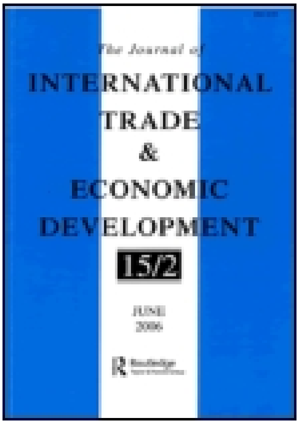

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Total factor productivity and macroeconomic instability

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Total factor productivity and macroeconomic instability

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Total factor productivity (TFP) is an important component of growth for most countries. This article assesses the role of macroeconomic instability on TFP growth. We consider volatility in inflation, openness of an economy and financial market deepness as measures of macroeconomic instability. Empirical evidence provided from Turkey suggests that volatility of openness and financial market deepness reduce TFP growth, whereas volatility of inflation increases TFP growth.

Keywords: macroeconomic instability; TFP growth; VAR-GARCH models

JEL Classifications: D24; E22

1. Introduction

Total factor productivity (TFP) has long been a variable of interest in economics growth literature. Empirical evidence suggests that it is TFP, rather than the accumulation of production factors, that accounts for most cross-country differences in the level and growth rate of per capita income. Abromovitz (1956) and Solow (1957) both argue that only a small fraction of output growth can be attributed to factor input accumulation, but that 88–90% of growth is attributed to TFP increases.[1] Finding an answer to the question of what determines TFP has become the main goal of a growing body of research.

Subsequent studies have argued that it is important to account for changes in the quality of factors of production that are otherwise attributed to TFP. There is a set of studies that suggests that TFP is affected by factors such as investments in education, training and human capital development,[2] the openness of the economy to international trade and foreign direct investment (FDI),[3] lower inflation rate,[4] financial development[5] and investments in machinery and equipment.[6] The investigation of the determinants of TFP is not limited to the studies mentioned above. Table 1

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Table 1. Summary of the literature.

Subject	Direction of effects	Studies
TFP-growth accounting methodology	Positive	Kendrick (1961); Denison (1985); Jorgenson, Gollop and Fraumeni (1987); Maddison (1995); Klenow and Rodriguez-Clare (1997); Jones (1997); Abramovitz and David (2000); Solow (1957); Jeong and Townsend (2004).
Determinants of TFP growth		
Human capital development	Positive	Harris (1999); Aiyar and Feyrer (2002); Black and Lynch (1996); Schultz (1961); Becker (1962), Becker, Murphy and Tamura (1990)
	Condition on openness: for low levels of openness, the relation between human capital development and TFP growth is negative. It reverses when openness is larger.	Miller and Upadhyay (2000)
Openness of the economy	Positive	Harris (1999); Cororaton and Zingapan (1999); Miller and Upadhyay (2000); Edwards (1998); Alcala and Ciccone (2004).
Volatility of exports	Negative	Miller and Upadhyay (2000)
Exchange rate[a]	Positive	Miller and Upadhyay (2000)
Inflation	Negative	Harris (1999); Miller and Upadhyay (2000); Clark (1982).
Taxes	Negative	Harris (1999)
Labor market flexibility	Positive	Harris (1999); Scarpetta and Tressel (2002)
Unionization	Negative	Warren (1985); Williams and Moomaw (1989); Haskel (2005).

(*continued*)

Table 1. (*Continued*).

Subject	Direction of effects	Studies
Research and development	Positive or negative, depending on market structure and technology regimes.	Cororaton and Zingapan (1999); Miller and Upadhyay (2000); Singh and Trieu (1996); Scarpetta and Tressel (2002)
Institutional settings	One of the factors explaining TFP growth differences is institutional differences.	Scarpetta and Tressel (2002)
Foreign direct investment	Positive	Cororaton and Zingapan (1999); Ferrett (2004); De Mello (1999); Sadik and Bolbol (2001); Liu and Wang (2003); Aitken and Harrison (2004).
Financial deepening	Positive	Kugler and Neusser (1998); Tadesse (2005); Jeong and Townsend (2004); Beck, Levine and Loayza (2000).
Innovation	Positive	Harris (1999).

Note: [a]Exchange rate is the domestic currency value of foreign currency. Thus, an increase in exchange rate equals depreciation.

reports some other variables that are considered in the literature. However, to the best of our knowledge, no study discusses the effects of volatility measures of macroeconomic variables on TFP, except Miller's and Upadhyay's (2000), who suggest that openness volatility decreases TFP.[7]

The purpose of this article is to assess the role of macroeconomic instability on TFP growth by using a reduced-form analysis. Based on the data availability of various variables, we choose to explore the volatilities of three variables as possible indicators of macroeconomic instability: inflation, openness of an economy and deepness of financial markets. In order to assess the roles of these volatilities we employ a reduced-form analysis within a vector autoregressive (VAR) model framework to determine how the conditional variability of these three factors affects TFP growth. We decide to use a VAR model to form our analyses because these models are successful at capturing the dynamics of a series with relatively few parameter estimates. This is especially vital for countries where data span availability is limited. Moreover, for developed economies, using reduced-form analyses to capture macroeconomic volatilities and their effects on economic performance is common in the literature; for example, Cogley (2005) and Cogley and Sargent (2005) use time-dependent variances in VAR contexts.

It is important to note that the volatility measures of the three variables that we use come from a reduced-form specification. Thus, a caution should be given about interpreting the estimated coefficients of volatility variables for the specifications. The estimated coefficients assess how the volatilities in the three variables as a measure of macroeconomic instability affect TFP growth. They do not capture the structural shocks that may occur to these three variables after other factors that affect the variables are accounted for.

1.1. Inflation volatility

Inflation volatility is the first macroeconomic instability measure that we consider. Friedman (1977) argues that inflation volatility adversely affects allocative efficiency by increasing unemployment and decreasing growth. To be specific, inflation uncertainty hampers the allocative efficiency of the price system. He discusses that unanticipated changes in inflation will cause systematic errors of perception on the part of employers and employees that will initially lead unemployment to deviate from its natural rate. Moreover, Lucas (1973) shows that inflation uncertainty can obfuscate the distinction between real and nominal shocks that economic agents suppose will respond differently. Studies such as Froyen and Waud's (1987), Holland's (1986) and Hafer's (1986) also analyze the hypothesis empirically and provide supporting evidence. Moreover, Dotsey and Sarte (2000) show that inflation uncertainty increases precautionary savings due to lower output and this lowers the nominal interest rates. On the other hand, Hahn (1970), Juster and Wachtel (1972a, 1972b), Juster and Taylor (1975) and Cukierman and Meltzer (1986) argue that inflation variability increases savings and creates the incentive to loosen monetary policy and thus decrease interest rates, which stimulates investment. If new investment is likely to increase capital stock that uses more advanced technologies, TFP will then increase.

1.2. *Openness volatility*

We use openness volatility, which captures the instability of a country's volume of transactions with the rest of the world, as a second macroeconomic instability measure. To be specific, openness volatility captures the ability of the economy to provide imported raw materials for the production process as well as machines and equipment for investment purposes and spare equipment for existing capital stock. Higher openness variability may discourage firms from adopting more efficient foreign technologies due to the difficulties they might experience in the future regarding spare parts or input requirements; instead, they adopt lower, domestically available technologies; this decreases TFP. Rodrick (1998) sets a macroeconomic model where an increase in the riskiness of exports calls for a reallocation of the economy's resources toward the safe activity, even when the return to safer activities lies below the (mean) return of other activities. This ultimately decreases TFP growth. Montalbano et al. (2005) provide empirical evidence that trade vulnerability in 1990s adversely affected the well-being of Eastern European countries.

1.3. *Financial market deepness volatility*

Lastly, volatility of the deepness of financial markets measures instability in the financial sector. The perception of higher vulnerability affects the behavior of financial intermediaries as well as firms that may claim credit. To be specific, higher vulnerability in the financial system discourages financial intermediaries from giving long-term loans despite that doing so might enhance TFP; they tend to concentrate on giving short-term loans. Firms also are less willing to receive credit from financial intermediaries, which decreases new investments. Moreover, in times of higher vulnerability (or the perception of it), companies tend to use internal resources to finance their investments. Lower external financing may also suggest that without financial intermediaries, investments are allocated less efficiently. Hence, productivity enhancement is lower at a given level of investment.

Angeletos (2006) argues that incomplete markets, which are associated with a lack of financial intermediation, reduces TFP by shifting resources from more risky but also more productive projects. However, Evers, Niemann and Schiffbauer (2008) argue that financial intermediation increases the qualitative composition of investment rather than the amount of investment, and this improves TFP. Acemoglu and Zilibotti (1997) offer a model that links financial development to economic growth. Levine, Loayza and Beck (2000) provide empirical evidence for this.

This article provides empirical evidence for the effects of inflation, trade openness, and financial market deepness volatilities on TFP growth by using Turkish data, which has various advantages. First, Turkey has had volatile growth and high and persistent inflation along with an unstable economic and political environment for more than three decades. All these factors decrease *Type-II* errors – the probability of not rejecting the null when it is true.[8] Second, Turkey has relatively well-developed and liberal financial markets without heavy regulations that might prevent the market mechanism from working properly. In thin markets, financial variables could change at the initiation of a few speculators (or manipulators) rather than because of the dynamics of the economy itself. Third, studying Turkey is an interesting exercise because although Turkey is an important emerging country on the way to membership in the European Union, it has so far failed to achieve income convergence with European countries. Recent high growth rates have facilitated some convergence with average income levels in the EU countries, but the sustainability of these growth rates and the future course of income convergence depend critically on the achievement of higher TFP. Therefore, modeling and understanding the determinants of TFP growth and analyzing the factors that increase its variability are vital not only for Turkey but also for other countries trying to close the income gap.

Table 1 summarizes the literature on the determinants of TFP to be human capital development, openness of the economy, volatility of exports, inflation, taxes, labor market flexibility, research and development (R&D) expenditures, institutional settings, FDI, financial deepening, innovation and exchange rate volatility. In this study, we do not cover all of these determinants. The lack of useful data is one of the constraints. For example, it is not easy to capture human capital development or labor market flexibility on a quarterly basis for Turkey. Likewise, quarterly data on institutional settings, R&D expenditures and innovation are not available. We include the exchange rate variable in our econometric specification. The estimates were sensitive to initial values and excluding (or including) additional observations changed the estimates too much. One reason for these changes is that Turkey adopted its monetary policy such that it stabilized the real exchange rate until 2000. The Central Bank of the Republic of Turkey (CBRT) depreciated the local currency parallel to the expected inflation (see Berument 2007 for details). Thus, the (expected) inflation and depreciation were highly collinear for most of the samples that we considered. Because of this, we exclude exchange rate from our analyses and limit our study to the key macroeconomic variables of inflation, openness and financial market deepness.

The outline of this article is as follows: Section II describes the modeling strategy. Section III presents the data. Section IV explains the model and Section V concludes the article.

2. Modeling

In order to capture how macroeconomic instability measures affect TFP, we employ an ARCH (Autoregressive Conditional Heteroskedasticity) class of model known as Exponential Generalized ARCH (EGARCH).[9] To be specific, we estimate the following specification

$$tfp_{\mathrm{t}} = x'_{\mathrm{t}} + \lambda h_{\mathrm{tfp_t}} + u_{\mathrm{tfp_t}} \tag{1}$$

where

$$u_{\mathrm{tfp_t}} \sim \left(0,\, h_{\mathrm{tfp_t}}\right)$$

and

$$\log h_{\mathrm{tfp_t}} = \tau + \sum_{j=1}^{\mathrm{p}} P_{\mathrm{j}} \log h_{\mathrm{tfp_{t-j}}} + \sum_{j=1}^{\mathrm{q}} Q_{\mathrm{i}} \left\{ \left| \frac{u_{\mathrm{tfp_{t-j}}}}{\sqrt{h_{\mathrm{tfp_{t-j}}}}} \right| - E \left| \frac{u_{\mathrm{tfp_{t-j}}}}{\sqrt{h_{\mathrm{tfp_{t-j}}}}} \right| - \varphi \frac{u_{\mathrm{tfp_{t-j}}}}{\sqrt{h_{\mathrm{tfp_{t-j}}}}} \right\} \tag{2}$$

where x'_t is the vector of explanatory variables for tfp_{t} at time t and the error term of the tfp_{t} equation is $u_{\mathrm{tfp_t}}$. The effect that the higher perceived variability of $u_{\mathrm{tfp_t}}$ has on the level of tfp_{t} is captured by the parameter λ.

If P_1 is greater than 1 and if the lag order of the EGARCH specification is 1 ($p = 1$), then the process of conditional volatility was found to be explosive. Thus, P_1 should be less than 1 in absolute value.

The φ parameter allows the effect of $u_{\mathrm{tfp_{t-j}}}/\sqrt{h_{\mathrm{tfp_{t-j}}}}$ on $\log h_{\mathrm{tfp_t}}$ to be asymmetric. If $\varphi = 0$, then a positive surprise has the same effect on volatility as a negative surprise. If $0 > \varphi > -1$, a positive surprise increases volatility less than a negative surprise does. If $\varphi > -1$, a positive surprise actually reduces volatility, while a negative surprise increases volatility.

The EGARCH model can be estimated by maximum likelihood, which specifies a density for $u_{\mathrm{tfp_{t-j}}}/\sqrt{h_{\mathrm{tfp_{t-j}}}}$. Nelson (1991) proposes using the generalized error distribution, normalized to have zero mean and unit variance.[10]

In this study, we also employ a multivariate GARCH when we consider the n equation system form

$$Y_t = Ax_t + \Gamma H_t + u_t \tag{3}$$

where x_t is a vector of explanatory variables and u_t is a vector of white noise residuals. Let H_t denote the $(n \times n)$ conditional variance-covariance matrix of the residuals:

$$H_t = E\left(u_t u_t' \,|y_{t-1},\, y_{t-2},\, \ldots\, x_t,\, x_{t-1}\, \ldots\right)$$

Engle and Kroner (1995) suggest the vector generalization of the GARCH (r,m) specification as:

$$\begin{aligned} H = \kappa + \Delta_1 H_{t-1} \Delta_1' + \Delta_2 H_{t-2} \Delta_2' + \cdots + \Delta_r H_{t-r} \Delta_r' \\ + \Lambda_1 u_{t-1} u_{t-1}' \Lambda_1 + \Lambda_2 u_{t-2} u_{t-2}' \Lambda_2 + \cdots + \Lambda_m u_{t-m} u_{t-m}' \Lambda_m \end{aligned} \tag{4}$$

Here, κ, Δ_s and Λ_s for $s = 1, 2, \ldots$ denote $(n \times n)$ matrices of parameters.

3. Data

The data used in this article covers the 1987Q1–2007Q3 period. TFP used in the model is the usual Solow residual from a Cobb-Douglas production function with constant returns to scale.[11] The two components of the production function are capital stock and employment. Capital stock is calculated from the investment data by using the methodology of the Organisation for Economic Co-operation and Development (OECD) (see Saygili, Cihan and Yurtoglu 2005). Employment statistics used in the TFP calculation are taken from the Turkish Statistical Institute.

Inflation is the logarithmic first difference of the consumer price index (CPI). Deepness is measured by the ratio of M2Y to gross domestic product (GDP), where M2Y is the sum of M2 and foreign-exchange denominated deposits. Finally, openness is calculated as the ratio of the sum of exports and imports to GDP. The data on investment and GDP is gathered from the Turkish Statistical Institute and the remaining variables are obtained from the data delivery system of the CBRT. All the data used in the analysis is seasonally adjusted by using the X11 procedure.

In order to assess in which form these variables will enter into the analyses, we perform a set of unit root tests. If these series have a unit root and they enter into the analyses in levels, then the econometric analyses could give spurious estimates. Table 2 reports the Augmented Dickey and Fuller (ADF), Phillips and Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests. The null hypothesis is the unit root for the ADF

Table 2. Unit root tests.

			ADF	PP	KPSS[a]
Total factor productivity	Level	Constant	−0.42	−7.53[b]	1.50[b]
		Constant and trend	−1.88	−8.08[b]	0.14[c]
	First difference	Constant	−2.81	−17.93[c]	0.11
Inflation	Level	Constant	−1.20	−2.01	0.83[b]
		Constant and trend	−4.21[b]	−4.02[c]	0.28[b]
	First difference	Constant	−8.81[b]	−19.42[b]	0.39
$\frac{\text{Export+Import}}{\text{GDP}}$	Level	Constant	−0.61	−0.59	1.03[b]
		Constant and trend	−2.57	−2.53	0.10[b]
	First difference	Constant	−9.31[b]	−9.31[b]	0.07
$\frac{\text{M2}}{\text{GDP}}$	Level	Constant	−0.15	−0.10	1.04[b]
		Constant and trend	−2.91	−2.91	0.14[c]
	First difference	Constant	−9.96[b]	−9.95[b]	0.18

Note: [a]Null hypothesis of KPSS test assumes stationarity, whereas ADF and PP assume unit root. [b]Significance at 5%. [c]Significance at 10%.

and PP tests, but the non-unit root for the KPSS test. Rejecting the null for the first two tests means stationarity and rejecting the null for KPSS means the presence of a unit root in the series. At least two of three tests suggest a unit root for all the series with constants. One may consider inflation as trend stationary. However, all the series are difference stationary. Thus, we perform the analyses in their first difference form.

4. Model specification(s)

4.1. Univariate model

In order to assess the presence of the ARCH effect on TFP growth, we perform Engle's (1982) ARCH-LM test. Thus, first we regress TFP growth on a constant term and its first four lags.[12] Later, squared residuals were regressed on their first four and eight lags, along with a constant term, the number of observations times R^2 are calculated as 18.962 and 19.846, respectively. They are distributed χ^2 with four and eight degrees of freedom. The *p*-values for these statistics are 0.008 and 0.000, respectively. Thus we cannot reject the presence of the ARCH effect on TFP growth even at the 1% level.

Because of these results, we modeled TFP growth with a class of ARCH models. The existing literature assesses the relationship between TFP growth and its volatility by assuming that TFP growth volatility captures macroeconomic stability. As discussed above, we use the EGARCH specification for TFP growth's conditional volatility. After modeling the conditional variance of TFP growth with an EGARCH specification, we assess the effect of TFP growth variability on TFP growth itself. We model the TFP growth equation with a constant term, four lag values of the dependent variable and the conditional variance of TFP growth. The estimates are reported in Table 3.

Panel A of Table 3 reports the estimates of the mean equation (equation (1)). The table suggests that the estimated coefficient for the conditional variance of TFP growth for TFP growth is negative but not statistically

Table 3. EGARCH in mean specification for the TFP growth.[a]

	Dependent variable	Coefficients tfp_t
Panel A: mean equation		
Explanatory variables	Constant	1.8072
		(0.00)
	tfp_{t-1}	−0.0449
		(0.72)
	tfp_{t-2}	0.0177
		(0.82)
	tfp_{t-3}	−0.1407
		(0.08)
	tfp_{t-4}	−0.2681
		(0.01)
	h_t^{tfp}	−0.2196
		(0.08)
Panel B: conditional variance		
Explanatory variables of conditional variance	*Constant*	1.2035
		(0.00)
	$Log\ h_{tfp_{t-1}}$	−0.1515
		(0.43)
	$\lvert V_{t-1}^{tfp}\rvert - E\lvert V_{t-1}^{tfp}\rvert - \phi V_{t-1}^{tfp}$	0.9326
		(0.01)
	'''φ	−0.1077
		(0.59)
Panel C: specification tests: *p*-values		
	The sign bias test	(0.76)
	Ljung-Box Q-Stat. [4]	(0.61)
	Ljung-Box Q-Stat. [8]	(0.88)
	ARCH-LM [4]	(0.90)
	ARCH-LM [8]	(0.78)

Note: [a]*p*-values are reported under estimated coefficients in parentheses for the corresponding variables. The lag orders for the specifications are reported in brackets next to the specification tests.

Note: tfp_t denotes total factor productivity growth, inf_t denotes inflation, $openness_t$ denotes the ratio of sum of export and imports to GDP, and $deep_t$ is for M2Y to GDP ratio. V_{t-1}^{tfp} denotes for $u_{t-1}^{tfp}/\sqrt{h_{t-1}^{tfp}}$.

Sample includes quarterly observations from 1987Q1 to 2007Q3 for a total of 83 observations.

significant.[13] We could not find statistically significant evidence that TFP growth variability adversely affects TFP growth itself.[14] Second, in Panel B of Table 3, we observe a negative leverage effect, φ, and the effect is less than 1 in absolute value. This suggests that a negative shock to TFP growth increases its variability more than a positive shock, reflecting the asymmetry of the effects of positive and negative shocks on TFP growth's conditional volatility. Moreover, the estimated coefficient for the lag value of the logarithm of the conditional variance is less than 1. This satisfies the non-explosiveness of the conditional variance requirement.

Panel C of Table 3 reports the *p*-values of the specification tests. We consider a non-parametric sign-biased test, Ljung-Box Q, at four and eight lags for autocorrelation on squared standardized residuals and ARCH-LM tests at four and eight lags for heteroskedasticity on the standardized residuals (see Berument, Ceylan and Olgun 2007 for the calculations of and elaborations on these tests). None of the test statistics was statistically significant; this supports the TFP growth specification.

Various reasons can be postulated as to why we could not find statistically significant relationships. The first one is that TFP growth is affected by factors other than its history. Including other sets of variables may help to explain the behavior of TFP growth and its own innovations. Second, TFP growth might be affected by macroeconomic instability but TFP growth volatility may not capture the macroeconomic instability.

Note that the specification we use to measure macroeconomic instability is of a non-linear system. It is possible that the inclusion of a large number of statistically insignificant coefficients will increase the variability of the model's forecast. Therefore, our concern is to fit a parsimonious model and use a nonstructural approach such as VAR to capture the dynamic relationship among these variables. VAR models are often used in reduced-form specifications and are considered successful in capturing a rich array of dynamic relationships among a set of variables with relatively few parameter estimates. Here, we also assume that the conditional variance of TFP growth is constant, because we could not detect the effect of TFP growth variability on TFP growth. Introducing TFP growth volatility to the system would create more difficulties for convergence and the estimates would be more sensitive to initial values.

4.2. The multivariate model specification(s)

Table 4 reports the estimates of three different VAR-GARCH specifications. Specification 1 includes three variables: *inflation, openness* and *tfp*. Equation (1) of Specification 1 in the table models *inflation* with its two lags, two lags of *openness*, two lags of *tfp*, and the constant term. Equation (2) is for *openness*, which is modeled with two lags of *inflation, openness*, and *tfp*. The last one (equation (3)) is for the *tfp*, which is modeled as a function of two

Table 4. Determinants of TFP growth: multivariate analyses.[a]

		Specification 1	Specification 2	Specification 3
		Panel A: mean equation		
	Dependent variables of equation (1)	inf_t	inf_t	$deep_t$
Explanatory variables of equation (1)	*constant*	0.2102 (0.00)	0.0735 (0.00)	3.0148 (0.36)
	inf_{t-1}	−0.4539 (0.00)	−0.2199 (0.00)	
	inf_{t-2}	−0.2605 (0.00)	−0.0664 (0.00)	
	$openness_{t-1}$	2.8669 (0.00)		−0.2826 (0.12)
	$openness_{t-2}$	5.0420 (0.00)		0.1579 (0.76)
	tfp_{t-1}	2.2592 (0.00)	1.8832 (0.00)	−0.3447 (0.62)
	tfp_{t-2}	5.6044 (0.00)	4.0346 (0.00)	0.2431 (0.52)
	$deep_{t-1}$		2.9772 (0.00)	−0.0470 (0.86)
	$deep_{t-2}$		1.5168 (0.00)	−0.0631 (0.67)
	Dependent variables of equation (2)	$openness_t$	$deep_t$	$openness_t$
Explanatory variables of equation (2)	*constant*	0.3008 (0.00)	0.0255 (0.00)	0.2201 (0.54)
	inf_{t-1}	0.0012 (0.87)	−0.0004 (0.38)	
	inf_{t-2}	0.0043 (0.00)	0.0161 (0.00)	
	$openness_{t-1}$	−0.0961 (0.01)		−0.1275 (0.85)
	$openness_{t-2}$	−0.0642 (0.07)		1.6246 (0.58)
	tfp_{t-1}	−0.0786 (0.01)	−0.2666 (0.00)	−0.7352 (0.54)
	tfp_{t-2}	−0.0923 (0.00)	−0.1600 (0.00)	1.1661 (0.59)
	$deep_{t-1}$		−0.3316 (0.00)	0.2201 (0.54)
	$deep_{t-2}$		−0.0399 (0.00)	−0.6147 (0.00)

(*continued*)

Table 4. (*Continued*).

		Specification 1	Specification 2	Specification 3
	Dependent variables of equation (3)	tfp_t	tfp_t	tfp_t
Explanatory variables of equation (3)	*constant*	0.0110 (0.00)	0.0088 (0.00)	1.2410 (0.00)
	inf_{t-1}	−0.0023 (0.00)	−0.0467 (0.00)	
	inf_{t-2}	0.0030 (0.00)	0.0170 (0.00)	
	$openness_{t-1}$	−0.2911 (0.00)		−0.0185 (0.46)
	$openness_{t-2}$	−0.0400 (0.00)		−0.0381 (0.15)
	tfp_{t-1}	0.0749 (0.00)	−1.3281 (0.00)	−0.0317 (0.20)
	tfp_{t-2}	0.0061 (0.00)	−0.8402 (0.00)	−0.0415 (0.00)
	$deep_{t-1}$		−0.6936 (0.00)	−0.0935 (0.00)
	$deep_{t-2}$		−0.1540 (0.00)	−0.0571 (0.00)
	h_{inf_t}	0.0967 (0.00)	0.0580 (0.00)	
	h_{open_t}	−0.4039 (0.00)		−0.0085 (0.79)
	h_{deep_t}		−0.7956 (0.00)	−0.6060 (0.00)
		Panel B: conditional variances		
	Dependent variables of (conditional) variance	h_{inf_t}	h_{inf_t}	
Explanatory variables of CV	Constant	0.0299 (0.00)	0.3204 (0.00)	
	$u^2_{\mathrm{inf}_{t-1}}$	0.0001 (0.98)	0.2109 (0.00)	
	$h_{\mathrm{inf}_{t-1}}$	0.9648 (0.00)	0.0100 (0.00)	
	Dependent variables of (conditional) variance	h_{open_t}		h_{open_t}
Explanatory variables of CV	Constant	0.1570 (0.00)		0.1853 (0.00)
	$u^2_{\mathrm{open}_{t-1}}$	0.0078 (0.00)		−0.5870 (0.00)
	$h_{\mathrm{open}_{t-1}}$	0.2437 (0.00)		0.2882 (0.00)

(*continued*)

Table 4. (*Continued*).

		Specification 1	Specification 2	Specification 3
	Dependent variables of (conditional) variance		h_{deep_t}	h_{deep_t}
Explanatory variables of CV	Constant		0.7467 (0.00)	0.7807 (0.42)
	$u^2_{deep_{t-1}}$		0.0112 (0.00)	0.1769 (0.58)
	$h_{deep_{t-1}}$		0.1003 (0.00)	−0.1378 (0.16)
	Var(tfp_t)	4.0725 (0.00)	7.4912 (0.00)	4.6590 (0.00)
		Panel C: time-independent covariances		
	cov (u_{inf_t}, u_{open_t})	1536.67 (0.00)		
	cov (u_{inf_t}, u_{deep_t})		21.8605 (0.00)	
	cov (u_{deep_t}, u_{tfp_t})		20.2241 (0.00)	−5.0514 (0.00)
	cov (u_{inf_t}, u_{tfp_t})	−3.5370 (0.00)	−4.4942 (0.00)	
	cov(u_{deep_t}, u_{open_t})			341.66 (0.46)
	cov (u_{tfp_t}, u_{open_t})	−7.7569 (0.19)		−0.5766 (0.98)

Note: Sample includes quarterly observations from 1987Q1 to 2007Q3 for a total of 83 observations. $h_{inf_{t-1}}$, $h_{deep_{t-1}}$ and $h_{open_{t-1}}$ the conditional variances of inflation, deepness and openness variables, respectively. tfp_t, total factor productivity growth; inf_t, inflation growth; $openness_t$, the growth rate of the ratio of sum of export and imports to GDP; $deep_t$, M2Y to GDP ratio growth.

[a]*p*-values are next to estimated coefficients for the corresponding variables.

lags of *inflation, openness*, and *tfp*; *tfp* is also explained by the conditional variances of *inflation* and *openness* to assess the role of these instabilities in explaining the behavior of *tfp*.[15] Moreover, we model the conditional variances of *inflation* and *openness* with a GARCH (1,1) specification.[16] Specifically, we estimate the following set of equations:

$$Inf_t = \alpha_0^{inf} + \sum_{i=1}^{2} \alpha_i^{inf}\, inf_{t-i} + \sum_{i=1}^{2} \beta_i^{inf} open_{t-i} + \sum_{i=1}^{2} \gamma_i^{inf} tfp_{t-i} + u_{inf_t} \tag{5a}$$

where $u_{inf_t} \sim (0, h_{inf_t})$;

$$h_{inf_t} = \kappa_{inf} + \delta_{inf} h_{inf_{t-1}} + \mu_{inf} u^2_{inf_{t-1}} \tag{5b}$$

and

$$open_t = \alpha_0^{open} + \sum_{i=1}^{2} \alpha_i^{open}\, inf_{t-i} + \sum_{i=1}^{2} \beta_i^{open} open_{t-i} + \sum_{i=1}^{2} \gamma_i^{open} tfp_{t-i} + u_{open_t} \tag{6a}$$

where $u_{open_t} \sim \left(0,\ h_{open_t}\right)$;

$$h_{open_t} = \kappa_{open} + \delta_{open} h_{open_{t-1}} + \mu_{open} u^2_{open_{t-1}} \tag{6b}$$

and

$$tfp_t = \alpha_0^{tfp} + \sum_{i=1}^{2} \alpha_i^{tfp}\, inf_{t-i} + \sum_{i=1}^{2} \beta_i^{tfp} open_{t-i} + \sum_{i=1}^{2} \gamma_i^{tfp} tfp_{t-i} + \phi_{inf_t} h_{inf_t} + \phi_{open} \mathrm{h}_{open_t} + u_{tfp_t} \tag{7}$$

where $u_{tfp_t} \sim \mathrm{N}\left(0,\ h_{tfp_t}\right)$ and

$$h_{tfp_t} = \kappa_{tfp}$$

The covariances of the equations are presented as follows:

$$\kappa_{inf,open} = \mathrm{cov}\left(u_{inf_t}, u_{open_t}\right)$$

$$\kappa_{inf,tfp} = \mathrm{cov}\left(u_{inf_t}, u_{tfp_t}\right)$$

$$\kappa_{open,tfp} = \mathrm{cov}\left(u_{open_t}, u_{tfp_t}\right)$$

The estimated coefficient for the inflation variability (h_{tfp_t}) in the *tfp* specification is positive and statistically significant, as reported in the equation (3) section of Table 4. This suggests that inflation volatility increases TFP growth. The estimated coefficient for the openness variability is negative and statistically significant. It is plausible that exports and imports could be affected by different factors and have different dynamics. Thus, in order to partially account for this, we define two new openness measures: export-GDP ratio and import-GDP ratio. When these two openness measures are included jointly in the econometric specification without including any other volatility measures, the estimated coefficients of openness volatility measures were jointly statistically significant and negative.

Next, we examine the validity of the variance specification estimates in Panel B. Note that all the estimated coefficients for the VAR-GARCH specifications for the inflation and openness variabilities are positive. This satisfies the non-negativity of the conditional variance specification. It is also important to highlight that the sum of the coefficients of $h_{\mathrm{tfp}_{t-1}}$ and $u^2_{\mathrm{tfp}_{t-1}}$, as well as the sum of the coefficients of $h_{\mathrm{open}_{t-1}}$ and $u^2_{\mathrm{open}_{t-1}}$, are less than 1. This also satisfies the non-explosiveness property of the conditional variances. Lastly, $\mathrm{cov}(u_{\mathrm{inf}_t}, u_{\mathrm{tfp}_t})$, $\mathrm{cov}(u_{\mathrm{inf}_t}, u_{\mathrm{open}_t})$, and $\mathrm{cov}(u_{\mathrm{tfp}_t}, u_{\mathrm{open}_t})$ are the time-independent covariances.

The deepness volatility of the financial market is an additional potential determinant of TFP growth. Thus, we perform the analyses by incorporating deepness and its volatility into the VAR-GARCH specification. Here, we do not include deepness as an additional variable of the three-variable VAR-GARCH specification, but rather substitute it with openness or inflation to avoid overparameterization.

Column 2 of Table 4 presents the coefficients of the VAR-GARCH model that is composed of inflation, financial deepness, and TFP growth. The sign of inflation variability in the tfp_t equation is positive and statistically significant. This result is consistent with the former specification. Financial deepness variability negatively affects TFP and this effect is also statistically significant.

The last set of estimates, shown in column 3 of Table 4, is for analyzing whether the openness and deepness volatilities affect TFP. The results support our previous analyses: both variables decrease TFP growth. However, the negative effect of the openness variable on TFP growth is not statistically significant, which may suggest that these two volatilities might be working from the same channel or that a high colinearity of these two variables exists.[17]

Lastly, the estimated coefficients for the VAR-GARCH specifications reported in Panel B are all positive. This satisfies the non-negativity condition of the conditional variances. Moreover, the sums of the slope coefficients for each of the VAR-GARCH specifications are all less than one. This supports the non-explosiveness of the conditional variances.[18]

Figures 1–3 report the actual and fitted values for the three TFP growth specifications from Table 4. The solid lines indicate TFP growth figures and

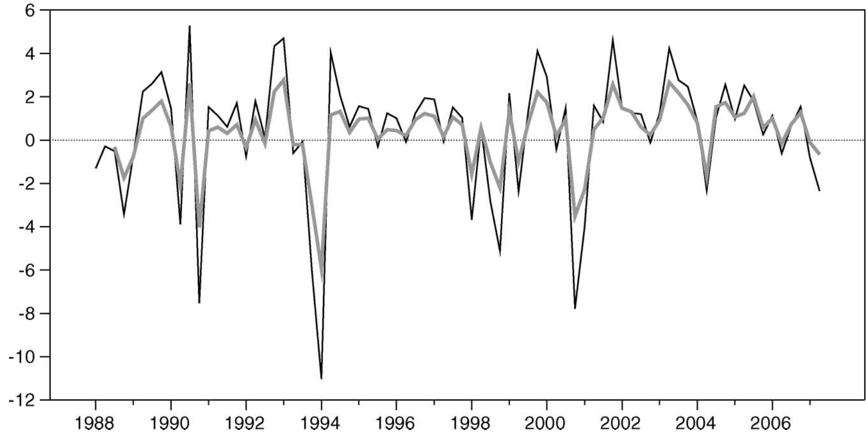

Figure 1. Actual and fitted values of TFP growth: specification 1.
Note. Solid line indicates TFP growth and grey line indicates the fitted values.

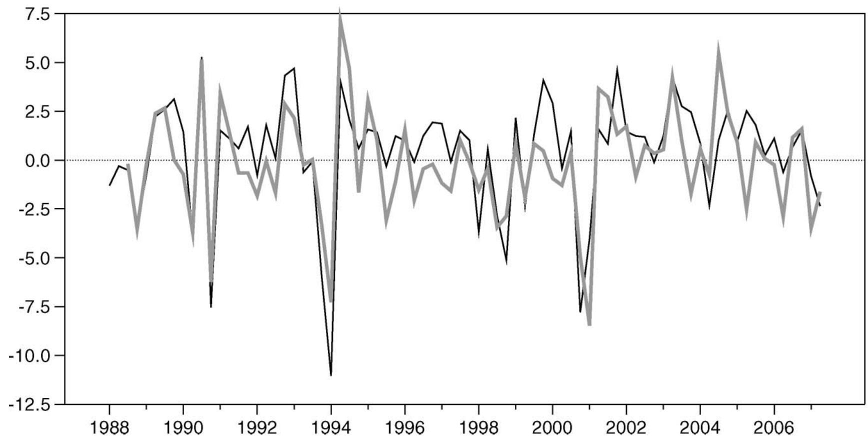

Figure 2. Actual and fitted values of TFP growth: specification 2.
Note. Solid line indicates TFP growth and grey line indicates the fitted values.

the grey lines indicate the fitted values for the three specifications that we estimate. All these three specifications capture the dynamics of TFP growth well, which further supports our specifications.

The empirical evidence provided in Table 4 suggests that inflation volatility increases TFP growth, whereas the volatilities of openness and deepness reduce TFP growth. Even if the positive effect of inflation volatility on TFP growth does not suggest the presence of the allocation inefficiency due to higher inflation uncertainty (as Friedman 1977 argues), Hahn (1970),

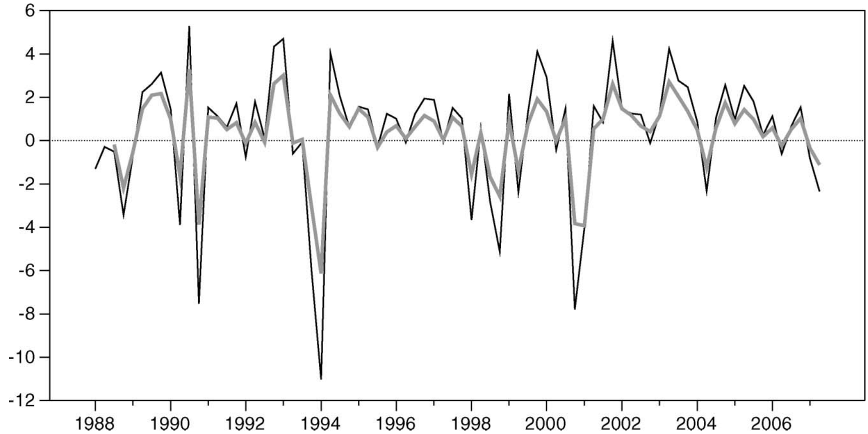

Figure 3. Actual and fitted values of TFP growth: specification 3.
Note. Solid line indicates TFP growth and grey line indicates the fitted values.

Juster and Wachtel (1972a, 1972b) and Juster and Taylor (1975) argue the presence of a negative relationship between inflation uncertainty and interest rates. The latter three studies suggest that consumers seek to protect themselves against inflation. If variability of income does not match inflation volatility, the latter will affect actual income variability because of loss of consumer confidence. Thus, consumers will increase their savings, which will cause consumption and interest rates to decrease. Moreover, Cukierman and Meltzer (1986) argue that unanticipated inflation can be generated by governments by decreasing short-term interest rates in order to stimulate their economies. Lower interest rates stimulate investment; new investment is more likely to increase capital stock that uses more advanced technologies, which may increase TFP growth.

Second, openness volatility decreases TFP growth. In the literature, there are various studies that analyze the relationship between the level of openness and TFP, but to the best of our knowledge, the only study discussing the effects of openness variability on TFP is that of Miller and Upadhyay (2000). Similar to our study, they find a negative relationship between openness variability and TFP growth; in other words, the less volatile openness is the higher TFP. Regarding the relationship between openness and TFP growth, they suggest that greater openness facilitates the economy's adoption of more efficient technologies for production, leading to a faster growth of production.

Third, the adverse effect of financial market deepness volatility on TFP growth is in line with the hypothesis that financial intermediaries and firms that need credit to finance their operations are both influenced by the higher vulnerability of the financial system. In an economy where there is higher

Table 5. Growth impact of lower volatility.

	Specification 1	Specification 2	Specification 3
0.16 lower inflation and openness volatility	0.33		
0.16 lower inflation and deepness volatility		−0.32	
0.16 lower openness and deepness volatility			0.57
0.16 lower inflation volatility	−4.77	−0.97	
0.16 lower openness volatility	5.29		0.28
0.16 lower deepness volatility		0.65	0.13

deepness volatility, financial intermediaries prefer short-term lending to long-term credit, which ultimately affects a country's TFP growth. Moreover, there are lower levels of new investment as financial firms are less willing to provide credit regardless of credit maturity. Furthermore, firms use more of their internal resources for investment. This likely decreases TFP growth because the liquidity provided by financial intermediaries allows for more efficient allocation of resources.

5. Conclusion

This article assesses how a set of macroeconomic instability measures contributes to TFP growth. The results suggest that inflation volatility increases TFP growth, and that openness and deepness volatilities reduce TFP growth.

As Turkey is a developing country that is also a candidate for full membership to the European Union, lowering macroeconomic instability may help Turkey catch up with European Union countries, as noted above. Thus, we perform an exercise as to how much GDP growth would change if the three volatility measures were 16% lower. (We choose 16% because $Z_{1-0.16} = 1$ from Standard Cumulative Normal distribution[19]). Table 5 reports the calculations of this exercise.

Note that the estimates reveal that inflation volatility actually increases TFP growth, and thus GDP growth. Therefore, decreasing inflation volatility only decreases output growth by 4.77% in Specification 1 and by 0.97% in Specification 2. Decreasing inflation volatility with lower deepness volatility decreases output by 0.32% annually but if inflation volatility decreases with openness volatility, output is increased by 0.33%.

However, decreasing openness and deepness volatilities increases output growth. Lower openness volatility increases annual GDP growth by 5.29% for the first specification and by 0.28% in the third specification. Lowering deepness volatility increases growth by 0.65% in the second specification and 0.13% in the third specification.

When both openness and deepness volatility are lowered by 16% each, output growth increases by 0.57%. One needs to be cautious about 4.77% lower growth for lower inflation volatility or 5.29% higher growth for lower openness volatility from Specification 1, because these magnitudes are quite high, but consider them simultaneously. Thus, we may claim that 0.33–0.57% higher annual growth is feasible, which means 7–11% higher growth for the 19-year period that we consider. Turkey has failed to achieve convergence with EU per capita income levels in the past. The low per capita income growth (at about 2.25% between 1988 and 2006) was not sufficient to allow for income convergence since it was just above the growth of per capita income in the EU. However, our estimations indicate that a 16% decline in the volatility of openness and financial deepness would increase the annual average GDP growth by around 0.33–0.57%.[20] Such an increase in the GDP growth rate would result in a meaningful difference between per capita income growth rates in Turkey and the EU, and thereby significantly accelerate income convergence. Based on historical averages on population and GDP growths, a simulation exercise shows that Turkey could reach about 34–35% of the EU25 per capita income levels in 15 years from a base of 29% with a 16% reduction in the volatility of openness and financial deepness. Furthermore, without any decline in volatility, Turkey could reach 32% of the EU25 income level, which would be almost 10% lower, without changing the historical growth rates. Note that these calculations are based on real incomes and do not take into account any real exchange rate appreciation. However, the increase in TFP would also lead to an appreciation in the currency and therefore accelerate the convergence.

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Notes

1. Although later work has indicated a lesser role of TFP in growth, it still remains the major factor accounting for growth (see, for example, Kendrick 1961; Denison 1985; Jorgenson, Gollop and Fraumeni, 1987; Maddison 1995; Mankiw, Phelps and Romer 1995; Klenow and Rodriguez-Clare 1997; Jones 1997; Abramovitz and David 2000).
2. Schultz (1961); Becker (1962); Becker Murphy and Tamura (1990); Black and Lynch (1996); Miller and Upadhyay (2000); Aiyar and Feyrer (2002).
3. Edwards (1998); Harris (1999); Cororatan and Zingapan (1999); Miller and Upadhyay (2000); Alcala and Ciccone (2004).
4. Miller and Upadhyay (2000); Clark (1982).

5. Kugler and Neusser (1998); Levine (2003); Tadesse (2005); Jeong and Townsend (2004); Beck, Levine and Loayza (2000).
6. Harris 1999.
7. Volatility measures are the proxy of second moments such as moving variance or conditional variance of macroeconomic variables.
8. *Type-II* error is defined as not rejecting the null although it is false. The way to reduce *Type-II* errors would be to either increase the level of significance denoted by (a) or decrease the confidence coefficient denoted by ($1 - a$). Apart from these conventional methods, another suggestion is to increase the dispersion of the collected data as per Netter, Wasserman and Kutner (1985), p. 71. They argue that increasing spacing results in an increase in the t-statistics of a given estimated parameter, the sample size and the variance of the errors. In addition, increasing spacing also decreases the standard errors of the parameters of interest. Concerning the fact that Turkey is the only country experiencing high and sustainable inflation, the result is that spacing is higher and *Type-II* error is lower (see also Berument, Akdi and Atakan 2005 for further discussion).
9. This article assesses the determinants of TFP growth; however, we will call this TFP in the text.
10. See Hamilton (1994, pp. 668–70) and Berument, Coskun and Sahin (2007) for the advantages of EGARCH specifications against other types of ARCH models and estimation using general error distribution.
11. The estimated coefficients of the Cobb-Douglas production function for capital is 0.42 and for labor is 0.58.
12. The lag order of 4 is determined by the final prediction error (FPE) criteria that set the lag length such that the residuals are no longer autocorrelated. Casimano and Jansen (1988) suggest that autocorrelated errors imply the presence of the ARCH effect even if the ARCH effect is not present.
13. The level of significance is at 5% unless otherwise mentioned.
14. We used various ARCH and GARCH specifications but the basic evidence on the mean effect is robust.
15. The lag order of 2 is selected by the final prediction error criteria when we consider a class of models with the same lag order across equations.
16. We also estimate the model with the EGARCH specification. The estimated coefficient for the leverage effect and the estimated coefficient for the conditional variances were not statistically significant (possibly due to over-parameterization), thus we did not elaborate on them here.
17. In this article, we explore the behavior of TFP growth by using three-equation VAR-GARCH specifications. We also estimate a model that incorporated deepness, TFP, openness and inflation simultaneously: a four-variable VAR-GARCH specification. The estimated coefficients for inflation volatility, openness volatility, and deepness volatility were too small, even if they were statistically significant, and the results were sensitive to initial values. This might be due to the highly nonlinear nature of the specification and the high collinearity of deepness, TFP and openness measures. We did not report and elaborate on these estimates here, but they are available for interested readers on request.
18. Conducting specification tests on the multivariate GARCH models is not an easy task, and we tried various classes of them. Since the tests are so extensive, we did not report them all; however, sign-biased, Ljung-Box-Q and ARCH-LM tests mostly passed for the tfp_t specification equation (3) of Table 4.
19. Introducing one-standard deviation shocks is a common exercise in empirical simulation. See for example, Sims and Zha (1999).

20. Since increasing inflation volatility may have other adverse effects, we did not pursue this avenue further.

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