the period from November 1983 to September 2024. Since this period of less than 41 years is long enough for the parameters to be potentially affected by structural instability, we augment the SUR method with Bai and Perron's (1998) sequential procedure for estimating models with endogenous structural breaks. We identify one significant breakpoint in August 1995, which marks the beginning of a tech-driven bull market and the onset of the Great Moderation in the United States. To the best of our knowledge, this joint approach is novel in the empirical literature. While the estimates are not affected by residual contemporaneous correlation or heteroscedasticity – both of which the SUR method is robust to - residual autocorrelation leads to an underestimation of their standard-deviations, thereby distorting the selection of common factors. We prevent this bias by implementing a block bootstrap strategy. We identify five common factors: the market factor, the default spread of interest rates, the oil price, the inflation rate and the real GDP growth rate. Because firms are exposed to the same macroeconomic influences but differ in their sensitivities, our fundamental values capture both the trends in equity prices and explain a significant portion of their short-term fluctuations. This finding contrasts with the volatility puzzle reported in index-level studies, which disappears in our DGM-APT framework when comparing the average change in equity prices and the average change in fundamental values. However, similar to these studies, we show that a mean-reverting process of equity prices towards fundamental values describes the dynamics of price deviation, although our results suggest the need to explore a more complex adjustment process in future research.

The remainder of the paper is organized as follows. Section 2 provides a literature review on stock prices and their fundamentals. Section 3 presents our modeling of fundamental value at the firm level. Section 4 describes the data. Section 5 outlines the econometric methodology. Section 6 presents the empirical results. Section 7 concludes.

2 Literature review

Literature offers two main categories of studies concerned with the determination of fundamental values: those based on stock price indices, and those grounded in firm-level equity prices.

Studies based on equity price indices

All studies aiming to determine the fundamental value of a stock price index rely on the infinite-horizon present value of expected dividends.[1] Assuming rational expectations, Lucas's (1978) intertemporal consumption-based asset pricing model implies that the stock market price is far more volatile than the fundamental value, thereby giving rise to the so-called "volatility puzzle" (Shiller, 1981). Moreover, Mehra and Prescott (1985) demonstrate that, for reasonable values of risk aversion and time preference coefficients, the Lucas model predicts a theoretical equity risk premium which, on average, is much lower than the observed values, thus giving rise to the so-called "equity premium puzzle". In response, many subsequent contributions have attempted to address these two puzzles through various approaches. Most of these studies relax the rational expectation hypothesis and introduce distorted expectations (Cechetti *et al.* (2000), Park (2006), Prat (2007), Adam *et al.* (2016)).

Departing from the consumption-based asset pricing model, most studies estimate fundamental value using Gordon's infinite horizon dividends growth formula. Unlike the Lucas model, this approach does not require specifying a utility function representing shareholders' preferences. In particular, while maintaining the rational expectations hypothesis, Campbell and Shiller (1988a, 1988b) proposed the so-called "dynamic Gordon

[1] Interestingly, Barberis and Thaler (2003) suggest that although investors under-react to news about fundamentals in the short term, they nevertheless gradually incorporate them in the long run.

growth model", derived from a first-order Taylor linear approximation of the Gordon formula. Expectations regarding the risk-free rate, the risk premium and dividend growth are then estimated using a backward-looking VAR model (see also Allen and Yang (2001), and Zhi et al. (2014)). However, the authors themselves acknowledge that this approach is subject to a spurious correlation bias. Moreover, this modeling does not distinguish between fundamental values and the adjustment process of the stock price toward the fundamentals, which is implicitly taken into account.[2] This is likely why studies aiming to estimate fundamental value often use the standard Gordon dividend growth formula, which, of course, leaves the question of expectations representation unaddressed. In this regard, it is now widely acknowledged that

> *rational expectations-based approaches have been useful to establish a benchmark, but asset prices have not yielded easily to rational expectations-based explanations (Stefan Nagel, in Brunnermeier et al. 2021).*

As an alternative, the growing availability of survey data has opened a valuable avenue for measuring expectations. A notable example is provided by Adam et al. (2017), who compare a standard stock pricing model incorporating survey-based expected returns with one based on rational expectations, and show that subjective beliefs replicate the empirical moments of stock prices, whereas rational expectations do not.[3] The failure of rational expectations hypothesis can be attributed to the assumptions that information is costless and the cognitive capacity of investors are unlimited. Studies which do not rely on rational expectations make use of auxiliary assumptions concerning the underlying variables of the Gordon formula: the risk-free rate, the risk premium and the long-term expected dividend growth rate. These assumptions range from constant values to behavioural rules based on a given set of backward-looking variables (Barsky and De Long, 1993; Bruneau *et al.*, 1999; Campbell and Shiller, 2001; Fama and French, 2002; Black *et al.*,2003; Manzan, 2003; Boswijk *et al.*, 2007; Prat, 2013; Prat and Le Bris, 2024).

Deviations of stock prices from their fundamental values naturally depend on the assumptions used to represent expectations and risk. However, regardless of the assumptions adopted, studies based on stock price indices show that fundamental values evolve smoothly compared to the market price, implying that deviations are often large and persistent. These deviations have given rise to various explanations which are bubbles (e.g. Craven and Islam, 2015), "irrational fads" (e.g. Shiller, 1981), investors' overconfidence (e.g. Daniel *et al.*, 1998), heterogeneity in expectations, mimetic behavior and information asymmetry (e.g. Poterba and Summers,1988; Boswijk *et al.*, 2007), and transactions costs or risky arbitrage (e.g. Anderson, 1997; Jawadi and Prat, 2012). Overall, one may question whether analysing fundamentals at the macro level using a stock market index inherently produces a smoothed

[2] For further discussion, see the Appendix in Jawadi and Prat (2016).

[3] In fact, the rational expectations hypothesis is not a priori consistent with numerous studies documenting the capacity of certain variables to predict stock market returns (e.g. Campbell and Shiller (2001)) nor with studies examining how experts form their stock price expectations (e.g., Abou and Prat (2000); Greenwood and Shleifer (2014)).

value, since index volatility - where idiosyncratic shocks cancel out - is lower than the average volatility of individual firms, each reacting differently to economic factors.

Studies conducted at the firm level

As with stock indices, all empirical approaches conducted at the firm level are grounded in a specification based on the dividends discount model. From our perspective, an important distinction must be made between studies where the value of shares depends solely on company-specific factors and those where the value is determined by factors that are common to all companies (market risk and macroeconomic variables).

In the first group of studies, security valuation and portfolio diversification are implicitly viewed as distinct issues, since in these models the risk premium only depends on firm specific and therefore diversifiable factors. Most of these studies rely on cross-sectional data and confirm that the valuation model significantly help explain price-earnings ratios at a given point in time, the risk premium being represented by various accounting ratios such as the book to market ratio, dividends/earnings ratio, debt ratios, firm size, and others. To our knowledge, studies based on firm-specific variables using time series data are very scarce. Using the Dividends Discount Model under the rational expectations hypothesis, Rahman and Hassan (2013) adopt a firm-level panel data approach to estimate fundamental values by relating share prices to company-specific factors in Asian countries over the period 1991 to 2005. They show that firms' fundamental value volatilities align, on average, with equity price volatilities.

As for the second group of studies, authors relax the rational expectations hypothesis and estimate the fundamental values using Gordon's Dividend Growth model (DGM). The discount rate is specified as the riskless rate plus a risk premium, which depends on factors that are common to all companies. From our perspective, this approach, adopted by very few studies, amounts to implicitly assume that investors building diversified portfolios evaluate equities on the basis of non-diversifiable risk, as the market prices only this type of risk. This ensures consistency between portfolio decisions based on allocative rationality and the equity valuation process. Considering Canadian equity prices, Booth (1998) models the expected dividend growth rate using factors such as inflation and real GDP growth rate forecasts. The risk-free interest rate being represented by the yield on government bonds, the author derives the DGM risk premium value for six shares in the Canadian telecommunications sector over the period 1966 to 1995. The average risk premium for these six firms exhibits a decreasing trend over the period. It is worth noting that the author does not attempt to model the risk premiums explicitly. This limitation is addressed in later work by Foerster and Sapp (2005), who combine the DGM with the Capital Asset Pricing Model (CAPM) to estimate the fundamental value of Bank of Montreal's equity using data from 1882 to 2003. The Bank of Montreal is one of the most prominent banks in North America known for paying regular dividends. In their framework, the discount rate is given by the government bond yield plus a risk premium, which is derived from the CAPM as beta times the difference between the expected market return and the government bond yield. As for the expected dividend growth rate, it is determined by a linear combination of GDP growth and inflation rate. Their empirical results show that the DGM-CAPM model proposed captures the trend in the equity price but fails to adequately account for short term fluctuations, suggesting some omitted factors. Moreover, the authors find that the rational expectations of dividends provide a poor representation of equity price, hence confirming similar conclusions from studies on stock price indices. Favouring a more comprehensive explanatory setting than the single-factor CAPM, Jawadi and Prat (2016) propose a DGM in which the long term risk premium is determined within the Arbitrage Pricing Theory (APT) framework. In this context, equity risk premiums depend on common factors shared by all firms, including the market risk premium previously considered by Foerster and Sapp. Using data from French firms, the authors identify four domestic and three international factors and find that fundamental values describe not only the trends but also a significant portion of equity price fluctuations. This result contrasts with the literature on fundamental values of stock price indices. However, Jawadi and Prat's (2016) study binds to a number of limitations. First, the monthly sample spans 18 years, which seems rather short for reliable estimation of fundamental values. Second and more importantly, parameter standard errors are biased due to residual autocorrelation, distorting the selection of the common factors. Third, while firm-specific fundamental values are less smoothed than index-based ones, the authors do not draw statistically supported conclusions about the volatility puzzle. In the present paper, we deepen this mixed approach by (i) analyzing US firms over an extended period of more than 40 years, (ii) allowing for potential parameter instability through endogenous structural breaks estimation, (iii) correcting residual autocorrelation bias via bootstrap-based standard errors of parameters to accurately identify the relevant common factors.

3 The model

Our approach departs from that of Lucas (1978), which is not operational when using individual data, as it requires knowledge, at each point in time, of the real consumption of the group of rational investors holding each equity - an obviously unfeasible requirement. We do not either rely on the dynamic version of the Dividend Growth model by Campbell and Shiller (1988a, 1988b), both for theoretical reasons discussed in section 2 and because it is not suited for determining the fundamental values of equities at the micro level, where common factors must be identified for all firms (see Appendix in Jawadi and Prat, 2016). Therefore, as commonly assumed in the literature, our fundamental values are inferred from the Gordon dividend growth model with infinite horizon. As much as investors are aware that dividend growth and discount rates will vary in the future, they are equally aware that their cognitive abilities are insufficient to anticipate changes in the values of these two rates throughout successive future periods. Hence, we assume that stockholders consider at any time the infinite horizon as a whole.[4] This perspective leads investors to view, at any time, the discount rate and the expected dividend growth rate as two constants over the infinite future timeline, provided that they revise at each period these constant values on the basis of new information. Accordingly, the fundamental value F_{it} of an equity *i* is at any time *t* given by the traditional Gordon dividend growth model (DGM) :

[4] In the same way, when a forecaster expects a variable one year ahead, they are not supposed to separately expect the values for each of the twelve months of the year.

$$F_{it} = \frac{\bar{D}_{it}}{r_{ot} + \varphi_{it} - \tilde{g}_{it}} \qquad s.t. \quad r_{0t} + \varphi_{it} - \tilde{g}_{it} > 0, \;\; i = 1, \dots, n \tag{1}$$

where $\bar{D}_{it}$ is the Hodrick-Prescott (HP) filtered trend-value of dividends associated with equity i [5], r_{0t} the risk-free rate, $\tilde{g}_{it}$ the long-term expected dividend growth rate, and φ_{it} the long-term risk premium. As these last three variables are not directly observable, we consider the following assumptions.

To evaluate the risk-free rate r_{0t} we refer to the Treasury bond yield r_t but unlike the usual practice we do not directly represent the former by the latter. Indeed, the risk-free rate represents a pure time preference while, due to the marketability of bonds, the observed Treasury bond yield includes a liquidity premium φ_t which adds to the time preference rate. Therefore, proxying the risk-free rate with the bond yield in a dividend discount model involves a substantial measurement bias in r_{0t} (Booth, 1998). Accordingly, an adequate representation of the latter requires that the liquidity premium be eliminated from the observed yield, that is, $r_{0t} = r_t - \varphi_t$. On the other hand, we assume that the liquidity premium can be decomposed into a cyclical component and a constant mean value, such that $\varphi_t = (r_t - \bar{r}_t) + \bar{\varphi}$, where we estimate the trend value $\bar{r}_t$ using the HP filter. As for the constant mean value $\bar{\varphi}$, we consider the standard model of interest term structure according to which the term spread equals the expected changes in the short-term interest rate r_t^S plus a risk premium (Shiller, 1990). Assuming that expected changes in r_t^S can be represented by an autoregressive process and using the 3-month Treasury Bills rate to measure this short rate, we regress the term spread $r_t - r_t^S$ on actual and past values of changes in r_t^S plus an intercept which corresponds to the average value of the liquidity premium sought. This regression led to an intercept of 2 % per year (four lagged values of changes in the short rate were found to be significant). Putting together the relationships in r_{0t} and φ_t above, the risk-free rate is thus evaluated as the trend of the Treasury bond yield reduced by the estimated intercept, that is $r_{0t} = \bar{r}_t - 2.00$.

Concerning the long term expected growth rate of dividends $\tilde{g}_{it}$, we assume that it follows a traditional regressive process

$$\tilde{g}_{it} = g_{it} + \lambda_i (g_{0i} - g_{it}) \qquad \text{with } \lambda_i \geq 0 \tag{2}$$

where g_{0i} is the "normal" or steady-state value of dividend growth corresponding to the dynamic equilibrium condition of the firm, g_{it} the annual-based trend-value of the dividend rate of change perceived at time *t* calculated as:

$$g_{it} = 100 \times 12 \times \ln\left(\frac{\bar{D}_{it}}{\bar{D}_{it-1}}\right) \tag{3}$$

and λ_i the speed of adjustment in the mean-reverting expectation process, which is to be estimated. The condition $\lambda_i > 0$ in Eq(2) indicates that the process is mean reverting toward

[5] Unlike aggregate dividends associated with stock price indices, firm-specific dividend time series exhibit stepwise patterns. The filtering procedure aims at smoothing these patterns, which is consistent with the long-term horizon characterizing the fundamental value.

its normal value; the particular values $\lambda_i = 0$ and $\lambda_i = 1$ imply $\tilde{g}_{it} = g_{it}$ (naive expectations) and $\tilde{g}_{it} = g_{0i}$ (steady-state-anchored expectations), respectively.

As for the equity risk premium φ_{it}, in line with the APT (Ross, 1976**),** long-term investors are supposed to hold efficient portfolios according to which only systematic risk is remunerated, with the impact of specific factors related to individual firms being eliminated through diversification. This means that our fundamental values are based on the allocative rationality hypothesis. Accordingly, equity risk premia for all firms are determined by a linear combination of *k* common factors X_{jt} (*j*= 1,…, *k*) with firm-specific sensitivities.

A well-known implication is that the risk premium φ_{it} of the risky asset *i* can be approximated as a linear combination of the risk premiums associated with *K* common factors φ_{kt} $(k = 1 \dots, K)$. The equity risk premium can thus be written as $\varphi_{it} = \sum_{k=1}^{K} \delta_{ik}\, \varphi_{kt}$, where the weighting coefficients δ_{ik} (or factor loadings) reflect the sensitivities of φ_{it} to the systematic risks φ_{kt}. Assuming that a linear relationship holds between each factor risk premium and the associated observable common factor X_{kt}, i.e., $\varphi_{kt} = a_k + b_k X_{kt}$, the equity risk premium can be expressed as

$$\varphi_{it} = \beta_{i0} + \sum\nolimits_{k=1}^{K} \beta_{ik} X_{kt} \tag{4}$$

where $\beta_{i0} = \sum_{k=1}^{K} \delta_{ik}\, a_k$ and $\beta_{ik} = \delta_{ik} b_k$.

The unobservable variables r_{0t}, $\tilde{g}_{it}$ and φ_{it} being now fully specified, the best approximation of Eq(1) for estimation purposes is to replace the fundamental value F_{it} by the equity price P_{it} and to write the latter equation such that all parameters to be estimated are in the right-hand side:

$$\frac{\overline{D}_{it}}{P_{it}} - r_{0t} = \varphi_{it} - \tilde{g}_{it} \tag{5}$$

Reporting Eq(2) and Eq(4) into Eq(5), we obtain the following expression of the DGM to be estimated :

$$\frac{\overline{D}_{it}}{P_{it}} - r_{0t} = c_i + \theta_i g_{it} + \sum_{k=1}^{K} \beta_{ik} X_{kt} + \varepsilon_{it} \tag{6}$$

where $c_i = \beta_{i0} - \lambda_i g_{0i}$, $\theta_i = \lambda_i - 1$ and ε_{it} is the estimation error term. θ_i must be not less than -1 for the regressive expectations condition $\lambda_i \geq 0$ to hold in Eq(2). If θ_i equals -1 or 0, the expected dividend growth rate $\tilde{g}_{it}$ is given by the actual rate or its steady-state value, respectively. For values of θ_i such that $-1 < \theta_i < 0$, the mean-reversion is gradual ($0 < \lambda_i <$ 1) while when $\theta_i > 0$ $(\lambda_i > 1)$ expectations overshoot the steady-state. Once Eq(6) is estimated, its deterministic part can be used to evaluate the right-hand-side of Eq(5), that is $\widehat{\varphi_{it} - \tilde{g}_{it}}$. The DGM-APT fundamental value of an equity *i* is then derived as:

$$\hat{F}_{it} = \frac{\overline{D}_{it}}{r_{0t} + (\widehat{\varphi_{it} - \tilde{g}_{it}})} \tag{7}$$

where the denominator must be non-negative.

4 Data

We use data for a panel of 33 companies of the S&P500 index covering all of the 11 activity sectors of the index.[6] We start by collecting from Datastream the longest, balanced and uninterrupted series of equity prices P_{it} and dividends per share D_{it} across all sectors, ensuring a minimum of three equities per sector. Equity prices refer to closing prices and dividend payments correspond to those made in the previous year, both variables being expressed in US Dollars. With these selection criteria our monthly sample period spans from November 1983 to September 2024. When a sector contains more than three firms, we select major companies from different sub-industries within that sector, ensuring that no two companies belong to the same sub-industry and that each company covers the period without interruption. All sectors meet this condition, except for *communication services* and *real estate*, which each comprise only three companies over the period. Note that, because they entered the S&P500 index relatively later after the beginning of our 33-firm balanced period, the largest technology companies such as GAFAM are not included in our panel. Table1 lists the selected companies with their stock symbols and their respective industry sectors and sub-industries. Throughout this paper companies are referred to by their stock symbols, listed in alphabetic order. Table 2 provides for each company the mean and the standard errors of the Hodrick-Prescott filtered dividend-based dividend yield $\overline{D}_{it}/P_{it}$ (referred to as dividend yield hereafter) and the rate of change in filtered dividend g_{it} given by Eq(3). It can be seen that these variables exhibit significant disparities across equities in terms of both levels and magnitudes of fluctuations. Such distinct time patterns justify examining fundamental values at the individual firm level. Figure 1 displays these two variables for each firm - namely the idiosyncratic variables appearing in Eq(6) - and confirms the substantial heterogeneity in their dynamics across firms.

[6] These sectors are communication services, consumer discretionary, consumer staples, energy, financials, heath care, industrials, information technology, materials, real estate and utilities.

Table1. The selected S&P500 firms and their economic sectors, nov.1983– sep.2024

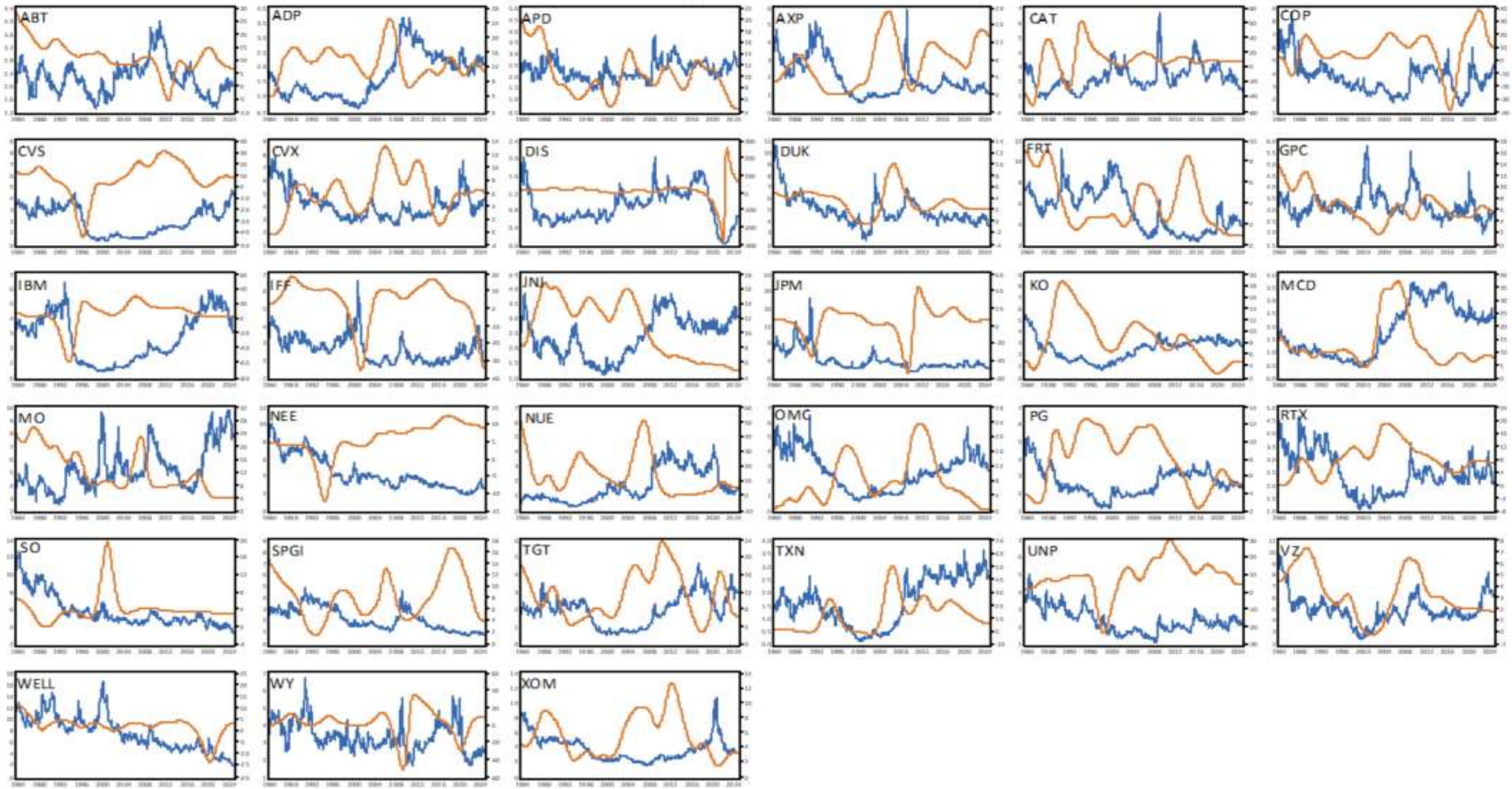
Symbol	Security	Sector	Sub-industry
OMC	Omnicom Group	Communication services	Advertising
VZ	Verizon		Integrated Telecommunication Services
DIS	Walt Disney Company		Movies & Entertainment
GPC	Genuine Parts Company	Consumer discretionary	Specialty Stores
MCD	McDonald’s Corporation		Restaurants
TGT	Target Corporation		General Merchandise Stores
MO	Altria Group	Consumer staples	Tobacco
KO	Coca-Cola Company (The)		Soft Drinks
PG	Procter & Gamble Company (The)		Personal Products
CVX	Chevron Corporation	Energy	Integrated Oil & Gas
COP	ConocoPhillips Company		Oil, Gas Exploration & Production
XOM	ExxonMobil Corporation		Integrated Oil & Gas
AXP	American Express Company	Financials	Consumer Finance
JPM	JPMorgan Chase & Co		Diversified Banks
SPGI	S&P Global		Financial Exchanges & Data
ABT	Abbott Laboratories	Health care	Health Care Equipment
CVS	CVS Health Corporation		Health Care Services
JNJ	Johnson & Johnson		Pharmaceuticals
CAT	Caterpillar	Industrials	Construction Machinery& Heavy Trucks
RTX	Raytheon Technologies Corporation		Aerospace & Defence
UNP	Union Pacific Corporation		Railroads
ADP	Automatic Data Processing	Information technology	Data Processing & Outsourced Services
IBM	International Business Machines Corp		IT Consulting & Other Services
TXN	Texas Instruments		Semiconductors
APD	Air Products and Chemicals	Materials	Industrial Gases
IFF	International Flavors & Fragrances		Specialty Chemicals
NUE	Nucor Corporation		Steel
FRT	Federal Realty Investment Trust	Real estate	Retail REITs
WELL	Welltower		Health Care REITs
WY	Weyerhaeuser Company		Specialized REITs
DUK	Duke Energy Corporation	Utilities	Electric Utilities
NEE	NextEra Energy		Multi-Utilities
SO	Southern Company		Electric Utilities

Table 2- Descriptive statistics of the dividend yield and the filtered dividend growth rate

Firm	Dividend yield		Filtered dividend growth rate	
	mean	std-dev	mean	std-dev
ABT	26.44	6.29	10.91	5.66
ADP	20.34	9.03	13.02	4.05
APD	27.27	4.88	10.24	3.62
AXP	22.60	13.02	7.06	5.28
CAT	27.20	9.84	8.40	19.87
COP	43.19	14.63	6.69	14.38
CVS	24.35	14.16	7.45	14.96
CVX	48.48	12.92	5.85	3.18
DIS	10.55	4.83	8.66	57.62
DUK	59.13	15.32	3.43	2.24
FRT	62.63	24.50	4.00	2.50
GPC	38.22	6.85	6.57	2.58
IBM	32.11	19.40	4.80	16.92
IFF	31.79	9.22	4.31	12.42
JNJ	28.24	8.16	10.60	3.88
JPM	46.85	28.51	4.43	17.40
KO	29.70	11.21	8.70	4.19
MCD	21.77	11.80	12.67	9.00
MO	62.31	20.14	12.32	6.41
NEE	51.98	22.72	5.50	5.13
NUE	19.85	13.21	13.48	13.00
OMC	31.65	15.72	7.96	6.38
PG	31.34	9.47	8.03	3.25
RTX	29.12	9.31	7.90	4.78
SO	68.35	22.48	4.09	3.45
SPGI	25.54	11.75	8.09	3.85
TGT	23.16	10.89	11.22	5.42
TXN	19.32	11.05	12.00	12.73
UNP	27.78	8.44	8.84	10.20
VZ	59.03	15.15	3.29	2.04
WELL	91.13	35.77	1.75	4.26
WY	39.54	10.07	2.07	15.10
XOM	44.97	19.87	5.53	2.90

Note - All variables are in percent per year.

Figure 1 –dividend yield and filtered dividend growth rate



Notes. All series are in % per year. Dividend yield (blue line) is scaled on the left axis and the filtered dividend growth rate (red line) on the right.

Regarding the selection of common factors for the equity risk premiums, we explored a broad panel of macroeconomic and financial variables, that are also commonly identified in the APT literature.[7] The factors we tested are the market factor, consumer confidence index, interest rate term spread, interest rate default spread, WTI oil price in euros, the effective exchange rate of the US Dollar, real and nominal GDP growth rates, industrial production growth rate, CPI inflation rate, and real and nominal money supply growth rates. All the raw data are extracted from Datastream. As a result of system estimations using the SUR methodology, five variables $X_{ik}(k = 1 \ldots, 5)$ were found to be significant for the vast majority of the 33 equities considered :

- The market risk premium $\varphi_{mt} = \frac{\bar{D}_{mt}}{P_{mt}} + \tilde{g}_{mt} - r_{ot}$ directly derives from Eq(5) and represents the market risk premium associated with S&P500 index P_{mt}, where $\bar{D}_{mt}$ is the HP-trend value of the S&P500 dividend D_{mt} while $\tilde{g}_{mt}$ is the expected growth rate of D_{mt}. As in Eq(2), $\tilde{g}_{mt}$ is assumed to follow a regressive process that can be written as $\tilde{g}_{mt} = (1 - \lambda_m)g_{mt} + \lambda_m g_{0m}$, where g_{mt} is the trend-value of the change in D_{mt} and g_{0m} is its 'normal' value. Since all firms are influenced by the common factors X_{2t} to X_{5t}, it follows that the market factor, called X_{1t}, necessarily depends on these same factors. To avoid multicollinearity through the market factor, only the part of this factor that is uncorrelated with the other five is retained for X_{1t}. The market factor can then be estimated, once rearranged, as $\frac{\bar{D}_{mt}}{P_{mt}} - r_{ot} = a_0 + a_1 g_{mt} + \sum_{k=2}^{K} \beta_{mk} X_{kt} + u_t$, where X_{1t} identifies to the residual $\hat{u}_t$. The expected sign of X_{1t} on the equity risk premium is positive.

- The log of the WTI oil price expressed in USD (X_{2t}). A rise in oil price leads to increased input costs, which in turn raises uncertainty regarding future corporate profits and results in a higher equity risk premium.

- The default spread of interest rates in % per annum, defined as the difference between corporate bonds yield and treasury bonds yield (X_{3t}). An increase in the default spread signals heightened credit risk and financial uncertainty, prompting investors to require higher equity risk premium.

- The year-over-year rate of inflation (CPI), in % per annum (X_{4t}). The expected sign of inflation on equity risk premium can be positive or negative, depending on the context. A moderate inflation may encourage production and growth, leading to higher corporate profits and to reduced perceived risk. On the other hand, higher inflation can increase uncertainty, resulting in a higher equity risk premium.

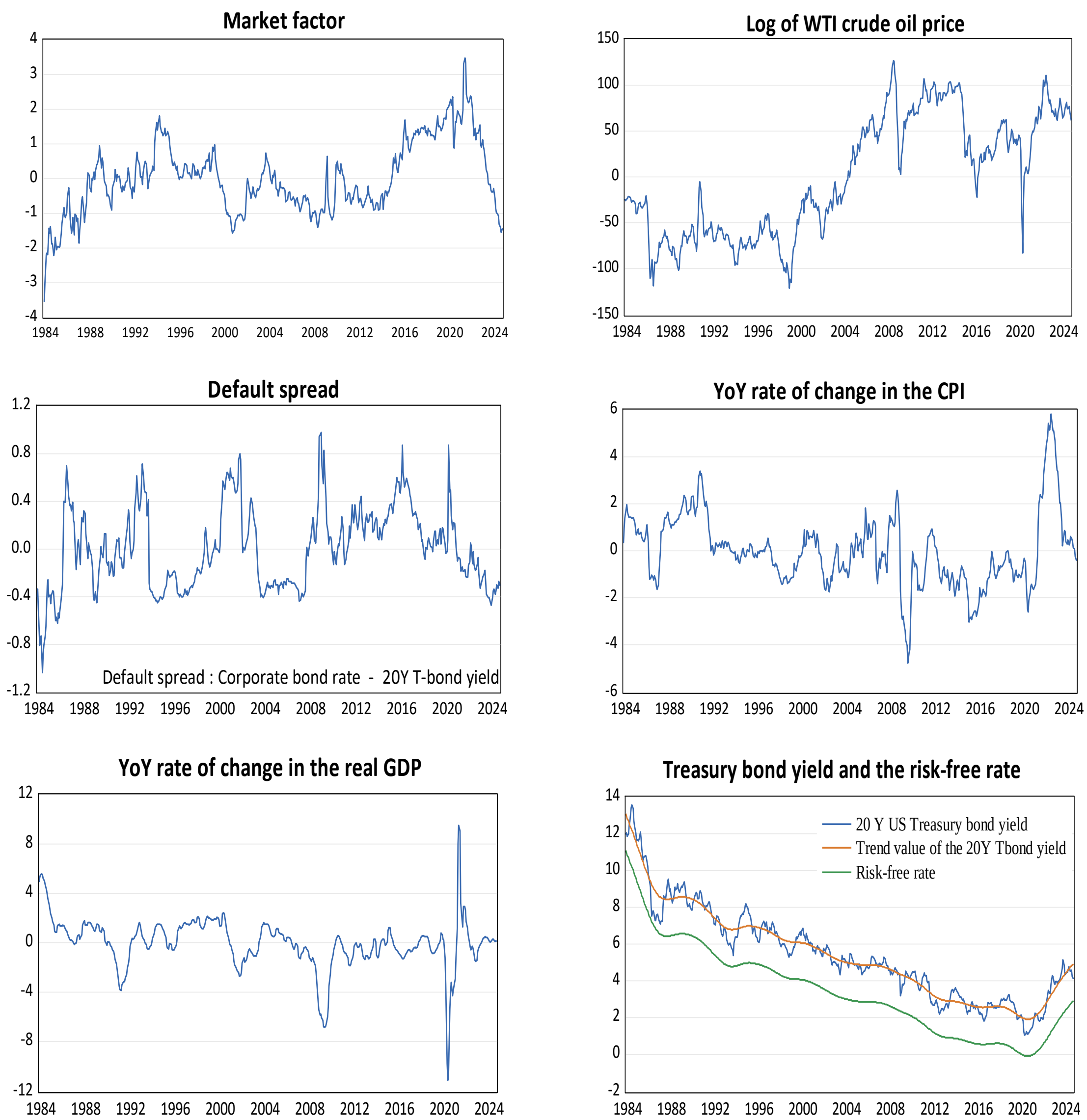
- The year-over-year rate of change in real GDP, in % per annum (X_{5t}). An increase in real GDP denotes economic expansion, fostering higher corporate profits and greater investor confidence, leading to a decline in equity risk premium.

[7] See Roll and Ross (1980), Chen *et al.* (1986), Fontaine (1987), Elton *et al.* (1994), Kryzanowski *et al.* (1997) and Jawadi and Prat (2016).

These factors are all demeaned, so that the intercept in Eq(6) captures, for each firm, the overall influence of all factors on the average level of the risk premium. Note that, since each of the variables is derived from a market price (market, WTI, spread) or is specified as the average rate of change over the last year (inflation, GDP), our common factors can be seen as capturing expectations that determine risk premiums.[8]

Figure 2 displays the time series of the five common factors, along with the risk-free rate, evaluated as described in Section 3. Although the risk-free rate is not a common factor in the APT model, it serves as a common factor in the DGM framework. It can be seen that our common factors exhibit highly fluctuating patterns, while Table 3 reports that some of them are moderately correlated.

Figure2 - The common factors



[8] See Abou and Prat (2010) who identified survey-based common factors such as expected inflation and expected GNP growth rate.

Table 3 – Correlations between the common factors

	Market factor	WTI oil price	Default spread	Change in the CPI	Change in real GDP
Market factor	1	0	0	0	0
WTI oil price		1	0.073319	0.020436	-0.209988
Default spread			1	-0.358141	-0.453423
Change in the CPI				1	0.311016
Change in real GDP					1

To check for the integration imbalance of our equations, we adopted a joint testing strategy for the (33x1) vector of dependent variables and (33x1) vector of filtered dividend growth. We conducted the Levin, Lin and Chu (2002) (LLC) panel unit root test, which tests the null that all variables in a set have a common unit root (other parameters of the test equations being firm-specific) against the alternative that they are all I(0). For both of the panel of dependent variables and the panel of filtered dividend growth rates, the test strongly rejects the null, confirming that stationarity can be globally accepted within each panel. As for the other variables of Eq(6), namely our five common factors, ADF tests indicate stationarity at all levels for the market factor, default spread, inflation and real GDP growth and at the 10% level for the WTI price (Table 4).

Table 4 - Unit root tests

Idiosyncratic variables : LLC panel unit root tests		Common factors : ADF unit root tests				
Endogenous variables	Filtered dividend growth rate	Market factor	WTI price	Default spread	Inflation	Real GDP growth
-16.64	-2.26	-3.65	-1.84	-4.26	-3.69	-4.11
0.0000	0.0118	0.0003	0.0633	0.0000	0.0002	0.0000

Note: Entries are the test-statistics and the corresponding p-values.

5 – Methodology

To identify the relevant common factors for our 33 firms, it is important to estimate Eq(6) simultaneously for all firms by considering a system of equations. Indeed, since investors engage in arbitrage at any time by selling overvalued equities to purchase undervalued ones, such behaviors create interdependencies between the market prices of different equities, justifying a simultaneous estimation of all 33 firms. Moreover, in such a system of equity risk premium equations, unobserved factors may simultaneously influence several equity premiums, such as sector-specific latent factors affecting all firms within a given sector, contagion effects from other sectors or from international asset markets or political instability. Such latent common drivers, along with potential measurement errors in included regressors, can lead to contemporaneous correlation between the error terms of different equations in the system. This justifies our choice of the Seemingly Unrelated Regressions (SUR) method, which is robust to potential error correlation and also to heteroskedasticity. Note that the efficiency gain of SUR over OLS arises from accounting for cross-equation residual correlation (through a non-diagonal covariance matrix estimated via Feasible GLS) and from allowing for non-identical regressors across equations. Due to potential cross-equation residual dependencies and the presence of the firm-specific long term dividend growth rate in each equation, system estimation using SUR is not equivalent to and is more efficient than estimating each equation separately by OLS.

Another important feature of our modeling strategy is related to our extended sample covering almost 41 years. This period is long enough to generate instabilities in the estimated coefficients. Indeed, it is very likely that the parameters in each equation are affected by structural shocks that impact all firms simultaneously, such as episodes of financial deregulation or crises, changes in macroeconomic policy, or major technological shifts. Ignoring these structural breaks may lead to inconsistent estimates and invalid inference. In particular, accounting for potential parameter instability is essential for accurately estimating the fundamental values of stock prices. To this end, we combine the SUR system estimation with the method developed by Bai and Perron (1998) for sequentially estimating linear models with multiple endogenous structural breaks. To our best knowledge, this is the first application of such a methodological combination.

The estimation of endogenous breaks in heterogeneous panel models (i.e., systems where the coefficients in the model differ for each cross-section unit) has been discussed by Baltagi et al (2015). The authors propose an extension, in this direction, of Pesaran's (2006) common correlated effects (CCE) approach, which is designed to estimate heterogeneous panels in which unobserved common factors induce cross-sectional dependence in the error terms and may also be correlated with certain regressors, thereby violating the exogeneity assumption and potentially leading to inconsistent parameter estimates. The authors show that the methods developed by Bai (1997) and Bai and Perron (1998) are appropriate to testing whether such heterogeneous panel models also exhibit unknown structural breaks in the parameters. Our setting involves a heterogeneous panel framework with correlated errors, possibly because they are affected by unobserved factors. We do not consider the (extreme) case in which the latter may influence our economic common factors to an extent that non-negligible endogeneity bias could result. However, we allow the error terms to be autocorrelated, possibly due to these omitted influences. Our framework thus corresponds to the simpler case discussed by Baltagi et al (2015). In this context, both contemporaneous error correlation and parameter instability can be efficiently addressed using SUR methodology provided it is adapted to account for possible structural breaks.

To allow for potential endogenous breaks, we rewrite model (6) as :

$$\frac{\overline{D}_{it}}{P_{it}} - r_{0t} = \sum_{j=1}^{m+1} \beta_{ij}' \psi_{it} 1_{t \in I_j} + \nu_{it}\,, \qquad i = 1, \ldots 33 \tag{8}$$

where $\psi_{it} = (1, \bar{g}_{it}, X_{kt}; k = 1, \ldots, K)'$, $\beta_i = (c_i, \theta_i, \gamma_{ik}; k = 1, \ldots, K)'$, m is the unknown number of breaks, I_j the subperiod between break dates t_{j-1} and t_j and $1_{t \in I_j}$ an indicator function such that $1_{t \in I_j} = 1$ when $t \in I_j$ and 0 elsewhere. Our breaks are endogenous in the sense that they are unknown and sequentially identified from the data. Each of the successive candidate break dates are drawn from a trimming region (excluding, say, the first and last $\tau = 15\%$ of observations) that ensures a minimum segment length between breaks. For each potential breakpoint, the full-sample sum of squared residuals (SSR_T) – aggregated across all 33 firms - is computed from our SUR estimations. The first breakpoint is then selected as the minimum of these SSR_T, namely $\hat{t}_1 = \arg\min_{1+\tau T \le t_1 \le T-\tau T} SSR_T(t_1)$. To identify a second breakpoint, the search process is repeated within each of the two sub-periods defined by the first estimated break. The second break $\hat{t}_2$ is selected as the one that yields the lowest SSR_T among the two local minima detected within the two subperiods. This process is repeated iteratively to identify additional breaks.

To determine the number of significant breaks, we use the $F(m+1/m)$ test proposed and tabulated by Bai and Perron (1998), which sequentially tests the null hypothesis of m breaks against the alternative of $m+1$ breaks ($m = 0, 1, \dots$). We retain the total of m break(s) when the test fails to reject the null. In the context of our system setting, a key issue is that the breaks are considered as common to all firms, as we are interested in structural changes that may affect the entire stock market, just as common factors do. In this sense, the breakpoints – or the economic structural shocks that give rise to them - can be regarded as common events complementing our common factors.

Note that the optimum partitioning of the full sample period implies that the estimated coefficients are stable within each subperiod. As a result, changes in parameter values between consecutive subperiods may lead to abrupt shifts in the fitted values of the model. To address this issue, we smooth the transition around each breakpoint by computing weighted averages of the estimated coefficients from adjacent subperiods. The weights are determined by a logistic function centered at the breakpoint and applied over a two-year window – one year before and one year after – resulting in 24 smoothed coefficient values. The rationale behind this smooth transition is that some economic agents may have anticipated the structural break and adjusted their long term risk premium requirements accordingly, while others may have reacted with a delay, resulting in a gradual rather than abrupt shift at the aggregate level.

Furthermore, our results exhibit residual autocorrelation, possibly due to remaining misspecification although a large set of potential common factors has been tested. Note that firm-specific factors may also contribute to explaining the variation in individual long run risk premiums. In this case, their omission would clearly be a reason of residual serial correlation. However, since these factors are associated with idiosyncratic risks, which can be diversified, they are not relevant for inclusion among the regressors of the model. While coefficient estimates remain unbiased in the presence of autocorrelation, their standard errors may be underestimated, thereby affecting the accuracy of significance tests and compromising the reliability of common factor identification. To ensure consistent standard errors, we apply the block bootstrap method, which is appropriate for preserving the serial-dependence of errors within each block without requiring the specification of a particular autocorrelation structure.

Our procedure is as follows. We first estimate our SUR system with multiple endogenous breakpoints. For each subperiod, we retain the estimated coefficients as final estimates and store the residuals for resampling. For each equation, we generate bootstrap residuals by drawing blocks of size 30 with replacement. These pseudo-residuals are then added to the original fitted values to construct bootstrap dependent variables. Using these pseudo-samples, we re-estimate the SUR system and store the resulting bootstrap coefficient estimates. We repeat this process 5000 times and calculate the standard deviations of the bootstrap coefficient distributions to get the bootstrap standard errors of the original coefficients. These, in turn, are used to compute bootstrap-based t-statistics and p-values, providing a more reliable assessment of parameter significance under serial correlation.

Our results indicate a structural break in August 1995 in the estimated parameters of the model for S&P 500 equity risk premiums. This break coincides with a U.S. monetary easing following an aggressive tightening stance in 1994. The resulting decline in bond yields, surge in the stock market, and reduced market volatility likely contributed to a regime shift in investor risk perception and equity pricing.

6 Econometric results

6.1 Estimation of the SUR system with endogenous structural breaks

The sequential estimation of our SUR system with endogenous breakpoints identified a first common break date in August 1995, splitting the overall sample into two subperiods of 140 and 350 observations, respectively. At this point the overall sum of squared residuals to all firms over the entire period was minimum, and the $F(1/0)$ test for the null hypothesis that no break is present against the alternative of 1 break was strongly rejected at all conventional levels of significance ($F(1/0)$=107.90 far exceeds the maximum critical value 28.01 at the 1% level for $q = 7$ variables subject to structural change). No second break was found to be significant, as the $F(2/1)$ test failed to reject the null at all levels ($F(2/1) = 11.89$ is less than the minimum critical value 23.41 at the 10% level). This holds despite the second subperiod covering a large portion (71.5%) of the total sample period (note that the first subperiod was not considered for an additional break search due to insufficient data). Accordingly, the highly significant break detected in August 1995 fulfills our objective of addressing potential parameter instability throughout our sample period. This break coincides with a shift toward accommodative monetary policy by the Federal Reserve, designed to support economic growth after the aggressive tightening stance of 1994. The subsequent interest rate cuts resulted in lower bond yields, making equities more attractive to investors. This, in turn, fueled one of the longest bull markets in U.S. history, which lasted nearly five years until the peak of the dot-com bubble in early 2000 and was largely driven by strong productivity growth linked to the internet revolution. During this period, stock indices saw dramatic increases, with the S&P500 more than tripling. Impulsed by the monetary easing of August 1995, this rally likely marked the transition to a new regime, which continues to shape the market today, driven by technological dominance, low interest rates, and financial market growth.

Table 5 provides the estimation results for the two subperiods, defined by the estimated breakdate of August 1995. At the 5% level of significance, ADF tests show that all errors are stationary. Regarding our macroeconomic factors, the question of their being qualified as "common factors" involves assessing their significance for a substantial portion of the firms. While there is no universally acknowledged threshold, we consider a variable as a common factor if it is statistically significant in at least 75% of the units analysed. To facilitate the comparison of our results with this rate, Table 6 summarizes the relevant information from Table 5 by indicating the percentage of times each independent variable is significant at the 10% level; similar proportions are also reported for positive or negative coefficients. In addition, Table 6 synthesizes the results from the two subperiods by reporting average proportions calculated as weighted averages, using the relative lengths of the subperiods as weights. The lengths of 140 and 350 observations correspond to weights of 0.285 and 0.715, respectively. This results in 95.24% of firms being sensitive to the market factor, 86.15% to crude oil price, 81.83% to the default spread, 90.50% to inflation and 73.16% to real GDP growth at the 10% level of significance. Note that, when the second subperiod is considered alone, the performance of real GDP growth (75.76%) meets our threshold. We can thus conclude that these five variables act as common factors for our set of 33 firms. Regarding the signs of their effects, they are consistent with the expected ones: on average over the two subperiods, the long term equity premium is positively affected by the market factor (97.77% of cases), by oil price (95.55%), by default spread (100%), and negatively affected by inflation (93.52%) and by real GDP growth (97.14%). As for the trend-value of the dividend growth rate, recall from Eq.(6) that $\theta_i = \lambda_i - 1,$ where λ_i is the regressive parameter. θ_i is statistically significant for 52.38% of firms, and 92.65% of these estimates are negative and lie strictly between -1 and 0, this implying $0 < \lambda_i < 1$. Consequently, 48.53% of our panel of equities (52.38% of 92.65%) exhibit long-term dividend growth expectations that gradually mean-revert to the steady state, in line with Eq.(2). For the 47.62% of θ_i's that are not significant, λ_i is statistically indistinguishable from 1, suggesting that for these equities, investors form steady-state-anchored expectations ($\tilde{g}_{it} = g_{0i}$). This shows that investors are heterogeneous in forming their dividend growth expectations. Furthermore, Table 5 reveals substantial heterogeneity in the responses of equity risk premiums to the identified common factors. As will be discussed in the next subsection, these elements significantly affect fundamental value volatility.

Table 5 also reports diagnostic test results for the residuals of Eq.(8). To check for stationarity, we performed Pesaran's (2007) Cross-sectionally Augmented Dickey-Fuller (CADF) unit root test which is appropriate for individual residuals exhibiting contemporaneous correlation. The test indicates that all residuals in the first subperiod are stationary at the 5% significance level. In the second period, the test also rejects the null of a unit root for all firms except two, for which it rejects at a level slightly above 10%. A striking result, however, emerges from the Durbin-Watson statistics, which shows that all residuals are serially correlated in each subperiod. A system-wide Portmanteau (Ljung-Box Q) test on the residuals was also conducted, strongly confirming the overall rejection of the null of no autocorrelation across each subperiod. As discussed in section 5, residual autocorrelation may reflect model misspecification in the form of unobserved common factors influencing equity risk premiums. Autocorrelation also suggests that deviations between prices and fundamental values are themselves serially correlated, which can be understood as market frictions causing prices to adjust gradually towards fundamentals (we will return to this issue in the following sections). To obtain consistent estimates of the standard-deviations and thus the t-statistics of the system parameters, we employed bootstrap methods, as previously detailed. In Table 5 all estimates are reported with their bootstrap t-statistics.

Table 5 - Seemingly Unrelated Regression system estimation of equity risk premiums under an endogenous structural break

	ABT	ADP	APD	AXP	CAT	COP	CVS	CVX	DIS	DUK	FRT	GPC	IBM	IFF	JNJ	JPM	KO
$\hat{c}$	0.29	-4.45***	-2.73***	0.51	-2.59***	1.32***	-0.89***	-0.20	-3.93***	-0.28	3.28***	-0.70***	-1.36*	-2.12***	-1.91***	-1.94	-2.05***
	(0.90)	(13.68)	(8.56)	(1.10)	(8.53)	(3.98)	(3.32)	(0.50)	(10.39)	(0.26)	(6.36)	(2.83)	(1.70)	(11.40)	(3.80)	(1.11)	(8.91)
	-0.003	-0.93***	-0.58*	-1.56***	-0.01	0.21	-1.31***	1.16***	-1.90***	1.70***	3.85***	1.42***	-0.11	-0.06	0.32	0.18	-0.34
	(0.02)	(-4.72)	(1.60)	(19.75)	(0.06)	(0.88)	(7.20)	(3.30)	(18.21)	(9.79)	(11.20)	(4.94)	(0.39)	(0.54)	(0.81)	(0.64)	(0.88)
$\hat{\theta}$	-0.16***	0.09***	-0.02	-0.09**	0.003	-0.09***	-0.03***	-0.14**	0.02	0.13	-0.22***	-0.04	-0.02	0.04**	-0.05	-0.007	-0.06***
	(8.41)	(4.31)	(0.76)	(1.76)	(1.21)	(5.93)	(3.66)	(2.19)	(0.98)	(0.56)	(3.00)	(0.94)	(1.72)	(2.34)	(1.20)	(0.16)	(5.49)
	-0.07***	-0.02	-0.002	0.008	-0.02**	0.006	-0.03**	-0.06	0.0004	-0.05	-0.30***	-0.17***	-0.07***	-0.03***	-0.09***	0.01	-0.04
	(4.32)	(1.40)	(0.05)	(0.94)	(1.93)	(0.42)	(2.44)	(1.27)	(0.52)	(1.08)	(3.19)	(3.12)	(3.66)	(3.21)	(2.57)	(0.82)	(0.89)
$\hat{\beta}_1$	0.83***	0.98***	1.07***	1.54***	0.95***	0.61***	1.37***	0.87***	1.06***	0.37***	0.95***	1.22***	1.00	0.97***	1.21***	0.41	0.75***
	(11.39)	(13.61)	(8.34)	(10.90)	(8.81)	(5.94)	(16.83)	(6.02)	(18.18)	(6.44)	(4.35)	(15.20)	(4.32)	(18.00)	(16.80)	(0.83)	(13.52)
	0.85***	1.10***	1.01***	1.12***	1.08 ***	1.05***	1.47***	1.44***	0.96***	0.96***	0.12	0.75***	1.94***	0.90***	0.96***	0.91***	1.27***
	(15.43)	(23.04)	(10.75)	(28.45)	(14.54)	(6.09)	(10.06)	(11.23)	(11.02)	(9.55)	(0.72)	(10.13)	(12.70)	(8.46)	(10.48)	(4.26)	(10.91)
$\hat{\beta}_2$	0.02***	0.02***	0.01	0.04***	0.02***	-0.006	0.02***	0.0002	0.02***	0.06***	0.02**	0.02***	0.06	0.01***	0.01***	-0.02	0.01***
	(9.40)	(8.16)	(1.41)	(5.78)	(6.00)	(1.40)	(5.68)	(0.06)	(8.86)	(2.27)	(2.52)	(6.20)	(1.85)	(5.45)	(3.78)	(0.92)	(5.54)
	0.02***	0.03***	0.02***	0.02***	0.02***	0.02***	0.03***	0.02***	0.02***	0.02***	-0.01***	0.02***	0.03***	0.01***	0.03***	0.01***	0.03***
	(18.79)	(35.98)	(14.23)	(25.65)	(12.79)	(7.09)	(8.41)	(9.55)	(13.72)	(12.88)	(2.84)	(12.38)	(13.04)	(7.43)	(13.13)	(3.74)	(16.71)
$\hat{\beta}_3$	1.02***	1.19***	1.48***	2.60***	1.14***	1.28***	1.60***	1.31***	1.25***	-0.001	0.67*	1.27***	3.39	0.95***	1.30***	1.51	0.82***
	(7.67)	(7.13)	(6.14)	(7.03)	(4.62)	(4.73)	(8.11)	(4.05)	(10.52)	(0.004)	(1.64)	(7.53)	(7.92)	(5.85)	(5.83)	(1.18)	(6.82)
	0.85***	1.11***	1.50***	1.23***	2.39***	1.62***	1.02**	0.82**	1.50***	0.21	2.29***	1.62***	0.72**	1.49***	0.89***	0.98	1.11***
	(4.97)	(7.15)	(5.71)	(9.60)	(10.08)	(2.95)	(2.31)	(2.08)	(5.84)	(0.62)	(4.61)	(6.82)	(1.76)	(4.97)	(4.05)	(1.58)	(3.92)
$\hat{\beta}_4$	-0.30***	-0.25***	-0.01	-0.10	-0.13	0.02	-0.24***	-0.03	-0.37***	-0.05	0.11	-0.25***	0.36	-0.17***	-0.22***	1.81***	-0.11***
	(7.70)	(4.93)	(0.18)	(0.67)	(1.53)	(0.19)	(3.13)	(0.31)	(9.16)	(0.56)	(0.68)	(3.37)	(2.08)	(3.00)	(2.60)	(3.09)	(2.90)
	-0.29***	-0.39***	-0.26***	-0.29***	-0.30***	-0.43***	-0.32***	-0.30***	-0.37***	-0.41***	0.07	-0.22***	-0.25***	-0.14**	-0.35***	-0.07	-0.36***
	(8.15)	(12.53)	(5.07)	(11.11)	(6.74)	(4.26)	(3.33)	(4.08)	(7.82)	(6.23)	(0.75)	(4.45)	(3.01)	(2.20)	(8.20)	(0.59)	(6.92)
$\hat{\beta}_5$	-0.10***	-0.15***	-0.18***	-0.13**	-0.24***	-0.05	-0.10***	-0.002	-0.13***	0.03	-0.32***	-0.22***	-0.17	-0.14***	-0.08*	-0.22	-0.03
	(3.97)	(4.71)	(3.23)	(1.88)	(4.74)	(0.91)	(2.35)	(0.03)	(4.33)	(0.83)	(3.29)	(5.28)	(1.89)	(4.10)	(1.74)	(0.70)	(1.34)
	-0.09***	-0.12***	-0.04	-0.16***	-0.08***	-0.04	-0.11**	-0.14***	-0.03	-0.14***	0.03	-0.07**	-0.19***	-0.02	-0.07***	-0.18***	-0.13***
	(4.13)	(6.33)	(1.25)	(9.37)	(2.94)	(0.69)	(2.02)	(3.06)	(0.86)	(3.47)	(0.43)	(2.20)	(3.46)	(0.63)	(2.69)	(2.80)	(3.71)
$\bar{R}^2$	0.98	0.98	0.95	0.93	0.92	0.84	0.97	0.78	0.97	0.55	0.87	0.97	0.88	0.97	0.96	0.57	0.90
	0.96	0.98	0.93	0.97	0.94	0.81	0.84	0.89	0.94	0.88	0.63	0.90	0.93	0.81	0.97	0.66	0.96
DW	0.39	0.27	0.32	0.27	0.19	0.63	0.45	0.38	0.47	0.78	0.34	0.35	0.31	0.52	0.35	0.32	0.51
	0.16	0.22	0.13	0.31	0.33	0.10	0.05	0.16	0.07	0.22	0.20	0.20	0.15	0.16	0.13	0.08	0.11
CADF	-4.95	-3.31	-3.42	-3.34	-2.99	-5.22	-4.39	-3.39	-2.88	-4.81	-3.22	-2.51	-3.30	-4.78	-3.36	-3.19	-5.26
	-3.97	-4.26	-4.11	-4.79	-4.07	-2.49	-2.00	-4.04	-3.10	-4.88	-4.17	-4.74	-4.20	-3.75	-4.42	-3.13	-3.12

Notes : Shaded rows correspond to the first subperiod (1983m11-1995m07, 140 observations) and unshaded rows to the second (1995m08-2024m09, 350 obs). Bootstrap t-statistics are provided in parentheses. $\hat{\beta}_i, i = 1, \dots 5$ are the slope coefficients of $X_{it}, i = 1, \dots 5,$ standing for the market factor, WTI price (log), default spread, CPI inflation and real GDP growth, respectively. Critical values for the CADF test : -3.27 and -3.24 at the 1% level for the first and second subperiods, respectively; -2.60 at the 5% level for both subperiods; and -2.27 at the 10% level for both subperiods.

Table 5 - Seemingly Unrelated Regression system estimation of equity risk premiums under an endogenous structural break (cont'd)

	MCD	MO	NEE	NUE	OMC	PG	RTX	SO	SPGI	TGT	TXN	UNP	VZ	WELL	WY	XOM
$\hat{c}$	-2.42***	0.32	2.75***	-4.04***	-2.51***	-2.36***	-0.89***	1.73**	-0.15	-1.86***	-2.53***	-2.72***	1.60***	5.62***	-1.00***	0.17
	(5.59)	(0.27)	(7.33)	(13.74)	(6.05)	(6.19)	(4.01)	(2.39)	(0.76)	(6.55)	(7.85)	(5.15)	(4.28)	(4.86)	(2.99)	(0.74)
	-1.12***	4.85***	0.73**	-0.74***	-0.69**	0.77***	-0.48**	1.85***	-0.46**	0.08	-1.32***	-0.67***	1.79)***	4.96***	0.30*	1.00**
	(7.48)	(9.05)	(2.15)	(4.58)	(2.44)	(3.05)	(2.06)	(14.27)	(2.41)	(0.27)	(6.34)	(5.62)	(8.79)	(23.09)	(1.89)	(2.21)
$\hat{\theta}$	-0.12***	-0.05	0.03	-0.01*	0.003	-0.04	0.04	-0.28**	-0.09***	-0.16***	-0.02*	0.09*	-0.07	-0.32***	-0.0001	-0.15***
	(3.02)	(0.67)	(1.31)	(1.71)	(0.06)	(1.23)	(1.60)	(2.42)	(3.35)	(3.90)	(1.86)	(1.59)	(0.88)	(2.76)	(0.005)	(4.02)
	-0.001	-0.21***	-0.001	-0.03***	-0.03	-0.15***	-0.04*	0.05**	-0.06***	-0.13***	-0.02	-0.02*	-0.10	-0.07	0.007	-0.17**
	(0.13)	(4.19)	(0.01)	(3.33)	(1.10)	(5.59)	(1.78)	(2.31)	(2.99)	(4.83)	(1.51)	(1.66)	(1.28)	(1.07)	(0.91)	(2.02)
$\hat{\beta}_1$	0.98***	1.46***	1.00***	1.03***	0.64***	0.70***	1.28***	-0.22	1.29***	0.92***	1.28***	0.85***	0.67***	0.31	1.01***	0.47***
	(19.74)	(6.11)	(8.15)	(16.61)	(6.54)	(6.76)	(18.45)	(1.31)	(12.44)	(6.38)	(12.99)	(7.83)	(5.52)	(1.18)	(11.20)	(6.30)
	1.20***	0.85***	0.52***	1.19***	1.69***	0.91***	1.14***	0.92***	0.85***	1.31***	1.55***	1.16***	1.07***	-0.53**	1.17***	1.86***
	(15.07)	(4.04)	(4.12)	(12.32)	(11.48)	(12.86)	(14.58)	(15.31)	(11.20)	(10.27)	(12.04)	(12.96)	(9.97)	(2.06)	(8.79)	(9.23)
$\hat{\beta}_2$	0.01***	0.01	0.03***	0.01***	-0.004	0.003	0.02***	-0.01	0.02***	0.005	0.02***	0.01**	0.02***	0.01	0.01***	0.003
	(8.12)	(1.26)	(5.68)	(3.21)	(0.83)	(0.75)	(7.49)	(1.27)	(6.53)	(1.31)	(5.65)	(2.38)	(4.08)	(0.68)	(2.98)	(0.71)
	0.04***	0.02***	0.01***	0.03***	0.03***	0.02***	0.02***	0.02***	0.02***	0.04***	0.03***	0.02***	0.03***	-0.02***	0.02***	0.03***
	(25.83)	(6.56)	(5.22)	(18.17)	(10.87)	(19.47)	(17.82)	(15.24)	(14.80)	(13.38)	(12.76)	(9.20)	(14.15)	(5.01)	(7.11)	(6.35)
$\hat{\beta}_3$	1.25***	0.55	1.05***	1.32***	1.64***	0.77***	2.17***	-0.52	1.79***	1.23***	1.49***	0.81***	0.44	-0.03	1.22***	0.56***
	(10.36)	(1.07)	(4.63)	(6.60)	(6.15)	(3.66)	(11.97)	(1.08)	(9.30)	(4.98)	(7.81)	(4.04)	(1.43)	(0.05)	(4.82)	(2.86)
	1.43***	0.11	1.17***	2.04***	1.28***	1.17***	0.99***	0.96***	1.10***	1.07***	1.39***	1.12***	-0.14	2.90***	1.79***	0.80
	(6.09)	(0.18)	(4.09)	(7.11)	(3.09)	(6.33)	(4.48)	(4.53)	(5.86)	(2.76)	(3.82)	(4.33)	(0.46)	(5.10)	(4.70)	(1.48)
$\hat{\beta}_4$	-0.26***	-0.56***	0.06	-0.24***	0.37***	-0.18**	-0.11**	0.15	-0.22***	0.09	-0.33***	-0.11**	-0.34*	0.63**	0.16**	-0.02
	(7.11)	(3.12)	(0.62)	(3.64)	(4.11)	(2.52)	(1.80)	(0.79)	(4.21)	(1.02)	(3.82)	(2.03)	(2.56)	(2.71)	(1.92)	(0.17)
	-0.48***	0.06	-0.26***	-0.46***	-0.26***	-0.32***	-0.28***	-0.33***	-0.31***	-0.45***	-0.38***	-0.27***	-0.27***	0.02	-0.34***	-0.33***
	(10.87)	(0.43)	(4.40)	(8.18)	(3.06)	(8.84)	(6.52)	(8.18)	(8.80)	(5.85)	(5.06)	(4.96)	(3.70)	(0.19)	(4.49)	(2.87)
$\hat{\beta}_5$	-0.10***	-0.03	-0.12***	-0.16***	-0.10**	-0.04	-0.10**	0.08	-0.20***	-0.11***	-0.26***	-0.13***	0.07	-0.18	-0.32***	-0.01
	(3.38)	(0.27)	(2.75)	(3.44)	(1.95)	(0.93)	(2.41)	(0.89)	(4.90)	(3.21)	(5.76)	(4.06)	(1.02)	(1.34)	(5.68)	(0.30)
	-0.08***	-0.36***	0.03	-0.10***	-0.15***	-0.07***	-0.13***	-0.02	-0.07***	-0.07	-0.11**	-0.07**	-0.21***	0.14*	-0.11**	-0.20***
	(2.99)	(4.40)	(0.74)	(3.05)	(2.88)	(3.19)	(4.91)	(0.65)	(3.15)	(1.43)	(2.46)	(2.20)	(4.68)	(1.61)	(2.61)	(2.89)
$\bar{R}^2$	0.98	0.85	0.83	0.96	0.83	0.86	0.97	0.43	0.98	0.97	0.96	0.94	0.74	0.73	0.92	0.85
	0.97	0.77	0.81	0.96	0.91	0.98	0.96	0.90	0.93	0.92	0.93	0.92	0.89	0.49	0.87	0.86
DW	0.42	0.24	0.59	0.27	0.66	0.30	039	0.41	0.39	0.43	0.35	0.37	0.48	0.40	0.40	0.53
	0.15	0.18	0.18	0.14	0.09	0.19	0.14	0.40	0.14	0.11	0.06	0.10	0.20	0.21	0.16	0.13
CADF	-4.01	-2.65	-4.64	-3.94	-2.83	-3.62	-4.05	-2.86	-4.05	-5.33	-3.82	-3.77	-3.23	-3.72	-3.78	-3.38
	-4.53	-3.99	-3.64	-4.15	-1.97	-4.17	-4.88	-4.01	-2.90	-3.72	-2.27	-3.63	-4.63	-3.60	-2.92	-4.74

See notes to the first part of the Table.

Table 6 - Summary results: significance and sign of SUR estimates under structural break

	significance	sign (among signif.coef.)
$\hat{\theta}$	52.38%	92.65% of λ_i ∈[0,1]
$\hat{\beta}_1$	95.24%	(+) 97.77%
$\hat{\beta}_2$	86.15%	(+) 95.55%
$\hat{\beta}_2$	81.83%	(+) 100 %
$\hat{\beta}_4$	90.95%	(-) 93.52%
$\hat{\beta}_5$	73.16%	(-) 97.14%

Note: Columns 2 and 3 report, respectively, the percentage of significant cross-sectional estimates and the percentage of positive or negative values of the indicated coefficient at the 10% level. The proportions are expressed as a weighted average of the proportions before and after the estimated break (1995m08), where the weights are the relative lenghts of the subperiods (0.285 and 0.715). $\hat{\beta}_i, i = 1, \dots 5$ are the slope coefficients of $X_{it}, i = 1, \dots 5,$ standing for the market factor, WTI price (log), default spread, CPI inflation and real GDP growth, respectively

6.2 Fundamental values

In this section we focus on constructing the fundamental values of equities based on the estimation of the system of equations (8). First, we generate a refined time series for the denominator of Eq(1) over the entire period by using, for each subperiod, the corresponding parameter estimates. We unify the two segments around the breakdate $t^* = 1995\text{m}08$ by smoothing the fitted values within a 2-year window centered on t^* (see Appendix)

We can then calculate the fundamental value of each equity over the full period using Eq(7). It is worth noting that $r_{0t} + \widehat{\varphi_{\iota t} - \tilde{g}_{\iota t}}$ is subject to the transversality condition that its values must be non-negative and must not fall too close to zero. In either case, $\hat{F}_{it}$ would take on irrelevant values. One or both of these conditions were locally violated for a few observations across nine firms, resulting in 14 negative values and 251 values below a certain threshold under which $\hat{F}_{it}$ exhibits an unfounded volatility peak. These undesirable cases are extremely rare, representing only 265 instances out of 33x491=16203 total observations, that is, just 1.64% of the cumulated sample. This very low frequency indicates that in nearly all instances our DGM-APT framework with endogenous break is well-suited for producing economically relevant estimates of fundamental values. To restore the transversality conditions in the anomalous cases, we eliminate the irregularities by appropriately increasing the intercept $\hat{c}_i$ in Eq.(6) over the segment in which the abnormal values occur, provided that the augmented intercept remains within the 95% confidence interval of $\hat{c}_i$.[9] This restriction ensures the legitimacy of our correction, as it remains within the bounds of the uncertainty

[9] More formally, let J denote a segment of consecutive dates centered on the divergent value. For a minimum permissible threshold α_i, ranging near 0.3 depending on the firm, we select a value $d_i > 0$ such that $d_i = \alpha_i - \min_{t \in J}(r_{0t} + \widehat{\varphi_{\iota t} - \tilde{g}_{\iota t}})$ subject to the restriction $\hat{c}_i + d_i \in [\hat{c}_i - 2\hat{\sigma}_{\hat{c}_i}\ ,\ \hat{c}_i + 2\hat{\sigma}_{\hat{c}_i}]$, which implies $d_i \leq 2\hat{\sigma}_{\hat{c}_i}$. We then shift the trough within J upward by portions of d_i so as to suitably flatten its curvature.

associated with the estimation of the intercept, thereby leaving the theoretical analysis of the model unchanged.

Figure 3 presents the equity prices and the associated fundamental values. Our fundamental values capture both the trends and a substantial part of equity price fluctuations, although large deviations occasionally arise. In this respect, the last two columns of Table 7 reveal a significant correlation between changes in prices and changes in fundamentals. Moreover, although fundamental values show a slightly lower average variability than equity prices (columns 3 and 4), the difference is not significant.[10] We can therefore conclude that they are similar. This contrasts with the evidence reported in the literature on stock price indices, which states that fundamental values are consistently smoother than market prices, situation referred to as the "volatility puzzle" (see section 2). Overall, two key considerations enable us to generate fundamental values with volatility levels comparable to those observed in market prices. First, our framework explicitly ties fundamental values to expected firm-specific dividend growth rates through the DGM. Second, it incorporates firms' individual sensitivities to various common factors via the APT structure. These components introduce heterogeneity and make it possible to generate fundamental values that broadly align with observed prices.

[10] A simple t-test is performed to test the null hypothesis that the difference in means is zero. Let $\bar{x}_P$, $\bar{x}_F$ and $\hat{\sigma}_{(\bar{x}_P-\bar{x}_F)}$ denote the average variability in the changes in P_t and in $\hat{F}_t$ and the empirical standard deviation of the difference in means, respectively. For our non-independent samples the resulting t-statistic is $t=\sqrt{33}\,(\bar{x}_P-\bar{x}_F)/\hat{\sigma}_{(\bar{x}_P-\bar{x}_F)}=1.14$. Given the critical value of 1.70 at the 5% level of significance with 32 d.o.f., we do not reject the null.

Figure 3 - Equity prices and fundamental values

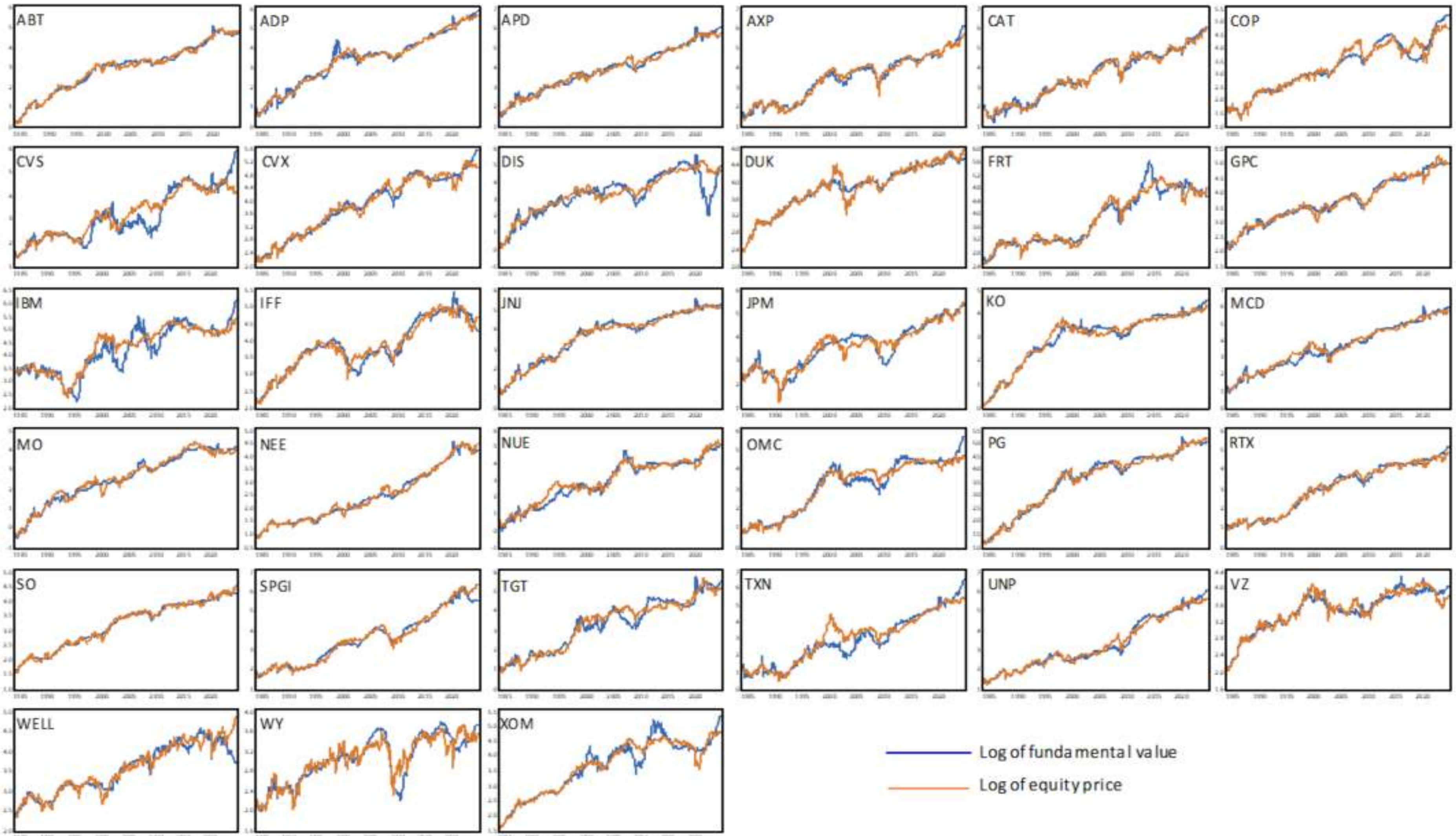


Table 7 - Statistical comparison between equity prices and fundamental values

Firm	RMSE	$\sigma(\ln \frac{P_t}{P_{t-1}})$	$\sigma(\ln \frac{F_t}{F_{t-1}})$	$r(\ln \frac{P_t}{P_{t-1}}, \ln \frac{F_t}{F_{t-1}})$	$r(\ln \frac{P_t}{P_{t-12}}, \ln \frac{F_t}{F_{t-12}})$
ABT	12.02	71.05	57.13	0.48	0.62
ADP	18.81	73.42	118.86	0.45	0.47
APD	18.16	86.62	79.48	0.41	0.30
AXP	17.08	101.74	89.56	0.64	0.77
CAT	17.55	107.14	88.00	0.50	0.62
COP	24.19	100.66	46.55	0.43	0.53
CVS	43.61	89.63	122.51	0.32	0.28
CVX	14.69	76.34	46.38	0.42	0.48
DIS	58.20	97.21	177.37	0.46	0.31
DUK	11.73	66.56	32.82	0.16	0.53
FRT	20.17	77.37	69.89	0.23	0.38
GPC	11.27	69.41	51.94	0.51	0.52
IBM	38.09	88.49	134.86	0.24	0.32
IFF	17.67	85.36	64.28	0.42	0.49
JNJ	14.44	67.42	84.47	0.46	0.49
JPM	30.66	111.51	72.39	0.29	0.50
KO	19.10	68.76	70.09	0.36	0.52
MCD	23.10	70.88	110.26	0.43	0.43
MO	19.65	87.37	69.77	0.24	0.42
NEE	12.80	66.35	47.29	0.13	0.45
NUE	29.04	118.47	111.70	0.48	0.50
OMC	28.98	98.31	101.75	0.32	0.54
PG	12.24	67.33	53.64	0.31	0.50
RTX	14.93	88.79	63.12	0.57	0.54
SO	8.28	59.61	24.37	0.10	0.48
SPGI	18.65	85.39	67.87	0.55	0.65
TGT	31.82	102.73	122.80	0.31	0.38
TXN	51.69	124.29	128.94	0.46	0.39
UNP	19.72	82.56	63.79	0.46	0.42
VZ	12.80	72.16	51.23	0.23	0.49
WELL	19.66	79.44	66.69	0.15	0.33
WY	18.49	101.81	55.49	0.54	0.61
XOM	23.22	67.86	75.81	0.26	0.42
Average	22.20	85.21	79.43	0.37	0.48

Note: As the fundamental values incorporate the structural break, the calculations were performed over the whole period (1983m11-2024m09). The RMSEs are expressed in percent and the standard-deviations in percent per year.

6.3 Analysis of the deviations between equity prices and fundamental values

This section examines the result that, although our equity prices and their fundamental values exhibit similar volatilities, they display short term deviations that vary in magnitude across firms (Figure 3). Table 5 reports a root mean square error (RMSE)-based measure of these deviations for each firm and shows that prices deviate from their fundamental values by 22% on average. Note that the individual RMSEs reveal substantial heterogeneity across firms (deviations are around 10% for some firms and 50% for others), thus underscoring the relevance of conducting the analysis at the firm level. Moreover, the average pairwise correlation of the considered deviations is only 0.25, indicating the presence of a dominant firm-specific component in the dynamics of the deviations. Furthermore, Figure 4 indicates that individual deviations exhibit serial dependence, as confirmed by the Ljung-Box test statistics for the log-deviations $\ln(P_{it}/\hat{F}_{it})$ reported in the last row of Table 8. These persistent divergences suggest the influences of firms' specific factors or omitted common factors. Such deviations may, in turn, help explain the autocorrelations observed in the SUR residuals, as documented in section 6.1.

A central question is therefore to assess the extent to which, when a deviation arises, equity prices tend to adjust toward their fundamental values - i.e., whether the market converges to allocative efficiency. To address this issue, one must account for the existence of market frictions, such as transaction costs (Anderson, 1997), and the risky arbitrage due to the uncertainty associated with the assessment of the fundamental value (Shleifer and Summers, 1990, Jawadi and Prat, 2012).[11] As shown by the authors, such frictions may induce delays in the adjustment of prices towards fundamental values. For any equity, this adjustment mechanism is driven by the presence of investors who engage in arbitrage when they observe price deviations. When investors observe a positive or negative deviation, they are prompted to take positions that are potentially profitable, possibly involving short selling or borrowing, respectively. For some investors, the absolute deviation may exceed their arbitrage costs (defined as the sum of transaction costs and a risk premium for arbitrage), leading them to contribute to a mean-reverting process that pushes market prices toward fundamental values. For others, however, arbitrage costs may outweigh the observed deviation, preventing them from participating in the adjustment. Nevertheless, given that the first group of investors is unlikely to disappear, we may reasonably consider that a market force exists which at any time encourages convergence towards fundamentals. The greater the proportion of these arbitrageurs, the stronger the adjustment force is likely to be. Accordingly, under the simplifying assumption that the relative proportions of these two investor groups remain stable over time, we estimate a simple linear Error Correction Model (ECM) to examine the existence and dynamics of delayed adjustments between equity market prices and fundamental values:[12]

[11] The fundamental value of a given equity is supposed common knowledge for stockholders but each of them has their own appreciation of uncertainty about this value.

[12] Recall that the basic specification of the ECM can be written as $\Delta p_{it} = c_i + \rho_i\left(p_{i,t-1} - \hat{f}_{i,t-1}\right) + \sum_{m=1}^{M} \alpha_{im}\, \Delta p_{i,t-m} + \sum_{n=0}^{N} \beta_{in}\, \Delta \hat{f}_{i,t-n} + \sum_{k=1}^{K} b_{ik}\, \Delta S_{k,t} + \nu_{it}$. Under the long-term equilibrium condition that price and fundamental value grow at the same rate ($\beta_{i0} = 1$) and assuming homogeneity in short term responses to

$$\Delta z_{it} = c_i + \rho_i z_{i,t-1} + \sum_{j=1}^{J} a_{ij}\, \Delta z_{i,t-j} + \sum_{k=1}^{K} b_{ik}\, \Delta S_{kt} + \nu_{it}\ , \quad \rho_i < 0 \qquad (9)$$

where $z_{it} = p_{it} - \hat{f}_{it}$ denotes the log-deviation for firm i expressed in percent, p_{it} is the log of the observed price P_{it} and $\hat{f}_{it}$ is the log of the estimated fundamental value $\hat{F}_{it}$. The error-correction parameter ρ_i measures the speed of the adjustment process. The control variables S_{kt} capture short-term influences in the dynamic adjustment process. They fall into two categories: firm-specific factors and macroeconomic variables (different than those selected for the risk premiums). Four firm-specific factors are uninterruptedly available over our sample period for all firms: (i) the dividends-to-earnings ratio, (ii) turnover by volume, (iii) book value and (iv) the cash-flow-to-sales ratio. The three macroeconomic variables used are (i) the term spread between the 20-year Treasury bond yield and the 3 month Treasury Bill rate, (ii) the year-over-year change in the nominal money supply M2, and (iii) the logarithm of US$ real effective exchange rate. All of these variables enter Eq(9) in demeaned form. As with the equity risk premium model given by Eq(6), Eq(9) is estimated as a system across our panel of 33 equities to account for interdependencies in price adjustments - namely, the possibility that some securities may be overvalued while others are simultaneously undervalued, which can lead to arbitrages between different equities through sales for some of them and purchases for others.

Estimation results for Eq(9) over the whole period are reported in Table 8. Our findings reveal several interesting points. First, all of the 33 error-correction parameters ρ_i are negative and statistically significant at the 1% level, suggesting the existence of a systematic mechanism by which prices converge toward their fundamental values. This result strengthens the credibility of our fundamental value specification, supporting the view that our fundamental values represent a long-term target for equity prices. Our firms are fairly evenly distributed across different speeds of adjustment, ranging from -0.01 to -0.12: the adjustment speed is slow for 11 firms ($|\rho_i| < 0.05$), slow to moderate for another 11 firms ($0.05 \leq |\rho_i| < 0.10$) and moderate for the remaining 11 firms ($|\rho_i| \geq 0.10$). This translates into half-lives of deviation shorter than 6.6 months for the fastest-adjusting firms and longer than 13.5 months for the slowest-adjusting firms.[13] This balanced dispersion of adjustment speeds suggests that arbitrage costs vary across equities, these costs including transaction costs as well as arbitrage risk arising from uncertainty in the measurement of fundamental values. Concerning the control variables, only one firm-specific factor significantly influences a majority of firms (18): turnover by volume. Among the macroeconomic factors, firms are sensitive to all three, with a particularly strong response (25 firms) to changes in nominal money supply (M2).

Residual diagnostic tests for our ECM residuals lead to the following results. The Breusch-Godfrey LM test shows that the null of no autocorrelation fails to be rejected for 30 firms over 33 at the 5% level of significance. The absence of serial correlation in almost all residuals suggests that the model captures the short term dynamics well. However, this

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past changes in prices and fundamental values ($\alpha_{im} = \beta_{in}$ for $m = n$), we obtain, after rearrangement, Eq(9). We allow the intercept to differ from zero since there is no a priori reason to expect the mean of the deviations to be null over the sample period.

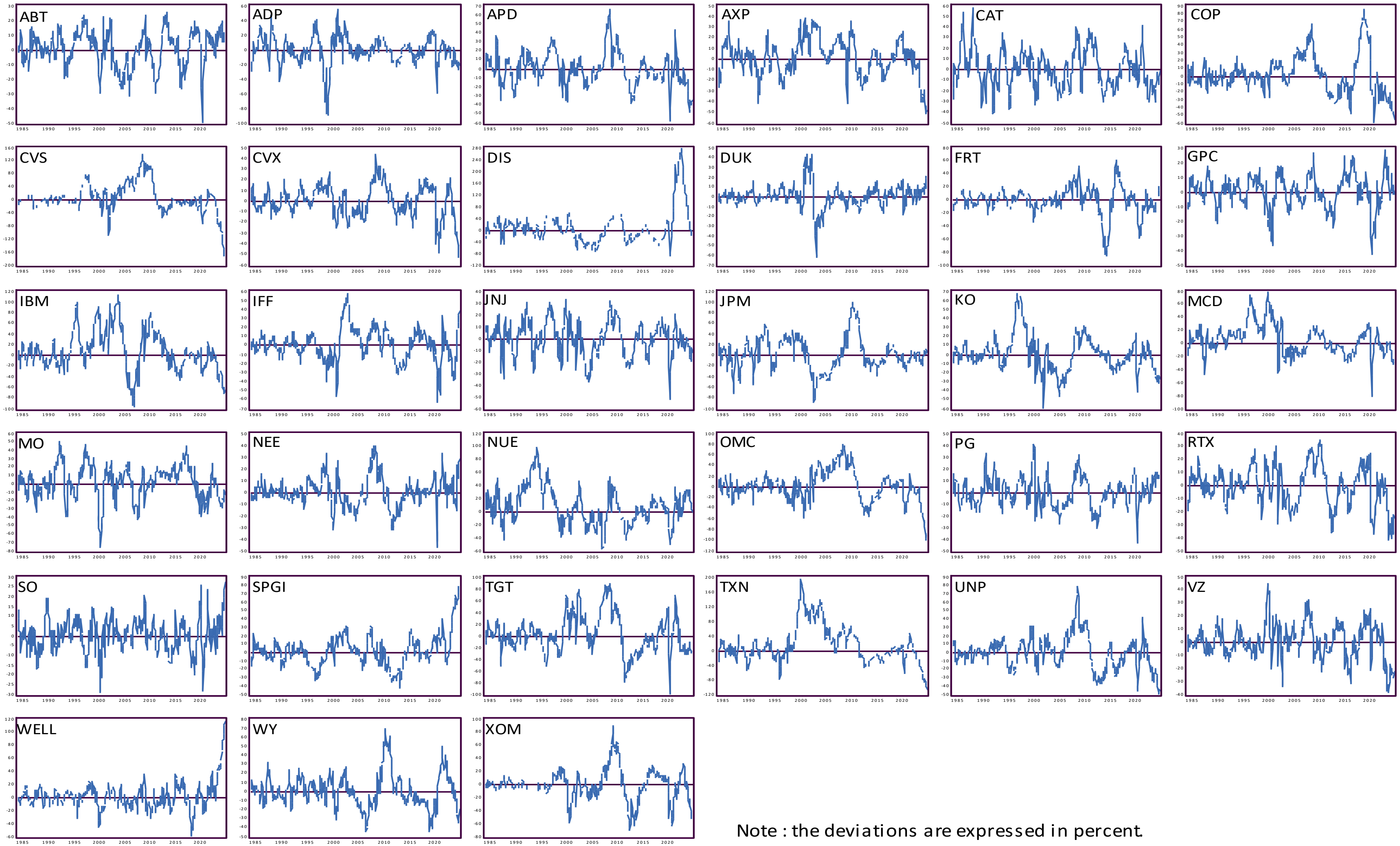
[13] The half-life of a deviation is the horizon h_i at which the deviation is reduced by half, i.e. $(1 + \hat{\rho}_i)^{h_i} = 1/2$, which implies that $h_i = \mathrm{Log}(0.5)/\mathrm{Log}(1 + \hat{\rho}_i)$.

encouraging result contrasts with a number of other tests. First, the adjusted coefficients of determination are very low, indicating that the model explains only a small portion of the variability in the deviation. Also, ARCH F-tests reject the null hypothesis of no heteroskedasticity for 20 firms at the 5% level (25 at the 10% level). This points to volatility clustering and, more specifically, to adjustment speeds or control variable coefficients that may change across regimes, which the linear model does not account for. Additionally, the widespread non-normality revealed by the Jarque-Bera test suggests that the linear model may overlook some aspects of the data's underlying distribution. This non-normality stems primarily from high kurtosis (statistics not provided but available), which aligns with the presence of heteroskedasticity. Finally, recall that the deviations include a structural change at August 1995 which is embedded in the parameters of the fundamental values. While the ECM therefore implicitly incorporates this break, it does not preclude potential instability in the short term adjustment dynamics. To explore this, we split the sample into two equal subperiods and performed a Wald test for equality before and after the median date. The test rejected the null of equality at all levels, indicating parameter instability and revealing the limitations of the linear framework in modeling the adjustment process.

A nonlinear ECM could then provide a more accurate description of the adjustment of prices to fundamentals, as has been done in some studies at the aggregate level with stock price indices. This approach could present an interesting avenue for future research. Such a process, where the strength of the mean-reverting mechanism depends on the size of the deviation, could better capture the variability in the percentage of investors for whom arbitrage costs either exceed or fall below their expected arbitrage profits.[14]

[14] This suggests the implementation of a Smooth Transition Error Correction Model (STECM), as applied by Jawadi and Prat (2012) for the G7 stock market indices.

Figure 4 – Deviations (in logarithms) of equity prices from their fundamental values



Note : the deviations are expressed in percent.

Table 8 - Seemingly Unrelated Regression estimation of equity price adjustment toward fundamentals

		ABT	ADP	APD	AXP	CAT	COP	CVS	CVX	DIS	DUK	FRT	GPC	IBM	IFF	JNJ	JPM	KO
dynamic variables	$\hat{\rho}$	-0.11***	-0.06***	-0.10***	-0.07***	-0.10***	-0.04***	-0.03***	-0.06***	-0.02***	-0.10***	-0.05***	-0.10***	-0.04***	-0.09***	-0.12***	-0.06***	-0.05***
		(6.47)	(4.04)	(7.15)	(3.96)	(5.62)	(3.65)	(3.86)	(4.92)	(2.77)	(6.19)	(3.79)	(5.87)	(4.44)	(5.87)	(8.18)	(4.81)	(4.25)
	$\hat{a}_1$	-0.01	-0.02	0.05	-0.03	-0.04	0.01	0.01	-0.07**	0.02	-0.03	-0.07**	-0.05	0.03	0.01	0.03	0.06	-0.07**
		(0.37)	(0.5)	(1.57)	(0.85)	(1.21)	(0.16)	(0.25)	(2.44)	(0.55)	(0.82)	(2.01)	(1.17)	(0.82)	(0.22)	(1.07)	(1.51)	(2.30)
	$\hat{a}_2$	0.03	-0.12***	0.01	-0.05	0.01	-0.11***	0.04	-0.01	0.03	-0.05*	0.01	0.01	-0.02	0.02	-0.00	0.02	-0.03
		(0.69)	(3.65)	(0.29)	(1.22)	(0.24)	(2.85)	(1.15)	(0.42)	(0.89)	(1.64)	(0.24)	(0.23)	(0.72)	(0.54)	(0.15)	(0.63)	(0.92)
firm-specific variables	$\hat{b}_1$	-0.15***	0.11	0.04	0.03	0.00	0.02	-0.01	-0.00	0.02	0.01	0.00	-0.00	-0.01	0.01*	0.06	0.05**	0.02
		(3.39)	(0.88)	(1.04)	(0.61)	(0.26)	(0.92)	(0.52)	(0.27)	(0.24)	(0.85)	(0.39)	(0.24)	(0.46)	(1.66)	(0.85)	(1.99)	(0.35)
	$\hat{b}_2$	-0.91***	-2.92*	-4.33	-0.44	-0.94	-1.33**	-3.13***	-1.96***	0.58	-8.25***	12.50	-4.11	-3.24***	-10.2***	-0.30***	-0.24	-0.70***
		(2.66)	(1.65)	(1.42)	(0.73)	(0.99)	(2.41)	(4.89)	(4.68)	(1.00)	(6.65)	(1.48)	(0.86)	(4.19)	(3.16)	(2.96)	(0.84)	(2.80)
	$\hat{b}_3$	1.03**	-0.01	-0.35	-0.25	-0.59	0.03	-0.04	0.00	0.04	0.47**	0.96*	-0.24	0.59	0.15	0.40	-0.15	-2.34
		(2.04)	(0.01)	(1.40)	(0.46)	(1.54)	0.12	(0.09)	(0.00)	(0.09)	(2.34)	(1.60)	(0.45)	(1.47)	(1.08)	(0.80)	(0.48)	(1.45)
	$\hat{b}_4$	-0.07	-0.08	-0.27	0.02	0.22	0.02	0.19	0.03	0.09	-0.20*	-0.30	-2.07	-0.13	-0.29	0.22	0.03	0.17
		(0.28)	(0.15)	(1.19)	(0.13)	(0.49)	(0.10)	(0.14)	(0.14)	(0.56)	(1.82)	(0.89)	(1.37)	(0.34)	(0.58)	(1.23)	(0.23)	(0.85)
macro variables	$\hat{b}_5$	1.41*	7.65***	-0.39	1.37	2.35*	-1.65	4.96***	1.22	2.56	0.73	-4.60***	1.08	4.95***	0.55	4.16***	-0.84	1.96**
		(1.64)	(5.67)	(0.34)	(1.27)	(1.80)	(1.38)	(3.10)	(1.34)	(1.22)	(0.83)	(3.86)	(1.32)	(2.73)	(0.52)	(4.11)	(0.55)	(1.96)
	$\hat{b}_6$	-0.55*	-1.91***	-2.53***	-1.12***	-0.10	-0.72*	-4.01***	-1.01***	-3.65***	0.17	-0.05	-0.66**	-3.58***	-1.71***	-1.53***	-0.78	-2.32***
		(1.78)	(3.91)	(6.06)	(2.87)	(0.23)	(1.65)	(6.87)	(3.06)	(4.78)	(0.55)	(0.11)	(2.25)	(5.46)	(4.40)	(4.17)	(1.44)	(6.33)
	$\hat{b}_7$	-0.17	-0.25	-0.36*	-0.30	0.75***	-0.58***	-0.09	-0.22	0.59	-0.30*	0.33	0.16	-0.97***	-0.27	-0.37**	-0.21	-0.36*
		(1.06)	(0.98)	(1.62)	(1.44)	(3.00)	(0.01)	(0.29)	(1.24)	(1.5)	(1.80)	(1.43)	(1.00)	(2.80)	(1.32)	(1.91)	(0.73)	(1.89)
$\bar{R}^2$		0.09	0.13	0.12	0.04	0.06	0.06	0.11	0.08	0.06	0.11	0.05	0.06	0.10	0.09	0.12	0.03	0.10
BG LM		0.70	0.12	0.05	0.99	0.31	0.99	0.17	0.91	0.23	0.75	0.18	0.98	0.44	0.80	0.02	0.00	0.64
ARCH F		0.00	0.00	0.054	0.76	0.055	0.00	0.01	0.00	0.02	0.03	0.00	0.00	0.68	0.11	0.00	0.04	0.00
JB		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG LM (z_{it})		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes : Intercepts were excluded from the final estimation due to their systematic insignificance. The coefficients $\hat{a}_j,\ j = 1,2,3$ correspond to the lagged deviation, the change in the deviation at t-1 and the change in the deviation at t-2, respectively. The coefficients $\hat{b}_k,\ k = 1, \dots, 4$ relate to firm-specific dividend payout, turnover by volume, book value and cash-flow-to-sales ratio. The coefficients $\hat{b}_k,\ k = 5, 6, 7$ are associated with the term spread, the change in nominal M2, and the change in the real effective exchange rate of the US dollar. Entries for the Breusch-Godfrey (BG) LM test for no autocorrelation (4 lags), ARCH F test for no heteroskedasticity (1 lag) and Jarque-Bera (JB) test for normality are the corresponding p-values. The last row presents the BG LM test for autocorrelation in the deviation z_{it}. t-statistics are reported in parentheses. *,** and *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 8 - Seemingly Unrelated Regression estimation of equity price adjustment toward fundamentals (cont'd)

		MCD	MO	NEE	NUE	OMC	PG	RTX	SO	SPGI	TGT	TXN	UNP	VZ	WELL	WY	XOM
dynamic variables	$\hat{\rho}$	-0.07***	-0.09***	-0.11***	-0.04***	-0.06***	-0.10***	-0.10***	-0.10***	-0.04***	-0.07***	-0.03***	-0.08***	-0.11***	-0.05***	-0.06***	-0.05***
		(5.92)	(5.65)	(6.14)	(3.35)	(4.92)	(5.82)	(6.48)	(4.81)	(3.15)	(6.35)	(3.22)	(5.87)	(5.51)	(3.60)	(4.18)	(5.06)
	$\hat{a}_1$	0.01	0.08**	-0.09***	-0.06	-0.01	0.06*	-0.10***	-0.01	-0.04	-0.04	0.02	-0.01	-0.02	-0.04	-0.13***	0.06**
		(0.21)	(2.02)	(2.63)	(1.48)	(0.18)	(1.84)	(2.67)	(0.28)	(0.96)	(1.33)	(0.5)	(0.39)	(0.47)	(1.13)	(3.31)	(2.16)
	$\hat{a}_2$	-0.06*	-0.03	0.02	-0.06	-0.06*	0.00	0.01	-0.17***	0.02	-0.02	-0.00	-0.04	0.01	0.05	-0.00	-0.02
		(1.84)	(0.81)	(0.73)	(1.50)	(1.87)	(0.05)	(0.26)	(5.46)	(0.59)	(0.49)	(0.11)	(0.98)	(0.16)	(1.32)	(0.04)	(0.88)
specific variables	$\hat{b}_1$	0.16*	-0.00	0.01	-0.01	0.10	-0.01	-0.02	-0.01	-0.01	0.03	0.19**	0.03	0.00	-0.00**	0.00	0.04**
		(1.84)	(0.09)	(0.76)	(1.02)	(1.30)	(0.21)	(0.75)	(0.72)	(0.59)	(0.81)	(2.12)	(1.32)	(0.38)	(2.00)	(0.26)	(2.29)
	$\hat{b}_2$	-0.28	-0.79***	-0.58	1.51	-12.8***	-0.65**	-2.28***	-2.64***	-9.18***	-0.71	-0.77	-0.49	-0.60**	-1.86	-1.45	-1.06***
		(0.37)	(5.51)	(1.39)	(0.77)	(7.29)	(2.00)	(4.27)	(3.63)	(5.00)	(0.88)	(1.21)	(0.55)	(2.30)	(0.77)	(1.47)	(4.51)
	$\hat{b}_3$	0.12	0.28	-0.65	0.17	-0.71	0.07	0.35	-0.51	-0.02	0.25	1.60	0.26	0.22	1.15**	-0.52	0.42
		(0.32)	(0.32)	(0.79)	(0.66)	(0.72)	(0.24)	(1.46)	(0.75)	(0.31)	(0.35)	(1.16)	(0.59)	(0.59)	(1.96)	(0.81)	(1.41)
	$\hat{b}_4$	-0.09	0.05	0.24*	-0.95**	-0.61	-0.41	0.48	0.02	0.31	1.78	0.73**	0.01	-0.16	-0.04	0.07	0.26
		(0.17)	(0.21)	(1.61)	(2.03)	(0.65)	(0.97)	(1.40)	(0.20)	(1.50)	(1.53)	(2.00)	(0.07)	(0.57)	(0.28)	(0.41)	(0.73)
macro variables	$\hat{b}_5$	1.79	2.22*	-0.79	1.79	0.78	1.15	1.23	-2.18***	0.78	3.00*	5.62***	1.23	2.98***	-4.66***	0.46	2.14*
		(1.33)	(1.76)	(0.79)	(1.13)	(0.53)	(1.25)	(1.34)	(2.76)	(0.79)	(1.74)	(3.30)	(1.20)	(2.94)	(3.66)	(0.39)	(1.88)
	$\hat{b}_6$	-1.87***	0.06	-1.24***	-0.07	-3.45***	-1.36***	-2.11***	-0.53*	-0.58*	-3.76***	-2.77***	-2.33***	-0.02	0.83*	-0.82**	-1.35***
		(3.87)	(0.13)	(3.50)	(0.13)	(6.49)	(4.11)	(6.24)	(1.87)	(1.66)	(5.97)	(4.50)	(6.27)	(0.05)	(1.83)	(2.00)	(3.28)
	$\hat{b}_7$	-0.26	-5.08	-0.24	-0.52*	-0.20	-0.09	-0.49***	0.01	-0.14	-0.26	-0.51	-0.12	-0.66***	0.14	0.43**	1.18
		(1.01)	(0.21)	(1.29)	(1.74)	(0.70)	(0.53)	(2.80)	(0.04)	(0.78)	(0.80)	(1.57)	(0.62)	(3.40)	(0.58)	(1.98)	(0.05)
$\bar{R}^2$		0.06	0.09	0.08	0.02	0.14	0.10	0.15	0.12	0.05	0.08	0.07	0.07	0.09	0.03	0.03	0.07
BG LM		0.48	0.92	0.30	0.42	0.76	0.85	0.26	0.14	0.83	0.31	0.64	0.13	0.20	0.48	0.35	0.58
ARCH F		0.00	0.78	0.31	0.053	0.18	0.13	0.08	0.02	0.28	0.00	0.00	0.055	0.00	0.00	0.04	0.00
JB		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG LM (z_{it})		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

See notes to the first part of the Table.

7. Conclusion

This paper aims to determine the fundamental values of equities at the firm level. Investors are endowed with an allocative rationality, enabling them to construct efficient portfolios. To be consistent with this type of rationality, the stock valuation principle acknowledges the fact that only non-diversifiable risk is rewarded through returns to stockholders. Accordingly, contrary to many studies in the literature which rely on informational rationality and assume rational expectations, our framework combines the equity valuation principle based on the dividend growth model (DGM) with the arbitrage pricing theory (APT). According to this approach, although dividend levels and growth rates are firms-specific determinants of fundamental values, risk premiums are assumed to only depend on factors that are common to all equities.

To assess the empirical relevance of our DGM-APT model, we used a sample of 33 equities of the S&P500 stock price index. Our methodology yields estimates that are robust to heteroscedasticity and contemporaneous correlation of residuals across firms. It also accounts for potential instability in parameters by identifying a structural break in the parameters and controls for residual autocorrelation using bootstrap methods. We identify five significant common factors driving risk premiums: the market factor, the interest rate default spread, the oil price, the inflation rate and the real GDP growth rate. These factors align with those commonly found in empirical APT literature. Our estimated fundamental values capture both the trends and the main fluctuations of equity prices. On average across firms, the variances of equity prices and fundamental values are found to be significantly similar, indicating the absence of the so-called "volatility puzzle". This contrasts sharply with results from the literature on stock price indices, which systematically report smoother fundamental values than observed prices, especially under the assumption of rational expectations. Within our DGM-APT framework, the absence of a volatility puzzle can be attributed to the dual role of (i) common factors affecting individual risk premiums, to which each firm responds with its own sensitivity, and (ii) firm-specific dividend levels and growth rates. These findings suggest that allocative rationality—which reflects the actual behavior of market participants—provides a more accurate representation of equity price dynamics than the rational expectations hypothesis, which relies on implausible cognitive assumptions.

However, our firm-level results based on a linear error correction model (ECM) confirm that, due to arbitrage costs, equity prices adjust only gradually toward their fundamental values. Nevertheless, the ECM parameters are found to be unstable over time and the residuals exhibit poor statistical properties. These issues point to a misspecification in the linear adjustment mechanism, suggesting the need for a nonlinear specification – an avenue to be explored in future research.

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Appendix

Once model (8) is estimated and a significant breakdate t^* identified, the denominator of Eq(7) can be given a full period coverage by smoothly combining around the break the estimates obtained over the successive subperiods:

$$r_{0t} + (\widehat{\varphi_{\iota t} - \tilde{g}_{\iota t}}) = r_{0t} + (1 - u_t)\left(\hat{c}_i^{(1)} + \hat{\theta}_i^{(1)}\bar{g}_{it} + \sum_{k=1}^{5}\hat{\beta}_{ik}^{(1)}X_{kt}\right) + u_t\left(\hat{c}_i^{(2)} + \hat{\theta}_i^{(2)}\bar{g}_{it} + \sum_{k=1}^{5}\hat{\beta}_{ik}^{(2)}X_{kt}\right)$$

where the superscripts associated with the parameters denote the relevant subperiod and u_t is a 24-month transition sigmoid function which takes the values

$$u_t = \begin{cases} 0 & \text{if} \quad t < t^* - 12 \\ 1/(1 + \exp(-0.5t)) & \text{if} \quad t^* - 12 \leq t \leq t^* + 11 \\ 1 & \text{if} \quad t > t^* + 11 \end{cases}$$