Testing the Growth Links of Emerging Economies: Croatia in a Growing World Economy

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Abstract

We estimate a dynamic simultaneous equation model for 16 variables of the Croatian economy in order to test the links of growth with education, R&D, trade, savings and FDI. In order to motivate the choice of variables we review the related theories of growth and look at the relevant data. Permanent shocks increasing the intercepts of the equations for education, R&D, trade, savings and FDI show that most of growth links work well in Croatia, but they also enhance foreign imbalances. Policies to balance the two aspects are briefly discussed. All results should be interpreted with caution due to the small data sample we have up until now.

1. Motivation and introduction

When carrying out country studies, researchers living in the country under study, insiders, have some background knowledge from following the media and the (semi-) scientific publications of the country. This enables them to know the problems of the country and focus directly on these keeping the background knowledge in mind. In contrast, researchers living outside the country and not having the background knowledge can better follow a theory guided approach of empirical work. This is what we try in the rest of this paper. In section 2 we present the parts of growth theory which we consider most relevant for the purpose of studying the growth process of the Croatian economy since the early 1990s. In section 3 we look at the data related to the theory to get a first impression of the situation in Croatia. In section 4 we estimate an empirical dynamic model for sixteen equations and endogenous variables in order to see whether the major growth links from education, R&D and trade work in the sense of finding statistically significance regression coefficients. In section 5 we consider growth policies defined as permanent shocks in the form of increasing the intercepts of regression equations and simulate the effects on the whole model and testing the growth links in this way. Section 6 briefly summarizes and concludes.

2. Growth theory and accounting as a lens for data selection

2.1 The red line from classical to modern economics

The theory of economic growth has been developed during more than two centuries in close interaction with thinking about evidence related to the long-term social problems of the now rich countries. Malthus (1798) worried about the ability of countries to feed a growing population on the basis of a constant surface of agricultural land. Ricardo (1821) expected the pressure of population growth - in the presence of existence minimum wages and decreasing returns to capital and labour - to reduce the rates of land rent and profits.[2] Ricardo was aware of technical change in the form of 'improvements in machinery' and 'discoveries in the science of agriculture' (Ricardo 1821, p. 120). However, the general understanding is that he did not expect these aspects to contribute much to a solution of the tension between keeping the wages at the existence minimum level or the rents and profits rates at levels satisfactory for the owners. Marx (1894, Chapter 13) - writing in the broader perspective of his dynamic theory of conflict driven institutional change - focused on the tendency of the rate of profit to fall. In Chapter 14 he discusses 'counteracting forces', which will postpone and weaken the fall of the profit rate. One of these forces is increasing labour productivity which is seen to prevent the rate of profit from falling as it does in neoclassical growth models (Holländer 1974). Marx differs from the later neoclassical writers in his expectation that the counteracting forces will 'ultimately only speed up the causes' and inventions are only of temporary nature. Harrod (1939) and Domar (1946), under the impression of the productivity of industrialization and mass unemployment of the 1930s and the implied ample availability of labour, modelled output as a linear relation to capital, deemphasizing all the problems of the classical economists. Cobb and Douglas (1928) formalized earlier ideas of Von Thünen (1826) about the neoclassical production function integrating capital and labour in one function (Samuelson 1983). Solow (1956) extended the production function concept to a growth model with exogenous and costless technical progress, replacing the simple production function of Harrod and Domar by one of constant returns, of which the Cobb-Douglas function is a special case. According to the neoclassical production function the output from an additional unit of labour increases with technical progress. Under profit maximization the marginal product of labour equals the wage. It can be solved for labour demand. Labour demand then increases with technical progress. Classical disguised unemployment vanishes, and the wage increases beyond the existence minimum.[3] The income allows buying food also when supply is scarce and prices are high. Profit rates are constant in the long run rather than falling. In sum, under permanent and sufficiently large technical change, all the classical problems would vanish.

This nice theoretical result provokes new questions. Is technical change permanent or temporary as Marx expected. How high is it? How does it come about? How much does it cost? Can it be unprofitable and vanish therefore? The first question is dealt with in the research area called growth accounting, the others in endogenous growth theory. Both started immediately after Solow's (1956) paper in Solow (1957)[4] and Kaldor's (1957) request for a technical progress function.

2.2 Growth accounting and regression methods

Solow (1957) used the Cobb-Douglas production function, re-stated it in terms of growth rates and solved for total factor-productivity growth rates. Inserting yearly data for the USA on the right-hand side yields results for the left-hand side called 'the TFP residual'. These results showed enormous ups and downs because they include the effects of the business cycle on the degree of capital's degree of utilization. Similarly, in several investigations Denison showed that for the long run there is a rate of TFP growth in the order of magnitude of 1.5% percent; Mankiw et al (1992) suggest 1.7 percent; Kocherlakota and Yi (1997) 1.3% for the UK. However, as in Solow (1957) and Denison's paper, in shorter periods of weak economic activity the rates may be much lower and more variable (Branson and Litvack 1981). For the estimation over longer periods, instead of accounting, one can also use the Cobb-Douglas function (Young 1994), or the translog function (Verspagen 1995) or the CES function

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[2] See Appendix Growth under exogenous wages and decreasing returns to scale
[3] Ziesemer 1987.
[4] Tinbergen (1942) was earlier but escaped the attention.

(Ziesemer 2005).[5] Other methods are described in Feenstra et al. (2015). Fagerberg (1994) provides a survey of earlier work.

2.3 Endogenous growth theory

The question where the technical progress is coming from and what it costs was developed in three phases.[6] First, the output production function

$$Y = F(K_Y, AL_Y) \tag{1}$$

with labour-augmenting technical change A, was complemented by one for the change of A.

The social content of A in Arrow (1962) was cumulated learning–by–doing, in Uzawa (1965), Lucas (1988) was human capital, in Kaldor and Mirrlees (1962), Phelps (1966) was cumulated R&D, in Shell (1967) and Ziesemer (1990) was public goods. Ziesemer (1991) combined R&D and human capital. Ziesemer (1995a) combined R&D, human capital and public goods.

The problem of scale effects

von Weizsäcker(1969) was the first to notice that different specifications of the production function for A had a strong impact on the predicted long-run growth rates. Uzawa assumed

$$\hat{A} = \vartheta(l_A), \vartheta' > 0, \vartheta'' < 0 \tag{2a}$$

a '^' indicating a growth rate; the steady-state share of labour going into human capital formation would determine a constant growth rate. Phelps' assumption

$$dA/dt = K^\alpha L^{1-\alpha} \tag{2b}$$

leads to a steady-state growth rate

$$\hat{A} = \hat{L}/\alpha \tag{2b'}$$

Technical progress would go to zero if labour growth would stop. This case later was called semi-endogenous growth. Under Shell's (1967) assumption

$$(dA/dt)/A = K^\alpha L^{1-\alpha} \tag{2c}$$

the rate of technical progress on the left would keep growing if capital and labour would keep growing, leading to a growing growth rate, and not only cross-section size effects. The latter result, although favoured by von Weizsäcker (1969), seems implausibly optimistic and Jones (1995) coined it the scale effects problem. Models with

$$dA/dt = A^\gamma K^\alpha L^{1-\alpha} \tag{2d}$$

with *γ<1* would leads to Phelps type of results and were favoured by many. In contrast, Uzawa type of models were favoured by Lucas (1988) and Ziesemer (1991, 1995a)[7] and later by so-called scale-

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[5] The CES function with labour-augmenting technical change could also be used for the yearly calculations after solving for the technology term, provided output, capital and labour data are available and the researcher imposes an elasticity of substitution other than unity, the Cobb-Douglas case. The CES function $Y = [\alpha K^\rho + (1 - \alpha)(AL)^\rho]^{\frac{1}{\rho}}$, taken to the power ρ, subtraction the capital term, dividing by (1-α), taking both sides to the power 1/ρ, and dividing by L yields $A = \left[\frac{Y - \alpha K^\rho}{1 - \alpha}\right]^{1/\rho} \frac{1}{L}$. Data for *Y, K, L* and assumption for *ρ* and *α* determine the labour-augmenting productivity level.

[6] See Schneider and Ziesemer (1995) for a survey of the first two of the three phases.

[7] Lucas (1988) made (2a) linear for ease of exposition in comparison of equilibrium and optimum growth rates. Ziesemer uses *dA/dt = G(H/L_Y, A)* leading to $\hat{A} = g(h)$, where *g* could be *g = ln(ln(h)),* which has some similarity with Fagerberg's (1988) empirical specification.

corrected models (Howitt 1999). Both types of specifications are still in use although Ha and Howitt (2007), Madsen (2008) favour fully-endogenous over semi-endogenous growth models. This is an important difference in the modelling because Phelps-Jones type of semi-endogenous models do not allow for policy effects on the long-run growth rate unless it affects the growth rate of the labour input, which is mostly not distinguished from that of population in the early papers. Later, models with only labour in the technical progress function were called 'knowledge driven' and those with labour and capital 'lab equipment' models by Romer and Rivera-Batiz (1993).

The problem of micro-foundation and new endogenous growth theory

The above mentioned models from the 1960s do not have a microfoundation. Uzawa (1965) considers a central planner's approach; Phelps (1966) calculates steady-state results and Shell (1967) assumes a monopolistic firm or government decision. Romer (1986), Lucas (1988) and Ziesemer (1991, 1995a) could use perfect competition with externalities as fixed costs are irrelevant when human capital rather R&D drive productivity directly. These authors had a keen eye on the empirics and were aware of the scale effect problems early on. The second phase of models was based on Chamberlinian monopolistic competition with horizontal product differentiation by Judd (1985) for consumer goods and Romer (1990) for intermediates, and Bertrand competition based on vertical product differentiation by Aghion and Howitt (1992) for intermediates and Grossman and Helpman (1991) for consumer goods.

 The third phase consisted of applications to other market structures and all theories of international trade. With and without product differentiation there are endogenous growth applications in many areas of economics such as taxes, migration, history, fertility, life expectancy, industrial revolution; empirics of endogenous growth, in particular scale effects and spillovers (see Hoekman et al. 2005 for the latter).

Models with international trade in intermediates tend to be based on homothetic production and utility functions and therefore lead to the same type of growth results as those just described. However, the reallocation through trade may lead to more or less resources in growth production functions (Grossman and Helpman 1991b, chap.6). Moreover, basic trade theory implies that trade liberalization may drive factors into the more productive sectors.

More generally, in a multi-sector economy one can think of productivity A as a weighted index of the sectoral productivities A_i where the weights may be the expenditure or employment shares:

$$A = \prod_{i=1}^{n} A_i^{\mu} \tag{2e}$$

If incomes or trade specialization change, Engel curves (Singer 1999) or trade specialization (Brezis et al. 1993) may drive the weights to sectors with higher or lower productivity. This indicates the relevance of the demand side for productivity. Moreover, the R&D arguments suggested above would apply to the TFP growth of sectors now.

2.4 Growth in an open economy: imported capital goods, exports, and foreign debt
For growth results including income and price elasticities of export demand in the long-run growth formulas one needs to go to a different class of growth models.

For economies with a strong role of agriculture Zarembka (1972) has modelled competition for land for domestic agriculture and for export agriculture. A strong export demand raises demand and prices for land and makes agricultural land and goods for domestic consumption expensive. Surprisingly, unless export taxes correct the development, strong export demand then is welfare reducing for the domestic consumers (Ziesemer 1987, chapter 7).

For more diversified economies, one of the major problems is that they are specialized in the sense of not producing but importing capital goods. The assumption of output and investment being the same good makes no sense anymore. Ignoring debt and depreciation for simplicity the equality of savings and investment with *s* as saving ratio can be written as

$$spY = \dot{K} \tag{3}$$

As output is also exported, the relative price of output and imported investment goods defines the terms of trade, p. Capital goods then have to be paid for by exports, sooner or later depending on whether or not new foreign debt is incurred first. Exports X are driven by the income growth of the customer countries or the world, Z, and react to the terms of trade:

$$X = p^\eta Z^\rho, \eta < 0, \rho \geq 0. \tag{4}$$

Here η is a negative price elasticity and ρ is a non-negative income elasticity of export demand. A major question therefore is how strongly exports increase if the income of customer countries increases, which is the question of high or low income elasticity of export demand, ρ, emphasized by Prebisch (1959) and Singer (1999). If terms-of-trade are endogenous, a higher (lower) income growth driving up (down) export growth also enhances (lowers) terms-of-trade growth, both reinforcing (weakening) the export revenues and the potential for buying capital goods. The trade balance is

$$pX = \dot{K} + IM \tag{5}$$

M indicates other imports assumed to be exogenous here. Technical change will reduce the terms-of-trade as unit costs are reduced. The model is completed by a Cobb-Douglas function

$$Y = e^{gt}K^\beta L^{1-\beta} \tag{1'}$$

Solving the model for the steady state with exogenous growth rates for labour ε and technology g yields the following steady state results:

$$\hat{p} = \frac{(1-\beta)(\rho\hat{Z}-\varepsilon)-g}{\beta-\eta(1-\beta)} \tag{6}$$

$$\hat{k} = \frac{\rho\hat{Z}-\varepsilon-(1+\eta)g}{\beta-\eta(1-\beta)} \tag{7}$$

$$\hat{w} = \frac{\beta(\rho\hat{Z}-\varepsilon)-\eta g}{\beta-\eta(1-\beta)} = \hat{Y}-\varepsilon \tag{8}$$

The interpretation is as follows. The denominator of all expressions is positive and will be included in the interpretation only in the end of this explanation. Technical change would reduce costs and prices at rate g in (6). Under a high (low) price elasticity in (7) the negative valuation effect would (not) be outweighed and the export value would increase (decrease). This allows importing more (less) capital goods and letting the capital-labour ratio increase (decrease). If the price elasticity were minus unity this effect would be zero. The effect of g on the growth of wages and per capita income would be as in the Solow model but together with other effects. If the price elasticity is more negative than minus unity, exports and imported capital goods are larger and so is the demand for labour, wages and per capita income in growth rates. Technical change works as a handmaiden of growth in case of price-elastic export demand (Kravis 1970). The growth rate of exports at hypothetically constant terms-of-trade defines the growth rate of exports and imported capital goods and therefore increases the growth rate of the capital-labour ratio in (7). Higher growth of export demand drives up the growth rate of the terms-of-trade in (6). The enhanced growth of capital per worker also drives up growth of wages in (8). This part is called the engine of growth and represents the line of argumentation in Prebisch (1950). In sum, the model has two driving horses, technical change, which could also be zero, and customer countries' or world income growth. Unless they are well balanced, growth of the terms of trade can be positive or negative, for good or for bad reasons. Traditionally, based on static trade theory, falling terms-of-trade are seen as welfare reducing. This effect is also present here, as lower export prices at given quantities would buy less machines. However, this can be a result of more technical change and competitiveness leading to higher growth and future or dynamic welfare; or it

can be a result of sluggish export growth leading to lower growth and negative static and dynamic welfare effects. A high income elasticity of export demand is therefore of utmost importance and could be enhanced by product quality if consumers are willing to spend money on that.

The basic model for these considerations is that of Bardhan and Lewis (1970), which differs from Keynesian versions of balance-of-payment constrained growth in that the latter have exogenous terms of trade growth. Ziesemer (1995b) has adjusted their model by (i) separating efficient labour into technical change and exogenous or unlimited labour supply; (ii) introducing world income and the income elasticity into the demand function; and (iii) linking the classical version of the model to Adam Smith's vent-for-surplus idea; and (iv) linking the neoclassical version of the model to the Prebisch-Singer thesis and the related models. The model can be extended to perfect capital movements, and imperfect capital movements with application to the 1982 debt crisis (Ziesemer 1995c and 1998 respectively). Estimates of the non-linear central (differential) equations as they come out of the theoretical model (i.e. without linearization) - for Brazil (Mutz and Ziesemer 2008) and Mauritius (Habiyaremye and Ziesemer 2012) - show that plausible estimates for the parameters of the model can be found, confirming the realism of the model in spite of many simplifying assumptions.

3. Croatia compared to country panels: a nearest-neighbour-fit-lo(w)ess approach

In this section we try to get a first impression of the Croatian economy without trying to draw or insinuating strong conclusions. We will take a theory guided tour following the line of the argument in the text above. As Croatia has a GDP per capita in the range of 8000 to 15000$ (9-9.6 in natural logs) since the early 1990s, we will resist the temptation to look at wages as classical economists might have suggested.[8] The income range is important because we will compare Croatia mostly but not always with other countries using indicators plotted against income in logs below.

TFP and R&D

Growth accounting suggests looking at the TFP data estimates. TFP estimates are set equal to 100 in 2011 for all countries in PWT9. Therefore we look only at the linear lo(w)ess variant of the nearest-neighbor fit time trend for Croatia (see Greene, any recent edition).
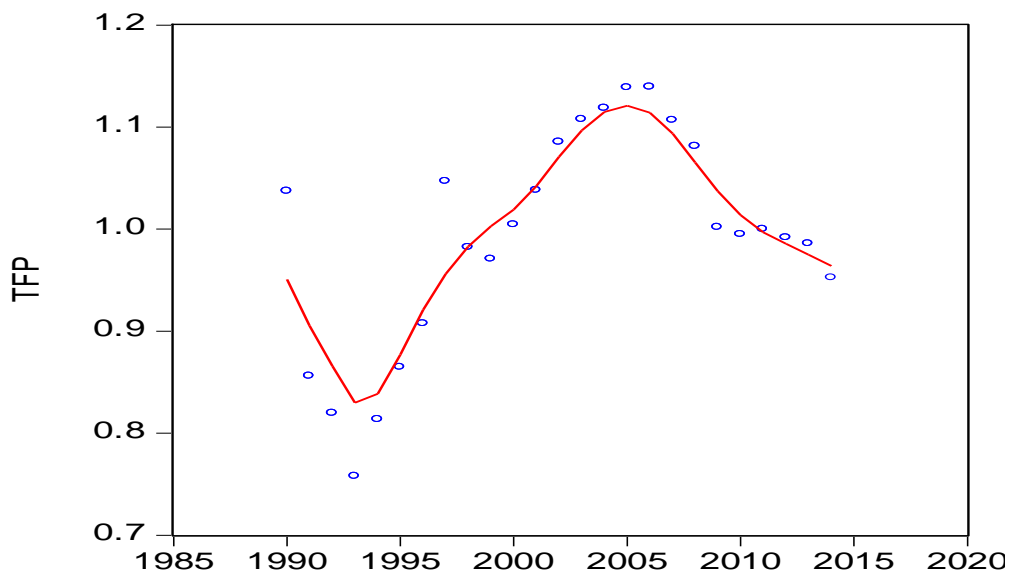

Figure 1: Croatia's total factor productivity 1990-2014

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[8] Aspects of population growth including migration may be interesting though in regard to problems of ageing.

After 1993 TFP levels increase until 2006 but with the onset of the sub-prime crisis TFP goes down. Growth rates are negative but increasing until 1993. Then they are positive and increasing until 1997, negative 1998/99 in the years of the Asian crisis, above one percent until 2004, zero in 2006 and negative afterwards during the financial crisis. All negative growth rates happen to occur during international crises. The war has reduced the level of 1990 and large parts of the achievement from 1993-2006 has been made undone during the financial crisis.
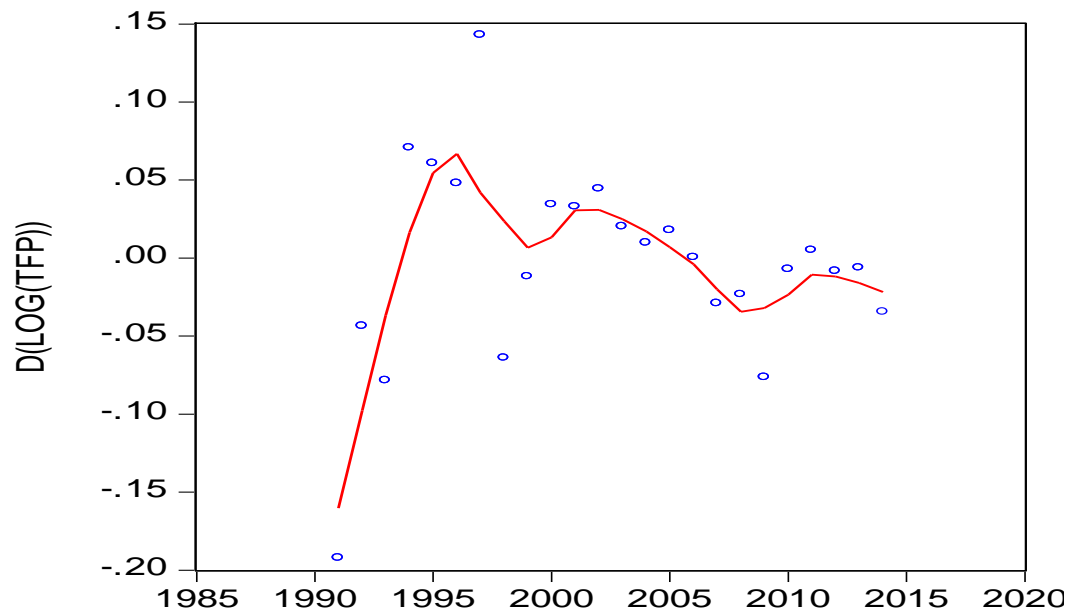
Figure 2: Croatia's total factor productivity growth 1991-2014
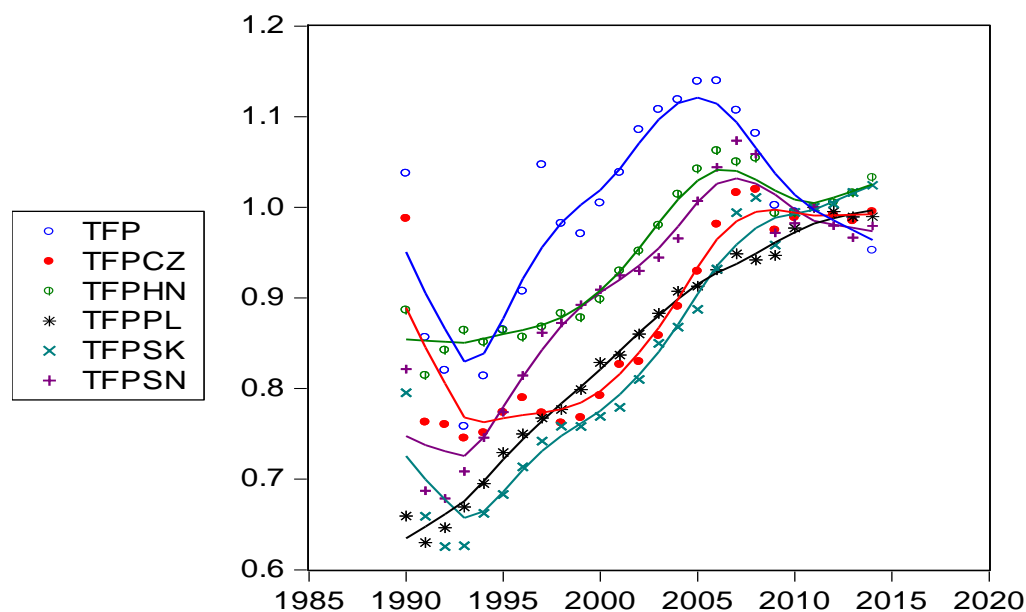
Figure 3: TFP of Croatia, Czech Republic, Hungary, Poland, Slovakia, Slovenia (2011=100)

Endogenous growth theory suggests looking at data for R&D according to lab-equipment models. R&D as a share of GDP is higher 1999-2005 then thereafter, 2006-2014. This should perhaps be reconsidered.
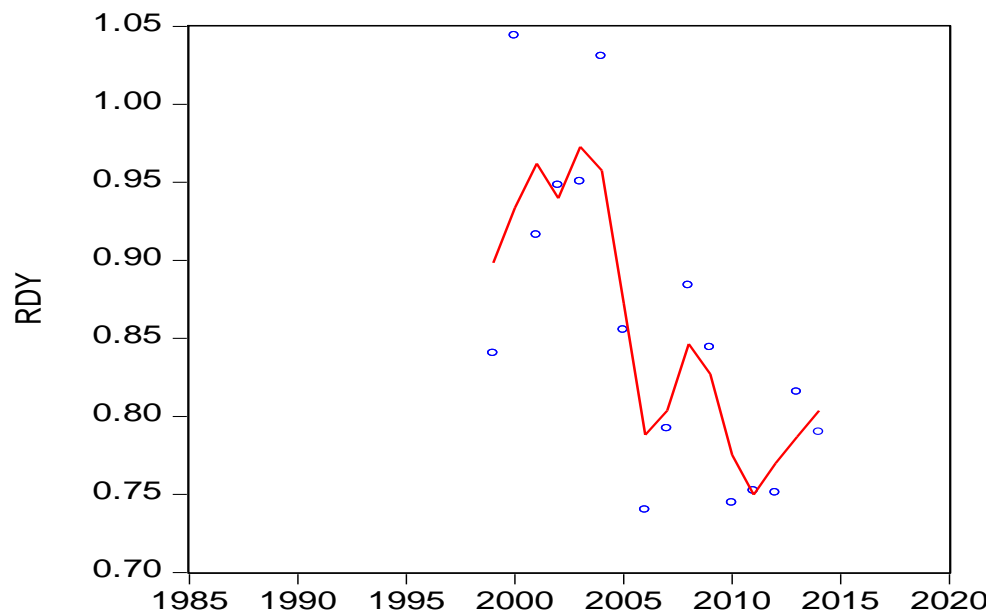

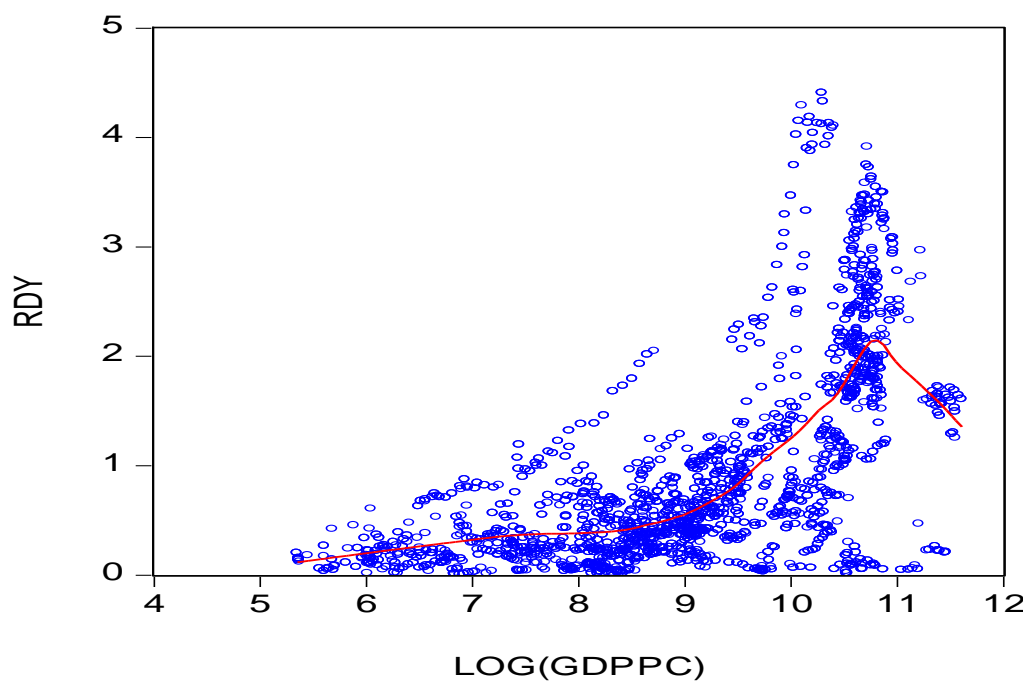Figure 4: R&D expenditure as a share of GDP in Croatia 1999-2015

Figure 5: The loess-fit relation between GDP per capita and R&D as a share of GDP for world panel data.

With R&D/Y between 0.8 and 1% Croatia is on the loess fit line of the ROW for which data are available. Moving up the line is a plausible target scenario and so is trying to be above the regression line.

According to knowledge driven models we should look at researchers as a share of the population or labour force. Researchers in R&D per million people are between one and two thousand but mostly 1300-1600, with a drop in 2005.
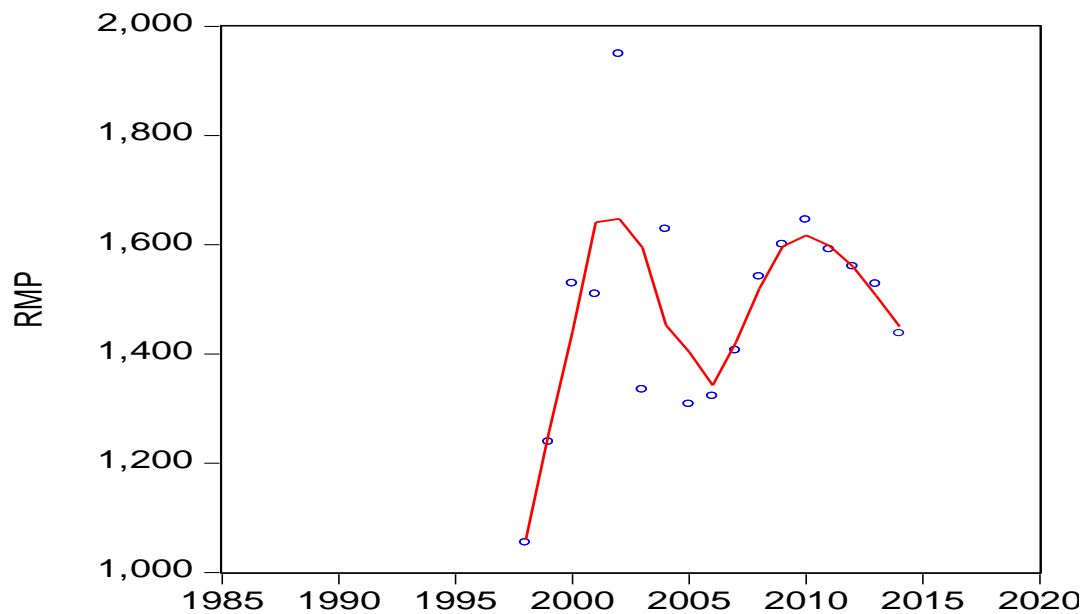

Figure 6: Researchers per million inhabitants in Croatia 1998-2014.

In international comparison the number is again near the loess fit line.
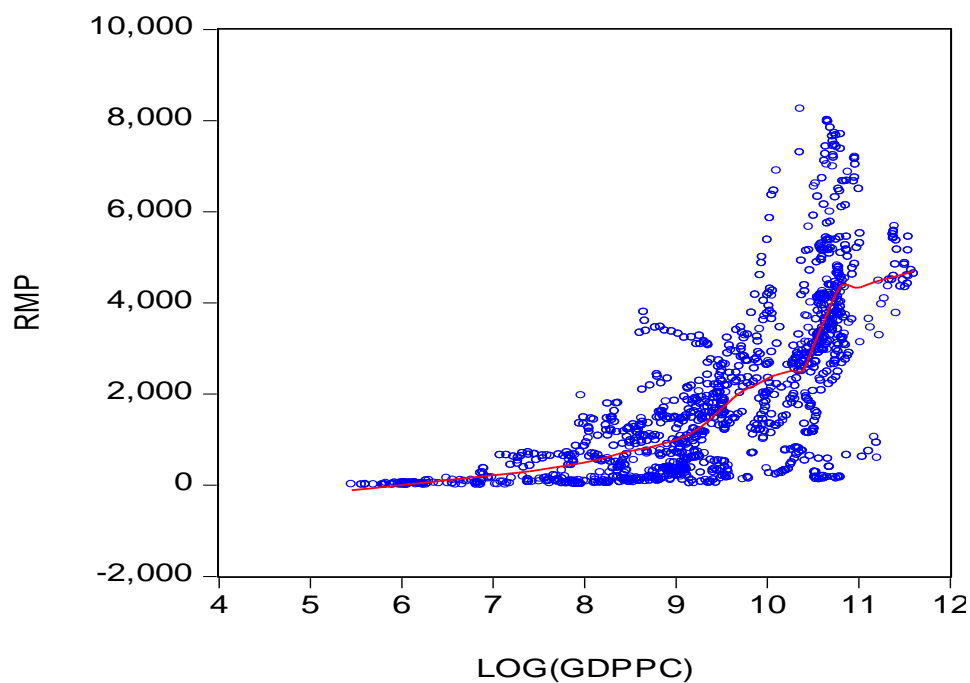

Figure 7: The loess-fit relation between GDP per capita in researchers per million inhabitants in world panel data.

Researchers will use several methods of protecting their findings. One of them is patent application, an indicator of research output. In the data they are differentiated according to residents and non-residents.
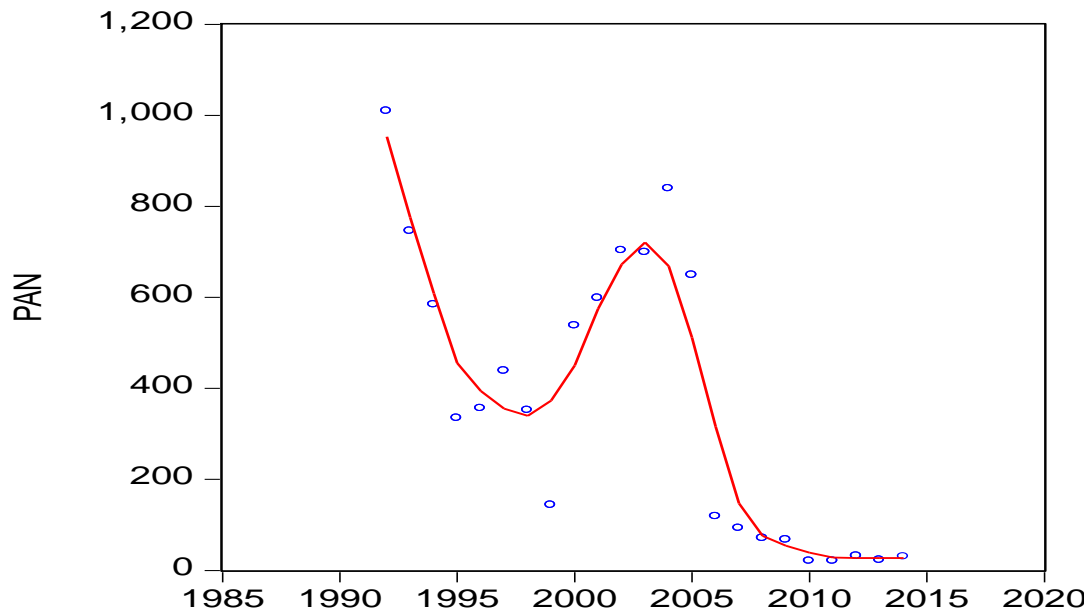

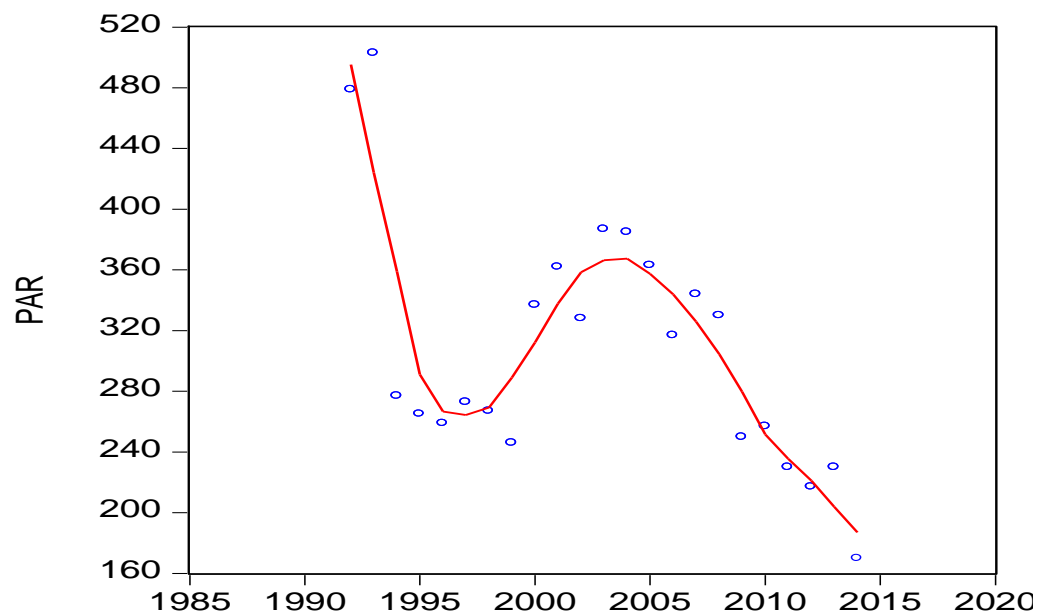Figure 8: Patent applications by non-residents in Croatia 1992-2014

Figure 9: Patent applications of residents in Croatia 1992-2014.

Besides the down-up-down pattern, there is a crash in non-residential patent applications 2005/6 (and the same for Iceland, Hungary, Poland, Romania, Serbia, UK; Turkey 2002/3) and in residential applications 2008. "The cooperation and extension agreement between Croatia and the European Patent Offices (EPO) is in force since 2004. It allows the extension of the same protection granted to full members of the EPO in Croatia. As a consequence of the entry into force of the extension agreement, the number of national patent applications has reduced significantly. Croatia has

undertaken the necessary steps for full accession to EPO, to be realized in 2007?"[9] Instead of filing a patent application in many countries, now one for many countries is enough and therefore the numbers have fallen to a lower level. They are constant for non-residents at a low level since 2010, but keep falling for residents. These statistical issues make these patent applications numbers of limited value as indicator for research output.

According to perfect competition models for invention and diffusion we should look at indicators for human capital. In the long run this is the basis for getting more researchers and it is important for diffusion. Enrolment in tertiary education in Croatia has gone form 21 percent in 1990 to 69.5 in 2014. This is from below to far above a world panel average. This may be a good basis for moving up in terms of researchers and R&D.
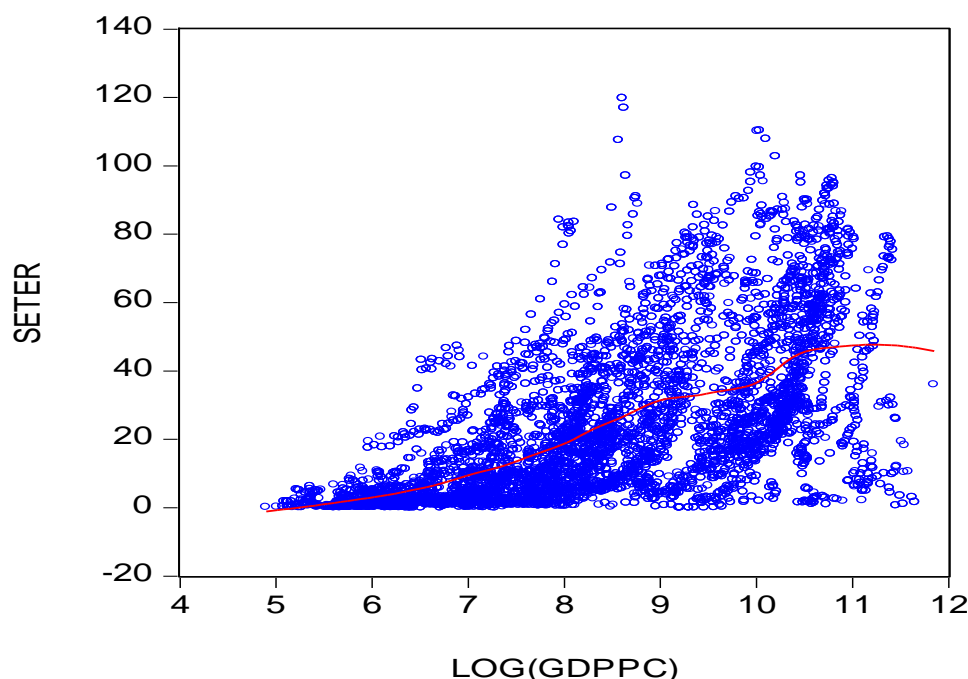

Figure 10: The loess-fit relation between GDP per capita and tertiary school enrolment in world panel data.

The technology transfer and diffusion literature argues that there may be spillovers from fdi (see Hoekman et al 2005). A first shot for further development and testing can be found in the following regression. Trade is also an often mentioned aspect that might generate spillovers. However, imports then are supposed to have a positive impact, whereas our regression shows that it is negative to the same extent that exports are positive. Moreover, both values are very high. It seems more plausible to argue in spirit of trade theory: Specialization on more productive goods increases productivity because of a higher share of exported goods and a lower share of imported goods (see equation (2e) above). Similarly, for FDI it is perhaps not spillovers what enhances the TFP but rather the high productivity of FDI inflows and the low one of FDI outflows; then both increase TFP through increasing the average productivity across plants. One reason for caution is that it does not work with lags other than the fourth used here. Below we will try to extend this regression to include the above mentioned research variables.

$$\text{LOG(TFP)} = 0.256 + 0.66\text{LOG(TFP(-1))} - 0.0097t + 0.0228\text{LOG(FDIYIN(-4))} +$$
$$0.0174\text{LOG(FDIYOUT(-4))} + 0.19\text{LOG(EXY(-4))} - 0.21\text{LOG(IMY(-4))} \quad\quad\quad (9)$$

Estimation method LS-HAC. Period 1999-2014. All p-values are 0.0000. Adj. R-sq.: 0.92. Durbin-Watson Statistic: 2.05.

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[9] Screening report, Croatia, Chapter 7 – Intellectual property law, 14 September 2006,

Open economy issues

The open economy growth model suggested above indicates that we should look at the terms of trade for goods and services, because without any trend the closed economy growth models would be observationally equivalent with their closed economy counterparts. We divide exports as capacity to import by exports of goods and services, both at constant local currency units, both taken from WDI. The result represents the terms of trade in levels and growth rates (plus 1):
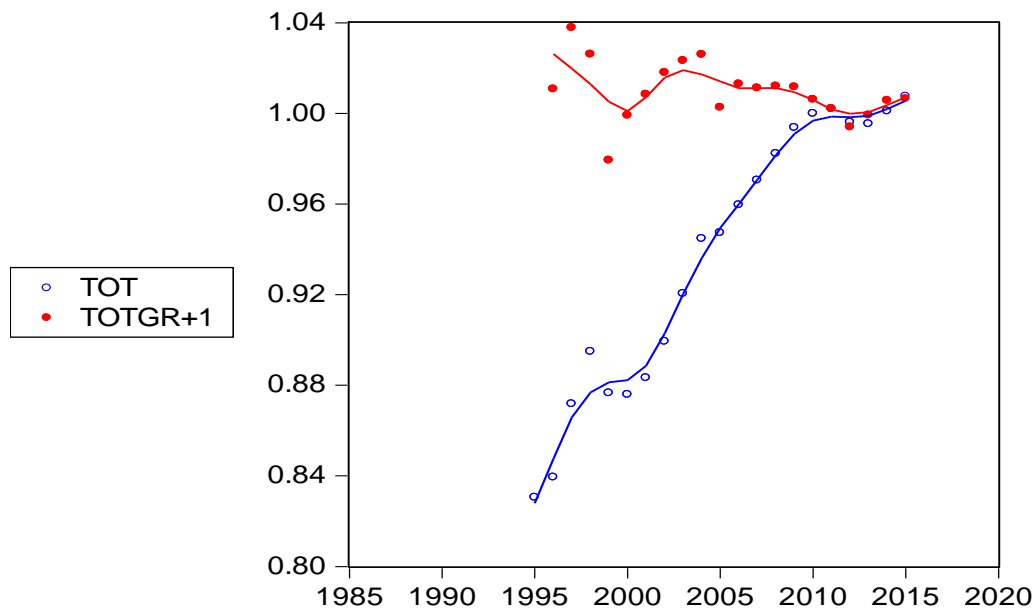

Figure 11: Terms of trade growth is positive but declining since 2010. Therefore the model with imported capital goods may be important.

Imported machinery (from WITS 2017) as a share of gross fixed capital formation is increasing since the crisis in 2009 and did so before the ICT bust in 2001. From 2002 to 2009 it was decreasing.
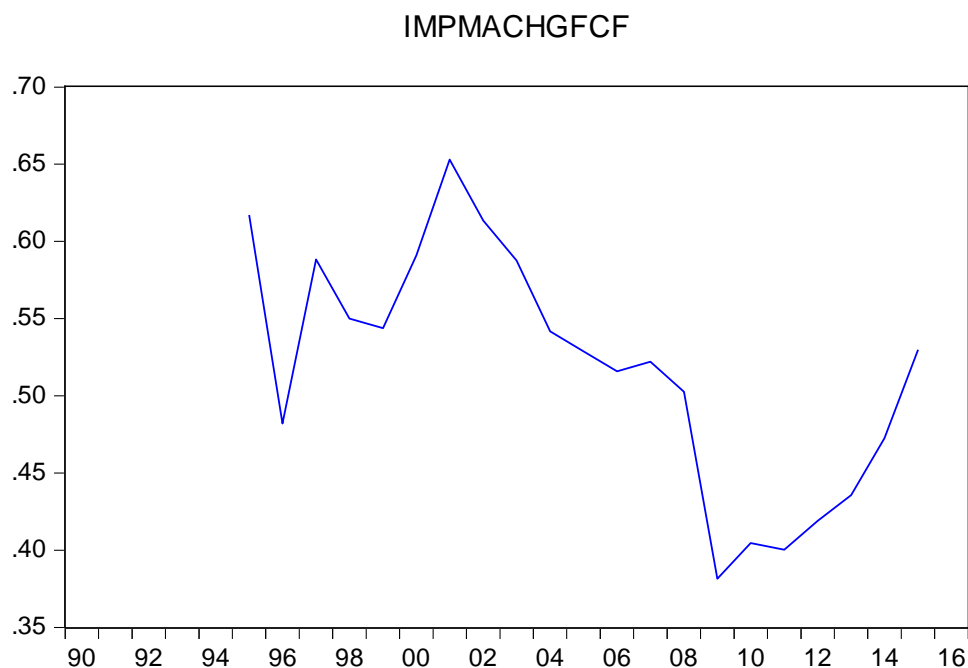
IMPMACHGFCF

Figure 12: Imported machinery as a share of total gross investment.

The share of exports needed to pay for this has fallen from 40 to 20 percent in Figure 13.
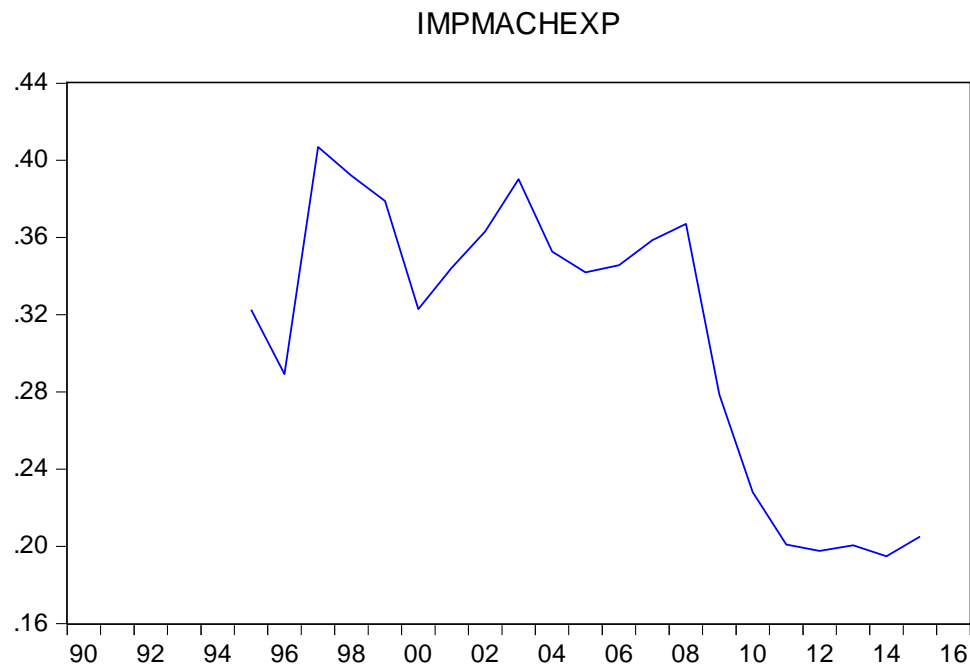
IMPMACHEXP

Figure 13: Imported machinery as a share of exports in Croatia 1995-2015

By implication, 80 percent of export revenues can be used for other imports like oil, intermediaries other than those captured in SITC7, or consumption goods. Major trade partners are: Austria, Bosnia, Germany, Italy, Slovenia, Hungary.
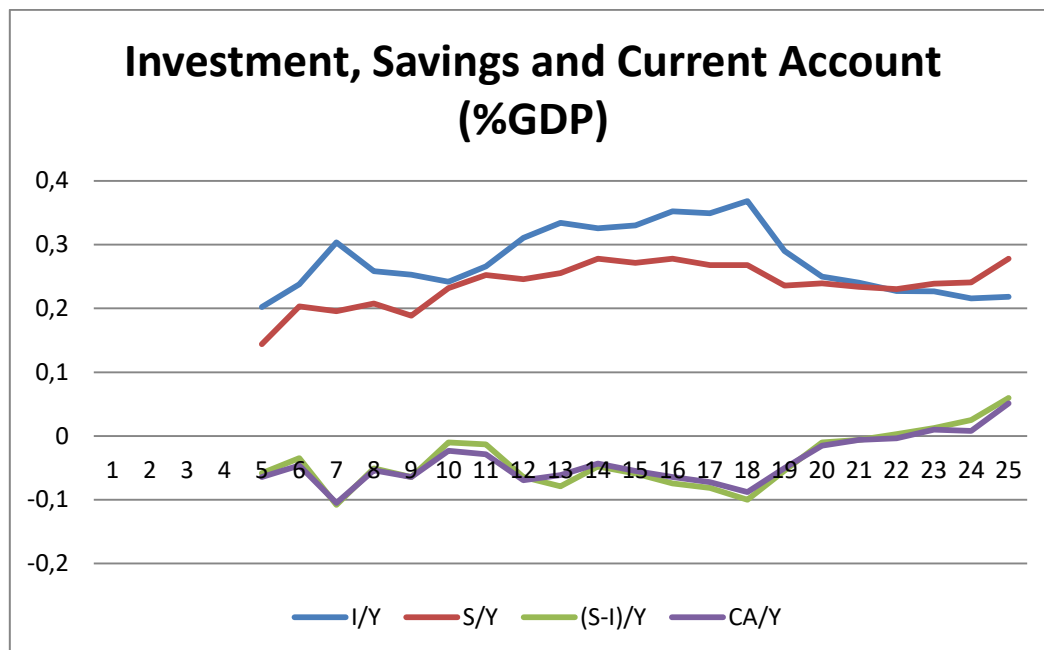

Figure 14: Investments and savings as a share of GDP, their difference and the current account, all as share of GDP changing to positive values in Croatia.

As lending interest rates are above nine percent, the recent increase in the savings ratio is a good policy to get the current account positive and stop foreign debt from growing at increasing risk mark-ups. The differences of investment and savings 1995-2015 add up over time to 0.55 of GDP. A formula for the growth of the debt/GDP ratio can be obtained as follows for $d \equiv D/Y$:

$$\dot{D} = I - S, \hat{d} = \hat{D} - \hat{Y} = \frac{I-S}{D} - \hat{Y}, \dot{d} = \frac{I-S}{Y} - \hat{Y}d. \tag{10}$$

Growth and excess savings reduce the debt/GDP ratio.

4. An empirical dynamic simultaneous equation model for growth links and policy analysis in Croatia

In this section we integrate the arguments discussed in the previous section into an empirical simultaneous equation model in order to test whether or not the growth mechanisms work in Croatia. All variables have their own equation and the number of equations equals the number of variables. For variables used as regressors but not explained through other regressors themselves, an autoregressive process was specified. Except for intercepts and time trends we have only endogenous variables. All results should be taken with caution because the available data are extremely short and a time-series analysis has just become possible.

P-values are reported only when they are larger than 0.0000. The estimation method is Seemingly Unrelated Regression (SUR). We have looked at issues of endogeneity but ultimately ignored it, because regressors are lagged often by several periods. Contemporaneous regressors never show contemporaneous correlation in the equation for reversed causality. We ignore forward endogeneity and predeterminateness, which means correlation of regressors with lagged and future residuals (Davidson and McKinnon 2004). The period for the system estimate is 1992-2015, implying a maximum of 24 observations per equation. This low number of observations is just enough to do time series analysis, also because we test up to six lags per variable to capture the lag structure well. Coefficients are iterated after estimating a one-step weighting matrix, requiring 16 iterations here.

The major driver of growth according to the theoretical and empirical literature is the total factor productivity. Coefficients presented below are rounded. Our equation explaining TFP is

LOG(TFP) = -0.978 - 0.045t + 0.34RDY(-3) + 0.15LOG(RDY(-5)) + 0.16LOG(RMP(-4))
+ 2.4$^{e\text{-}06}$SETER(-5)^3 +0.006SETER(-6) (11)

11 Observations; Adj R^2 = 0.987; Durbin-Watson stat = 2.24; p-values all 0.0000.

The time trend de-trends all growing variables and should not attributed to TFP only. TFP is driven by RDY, R&D as a share of GDP, three and five years ago and RMP, researchers per million inhabitants, four years ago. SETER, tertiary school enrolment, five or six years ago, just after leaving school, also drives TFP, and probably is capturing mainly the diffusion aspects. Once we have more observations, available other regressors like FDI and trade shares most probably can be added. Here we have selected only the most strongly significant ones.

LOG(RMP) = 9.89 + 0.012SETER(-6)+0.55LOG(RDY(-4)+0.376LOG(RMP(-2)
– 0.29LOG(RMP(-3)) - 0.49LOG(RMP(-4) (12)

Obs: 12; adj R^2 = 0.678; DW = 1.91. p-values all 0.0000.

Researchers per million inhabitants are increased by tertiary enrolment as of six years ago; by its own lags 2, 3, and 4, of which the first is positive and the later ones negative indicating drop out; R&D expenditure with lag 4 has a positive effect.

LOG(RDY) = 0.7 - 0.117LOG(1+FDIYOUT(-4)) + 0.00017RMP + 1.286LOG(SY) +
0.21LOG(20+FDIYIN(-1)) − 0.71LOG(RDY(-2)) + [AR(1)=1.26][10]   (13)

Obs: 12; adj R^2 = 0.92; DW = 1.97. p-values 0.0015 for FDIYIN or 0.0000.

R&D expenditures depend on the value two years before. Own savings are used to increase R&D expenditures. They are slightly higher when there are more researchers per million inhabitants, lower through lagged outward FDI indicating that the latter leads to reduction in R&D four years later, and higher through inward FDI from the previous years. In addition, all effects are stronger when lagged one additional period. As FDI is important for R&D we look at it next. For inward FDI we find the following.

(20+FDIYIN) = 7.744 +0.24*(20+FDIYIN(-1))-1.56(20+FDIYIN(-4))+5.11LOG(IMY(-4)) +
30.34(RDY(-3)) − 37.24LOG(TFP) + 1.87LOG(20+FDIYIN(-3))   (14)

Obs: 13; adj R^2 = 0.94; DW = 2.4. p-val. 0.024 for intercept, 0.1008 for FDIYIN(-3), for all others 0.0000.

Inward FDI depends on its own lags 1, 3 and 4 with changing signs and logs in the specification. Imports as of four years ago stimulate inward FDI suggesting that they are substitutes. Earlier R&D expenditures increase inward FDI perhaps because domestic input delivery is improved. But current TFP decreases inward FDI, which is perhaps a competition effect in the same market.

LOG(1+FDIYOUT) = 36.497+2.885RDY(-5) - 5.998LOG(20+FDIYIN(-4)) - 2.72LOG(RMP(-5)) +
0.87LOG(1+FDIYOUT(-5))   (15)

Obs: 12; adj R^2 = 0.41; DW = 2.76. p-values 0.0000 for all variables.

Outward FDI depends positively on its own five-year lag, negatively on inward FDI four years earlier indicating perhaps failure correction to earlier inward FDI. Domestic lagged R&D drives FDI out five years later; availability of researchers decreases outward FDI. As tertiary education is driving the number of researchers and TFP we explain it next.

LOG(SETER)   =   -0.1   +   1.39(SY)   +   0.37LOG(SETER(-6))   -   0.008(FDIYIN)   -
0.025LOG(1+FDIYOUT) + 0.62LOG(SETER(-2))   (16)

Obs.: 17; adj R-sq = 0.99; DW = 2.24; p-values are 0.0285 for the constant and 0.0013 for FDIYOUT.

Inward FDI reduces enrolment slightly perhaps because of higher probability of finding a job and outward FDI more strongly so because of less positive expectations. Tertiary enrolments depend positively on the second and sixth lag. As these coefficients add up to 0.9 the effects of FDI are ten times larger in the long run than the immediate effects.

LOG(IMY-MACHY) = 4.7 - 0.2*LOG(IMY(-4)-MACHY(-4)) + 1.3LOG(TFP) + 1.24e^{-06}(SETER(-6))^3 + 0.29LOG(IMY(-1)-MACHY(-1)) - 0.35LOG(IMY(-2)-MACHY(-2))   (17)

Obs.: 16; adj. R-sq = 0.81; DW = 2.12. p values are 0.0001 and 0.0049 for lag 4 and lag 1.

TFP and tertiary enrolments enhance imports other than machinery perhaps for consumption goods or computers and related products in other categories than SITC 7 for high-tech/skill workers.

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[10] As FDI variables can be strongly negative we add a value of 20 in order to make sure that the logs exist. Terms '*ar(p)=ρ*' indicate that the whole equation is added with lag *p* in the form *ρ(Y-Xβ)*.

SY= 0.25 + 0.157D(LOG(GDPPC(-2))) + [AR(1)=0.57,AR(4)=-0.596]   (18)

Obs.: 12; adj. R-sq = 0.59; DW = 2.79. p value 0.0002 for GDPpc and 0.0000 for the others.

The savings ratio depends on income two years ago and all other variables again lagged twice. Adding other arguments leads to overfitting.

LOG(MACHY) = -29.176   +   0.636LOG(MACHY(-1))+1.2LOG(TFP)   +   2.94LOG(TOT)   -4.5LOG(TOT(-1)) + 0.887LOG(Z)   (19)

Obs.: 19; adj R-sq = 0.87; DW = 2.43; p-values: 0.0368, 0.0000, 0.0000, 0.0329, 0.0021, 0.0446.

Imports of machines are enhanced by TFP and current terms of trade but reduced by lagged terms of trade, the latter suggesting intertemporal substitution.

LOG(EX) = -38.92+1.95LOG(Z) + 1.1LOG(TFP) -2.96LOG(TOT(-1)) + 0.185LOG(EX(-4))   (20)

Obs.: 16; adj. R-sq =0.99; DW = 2.44; all p-values 0.0000.

Exports have a high income elasticity of 1.95. Alternative models based on CES functions have the homotheticity property that implies unit income elasticities and therefore they could not capture high or low income elasticities of export demand. TFP is enhancing competitiveness with elasticity 1.1. Lagged terms of trade reduce exports with negative elasticity 2.96. Croatia is clearly a case for export optimism. The dependent variable lagged by four periods indicates that the long run effects are even larger. All the just mentioned arguments also have an impact on growth considered next.

LOG(GDPPC) = -12.18 + 0.62(LOG(GDPPC(-1))) + 0.3LOG(TFP)+0.2(IY(-1)-MACHY(-1)) –1.3D(LOG(POP)) - 0.01t + 0.07LOG(MACHY) - 0.063(LOG(TFP(-1))) + 0.5LOG(Z) -0.166LOG(TOT(-1)) + 5.02e^{-07}*SETER(-5))^3 (21)

Obs.: 19; adj. R-sq = 0.999; DW = 2.32. p-values 0.0016 for log(Z), 0.0127 for SETER(-5))^3, others 0.0000.

Growth is driven in line with the theoretical sections. Current TFP has a positive effect but the lagged TFP has a reducing effect, which may be a technical effect in relation to the lagged dependent variable. Lagged investments other than imported machines as well as imported machines enhance growth. World income has the highest of all positive elasticities in the growth equation (21). Tertiary enrolments have a positive effect in addition to those through TFP. Lagged terms of trade, population growth and a de-trending term reduce growth.

LOG(IY-MACHY) = 125.96 - 0.3LOG(IY(-4)-MACHY(-4))+1.4LOG(EXY) +4.24LOG(TFP(-1)) -4.36LOG(Z(-1)) – 0.9LOG(IY(-2)-MACHY(-2))+0.886LOG(EXY(-1))   (22)

Obs.: 15; adj R-sq = 0.83; DW = 2.61. p-values for lag four 0.0062, for exports 0.0796, all others 0.0000.

Lagged TFP and exports increase investment (net of imported machinery); own lags two and four reduce investment. Lagged world income reduces domestic investment unlike current world income growth enhancing imported machinery according to equation (19), which can partly be seen as de-trending exports; however, current and one-period lagged terms of trade are not statistically significant.

D(LOG(POP))=   -0.01   -   0.686D(LOG(POP(-3)))   +   0.09D(LOG(GDPPC(-4)))   +0.23D(LOG(GDPPC(-2))) – 0.137D(LOG(GDPPC(-3)))+0.054D(LOG(GDPPC(-5)))   (23)

Obs.: 15; adj. R-sq = 0.66; DW = 2.1; p-values are 0.0001 for lag four of GDPpc, 0.0018 for its lag five and 0.0000 for all others.

Population growth depends on its own lags three and four and lags two to five of the GDP per capita, where the latter have mainly a positive effect, with a negative intercept as in fully-endogenous growth theory of Howitt (1999).

$$LOG(TOT) = -5.77+0.25(LOG(GDPPC)) + 0.0996LOG(Z) +0.12LOG(EXY) - 0.0047(IMY - MACHY) + 0.013LOG(MACHY(-1))+ [AR(1)=-0.544, AR(2)=-0.2, AR(4)=-0.39, AR(3)=-0.39]$$ (24)

Obs.: 16; adj R-sq =0.998; DW =2.15; all p-values are 0.0000.

Terms of trade are increased by world income and export growth and decreased by non-machinery and machinery imports. GDP per capita increases the terms of trade, perhaps through increasing the demand of non-traded goods at the cost of imports or decreasing exports. An autoregressive process of degree four makes all variables relevant with four additional lags, which may be related to the J-curve complications running via exchange rates and the delay in adjustment of long-term contracts.

$$LOG(Z)=13.04 + 0.9LOG(Z(-1))-0.336LOG(Z(-2)) + 0.012t$$ (25)

Obs.: 24; adj R-sq = 0.997; DW = 2.11; p-values 0.0061, 0.0000, 0.0443, 0.0063.

World income growth depends on a time trend and two lags.

$$U = 18.28 + 0.49U(-1) -18.04D(LOG(GDPPC(-2))) - 20.7LOG(TFP(-1)) - 2.92LOG(SETER(-6)) -$$

$$(0.000) \quad (0.0000) \quad (0.0138) \qquad (0.0000) \qquad (0.0009)$$

$$77.8D(LOG(POP(-1))) - 55.9D(LOG(POP(-2))) - 36.65D(LOG(POP(-5)))$$ (26)

$$(0.0001) \qquad (0.0034) \qquad (0.0100)$$

Obs.: 17; R-sq. =0.84; DW = 2.14. p-values in parentheses.

Equations (11)-(26) consist of 16 equations determining sixteen variables. There are no exogenous variables because each one that is deemed to be important can be explained by one of the other fifteen. A baseline simulation of 1000 repetitions with a confidence interval of +- 2standard deviations is shown in Figure 15. Because of the low number of observations confidence intervals are getting larger at the end of the simulation period 2015. The ups and downs in the data are reasonably well followed by the simulation line.
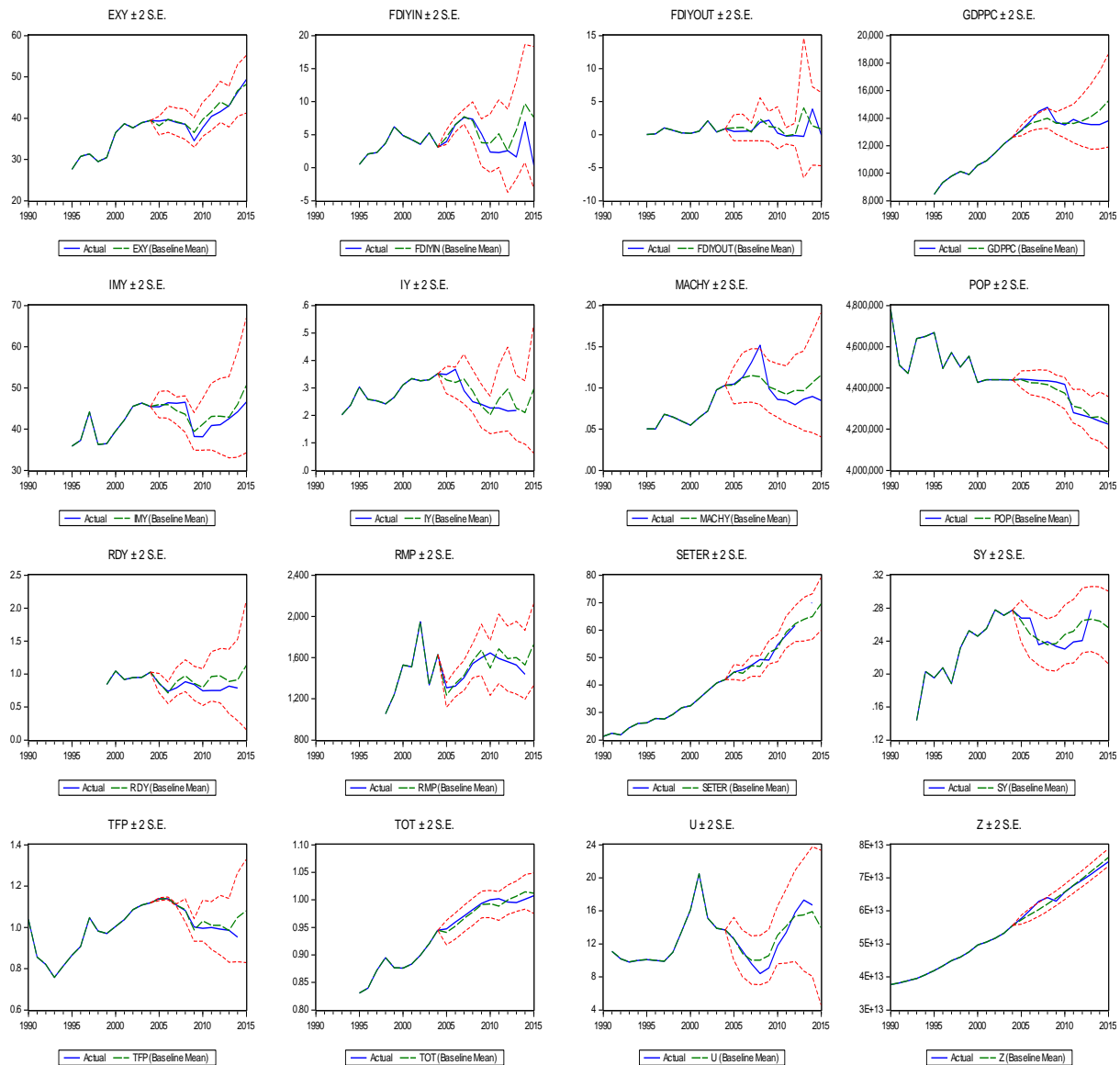
Figure 15: Baseline simulation of model equations (11)-(26) with actual data.

5. Policies mimicked by permanent shocks

As the equations have been estimated simultaneously, we can use the model for simulation of policies. We impose shocks as an enhancement of the intercepts of the respective equations. Croatia's impressive increase in tertiary enrolments can be interpreted as a shock to equation (16). We increase the intercept by 0.01, which is a one-percent increase in tertiary enrolment. The result is shown in Figure 16. The shock to SETER affects directly and positively mostly with five or six year lags its own dynamics (also with lag two), researchers per million inhabitants, total factor productivity, GDP per capita, non-machinery imports, and unemployment negatively. Indirect effects are that imports (also machinery) increase more than exports, investment more than savings, FDI more outward than inward. R&D expenditures and population (reduced net-emigration) increase, terms-of-trade decrease. In short, growth improves but foreign imbalances worsen.
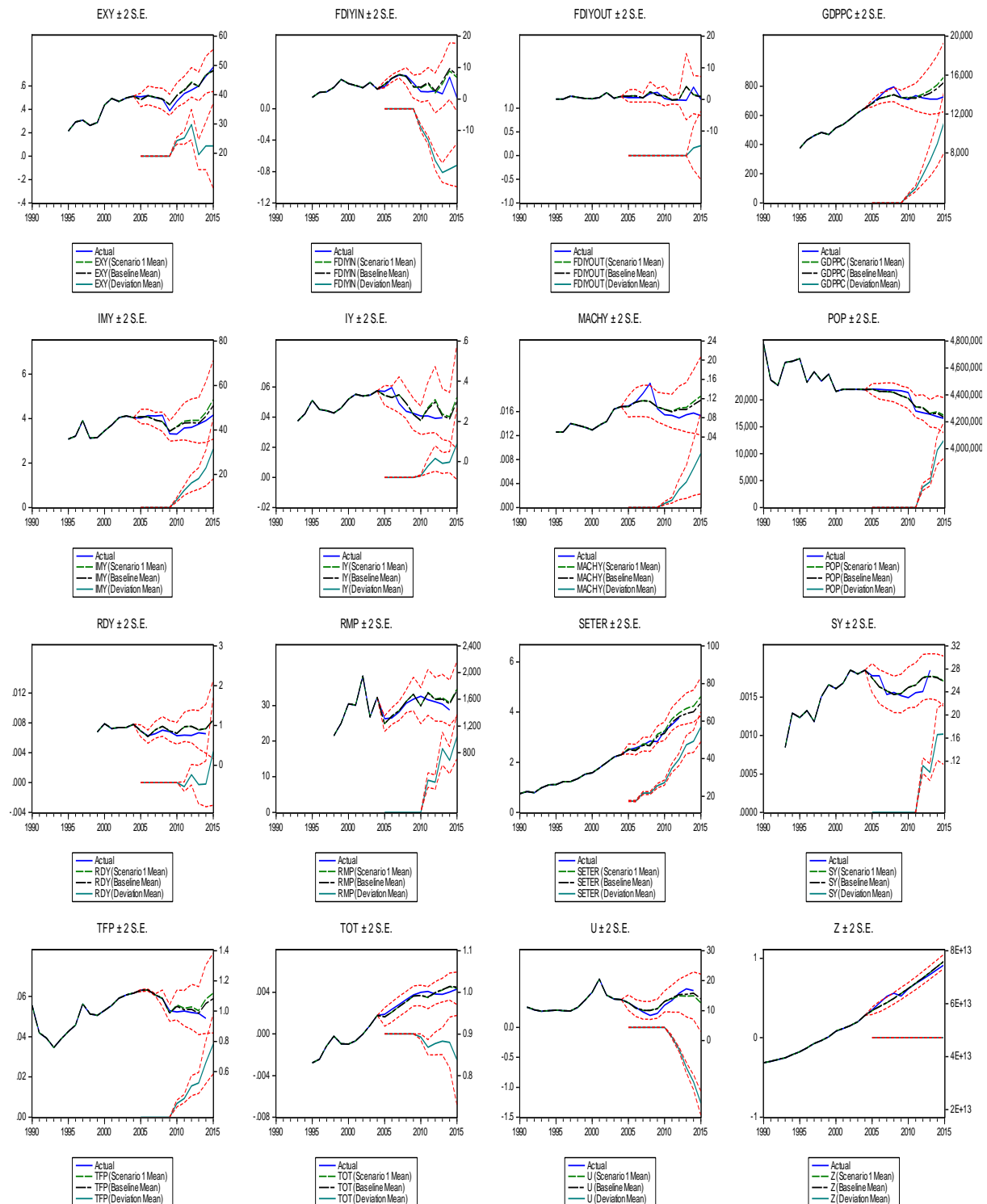
Figure 16: Simulation of a one-percent shock to tertiary education. The upper part in each graph has the simulation scenario with its confidence interval, actual data and the baseline simulation, all measured on the right-hand axis. The lower part shows the difference between scenario and baseline with its own confidence interval.

Next, a one-percent shock to R&D expenditures as a share of GDP, which would shoot Croatia from the low end of R&D expenditure to the EU mid-field, is analyzed with results shown in Figure 17.
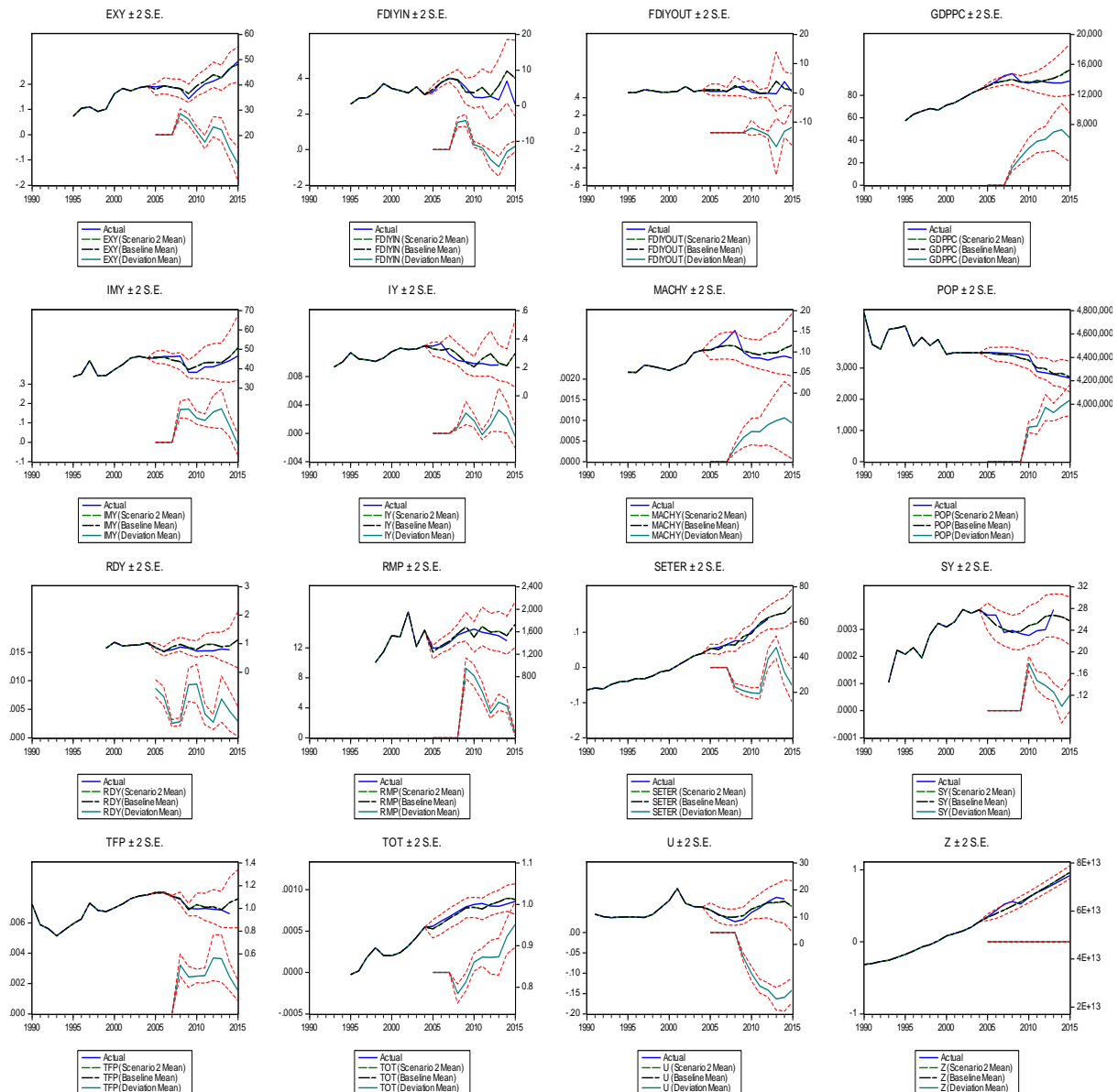
Figure 17: A one-percent shock to R&D expenditures as a share of GDP compared to baseline. Lines as explained below Figure 16.

The R&D expenditure share affects, after some years, its own dynamics, the number of researchers, TFP and FDI, inward as well as outward, positively. GDP per capita goes up although tertiary enrolments go down and machinery imports increase. Exports fall more than imports. Investments falls and savings increase slightly. Terms of trade and population increase whereas unemployment falls. Enhancing R&D expenditure has positive effects but again foreign imbalances are increased and require additional measures.

Increasing instead the number of researchers by ten percent has results shown in Figure 18.
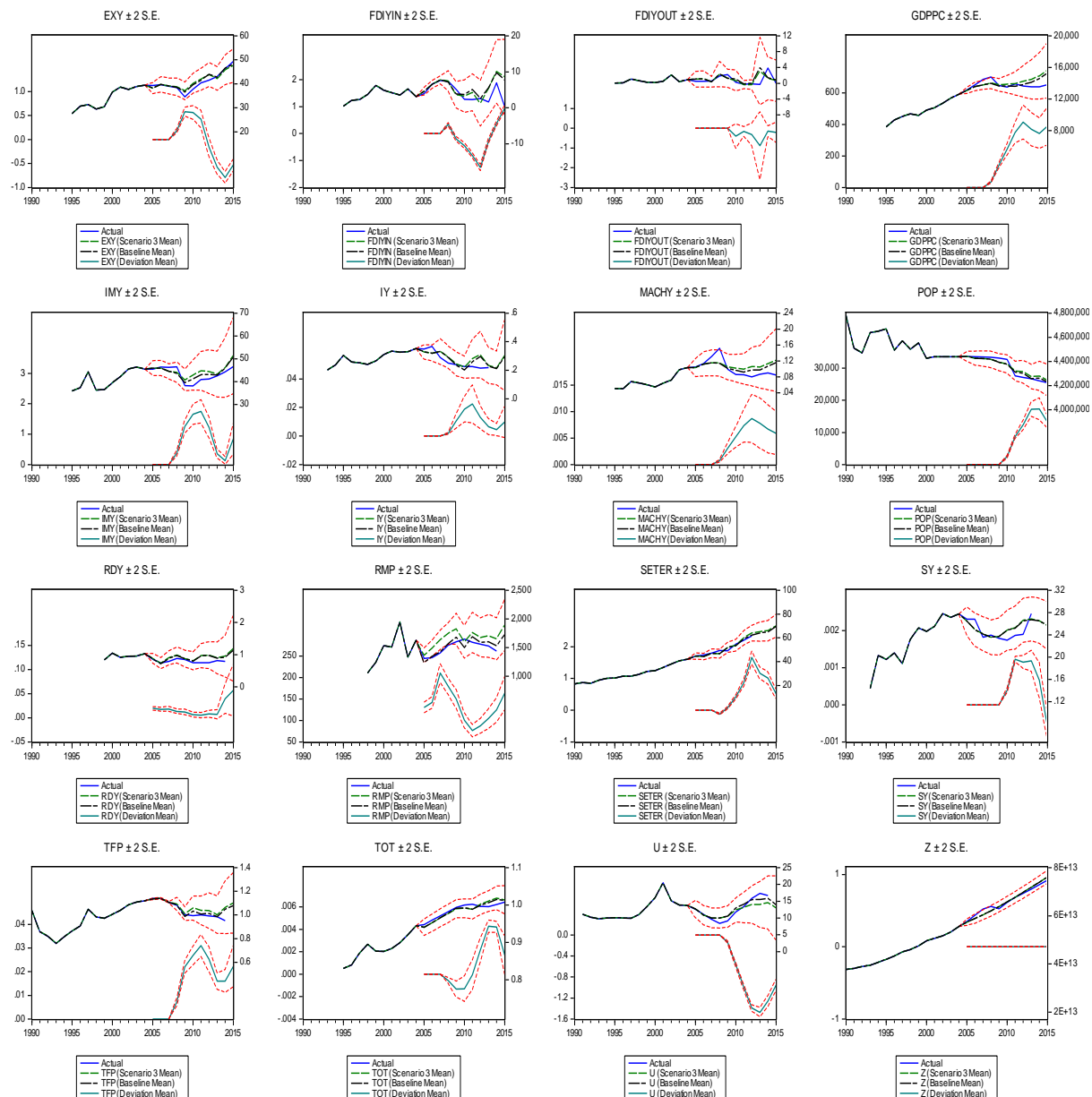
Figure 18: Simulation of a ten-percent shock to the number of researchers compared to baseline. Lines as explained below Figure 16.

The shock to the number of researchers directly affects its own dynamics, R&D expenditure and TFP positively and outward FDI negatively. Indirectly, tertiary education, population and terms of trade go up and unemployment goes down; export and savings fall, investments and imports increase; inward FDI increases, outward FDI decreases. The foreign effects are less negative here.

Could OECD or EU growth shocks help Croatia? Figure 19 shows the effects of a 0.5% shock to world GDP.
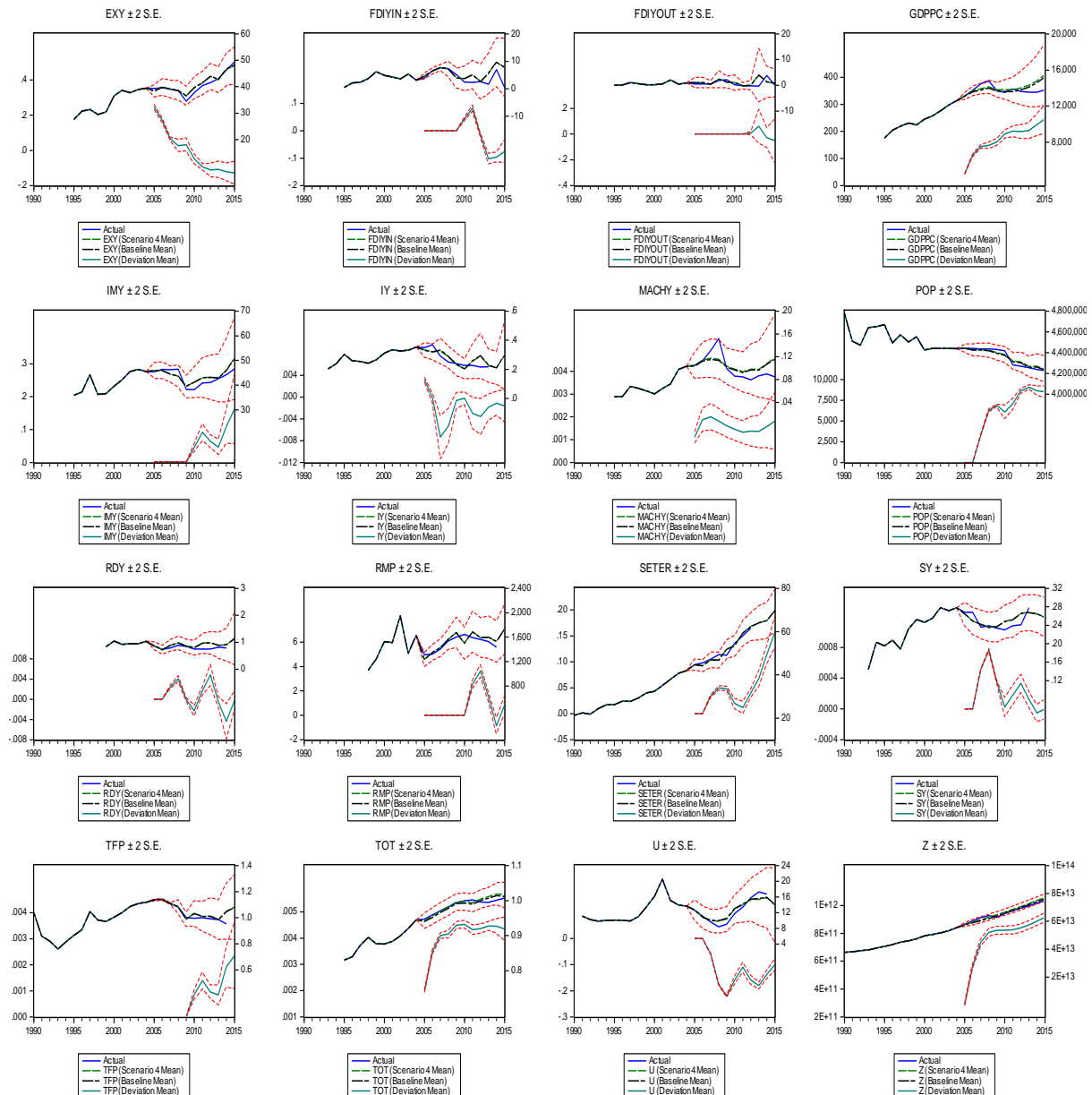
Figure 19: The effects of a 0.5% shock to world GDP. Lines as explained below Figure 16.

Export share are increased as long as the growth rate of world income is above baseline and then decreases. FDI variables both have a similar development. Imports, also for machinery, are above baseline. Terms of trade follow world income. R&D expenditures are only temporarily increased, but tertiary enrolment keeps growing and the number of researchers stays above baseline. TFP, GDP per capita and population stay above baseline but with decreasing growth rates as world income and unemployment rates fall to a lower level of fluctuations. Foreign imbalances captured as investment minus savings hardly change at the end of the period, but imports increase beyond exports strongly implying and improvement in payments for factor services.

As all growth policies considered increase foreign imbalances the question arises whether increased savings can improve this through reduction of the *investment-savings = imports-exports* difference. Figure 20 shows the effects of a one-percentage point increase to the savings ratio of equation (18).
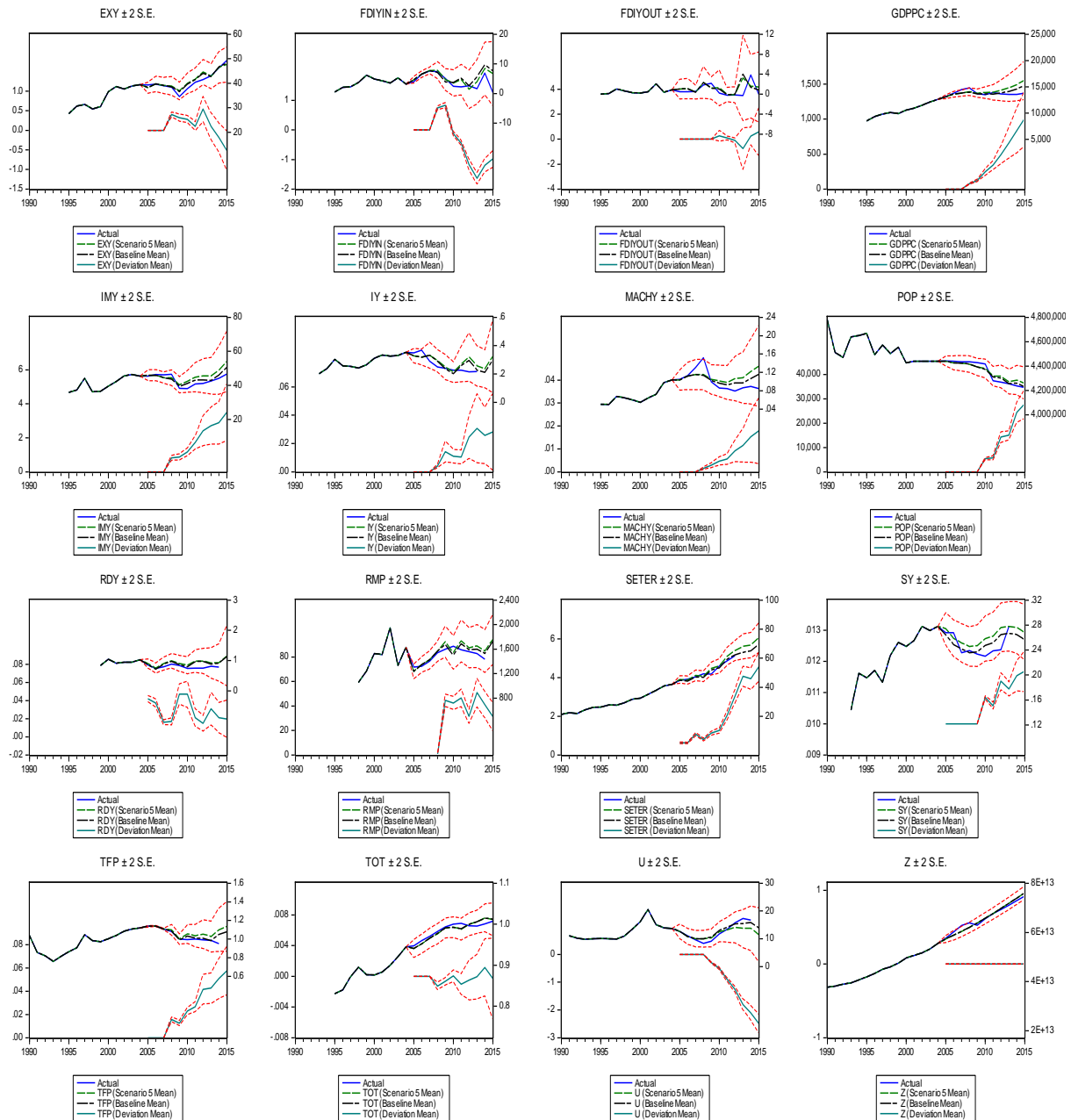
Figure 20: Effects of a permanent savings shock by 0.01. Lines as explained below Figure 16.

A savings shock has direct positive effects on education and R&D expenditures, and permanently on its own value. Number of researchers, TFP, GDP per capita and population increase. However, investments increase more than savings, imports increase throughout and exports first increase and then decrease. Similarly, outward FDI increases and inward FDI decreases; imported machinery stays on a higher level. Terms of trade show ups and downs. Overall, the type of increase of a savings ratio considered here is in itself not adequate to reduce foreign imbalances caused by growth policies. As investments were slightly higher (lower) than savings in the period 2010-2013 (1993-2009) a return to higher interest rates and investment falling below savings may exactly be compatible with the growth policies simulated above. Conversely, if interest rates increase at the end of the monetary expansion and probably decrease investment and growth, growth policies sketched above may be the way out.

Finally, governments that have been reluctant with spending money on education or research have tried to attract FDI. In Figure 21 we show the results of a 0.01 permanent shock on the intercept of equation (14).
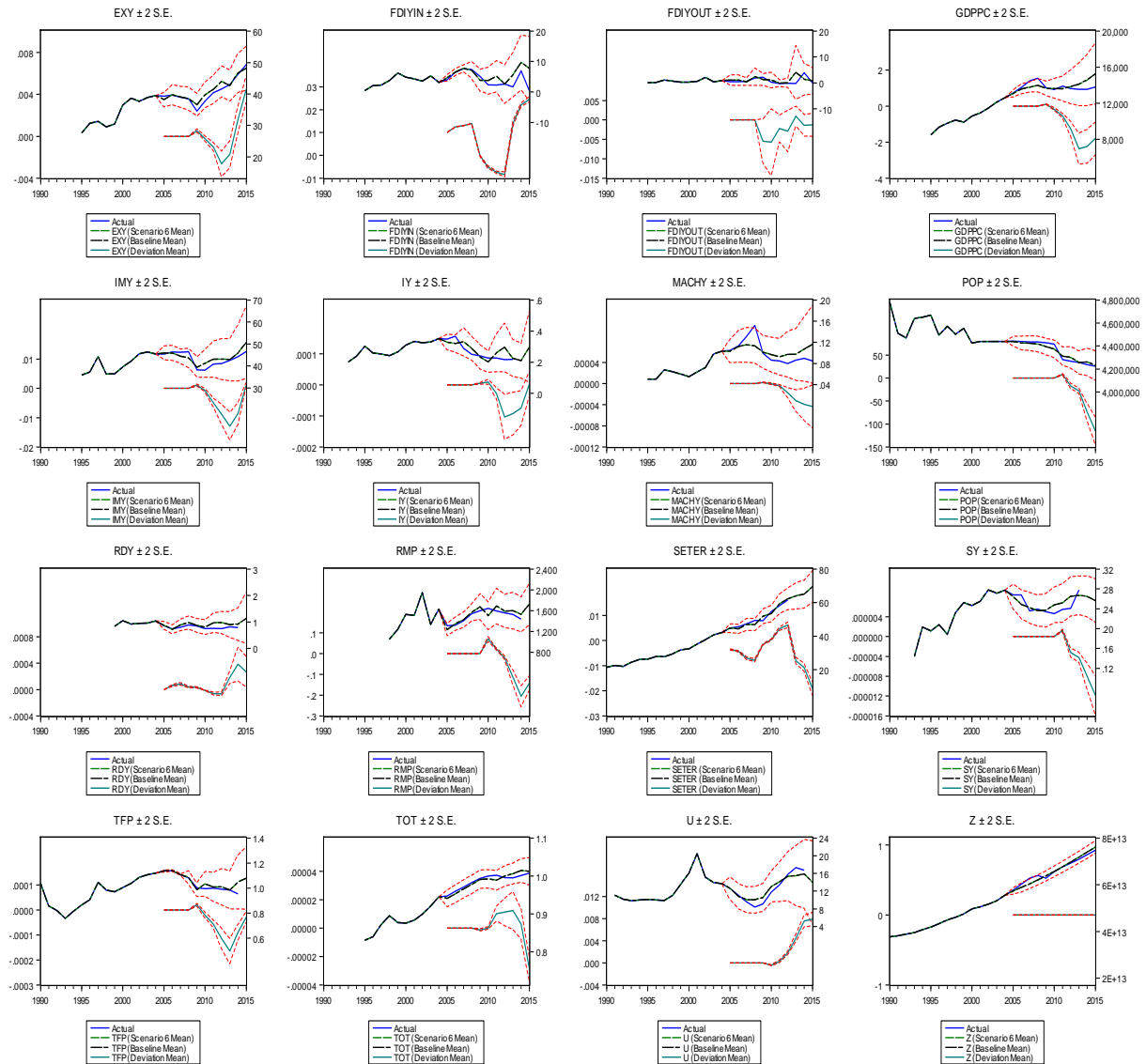
Figure 21: Effects of a permanent shock on inward FDI. Lines as explained below Figure 16.

A shock to inward FDI has positive direct effects on TFP and R&D expenditures and negative ones on outward FDI and education, but then go down and up. Growth and number of researcher then also turn down and so do employment, savings, population and terms of trade. Exports increase in the end as does inward FDI; imports remaining constant, less machinery is imported; investment and savings both fall slightly. The policy is good for the trade balance but bad for growth.

6. Summary and conclusion

We have given a survey presenting the most important determinants of growth. A look at the data showed the recent 25 years of the development of these variables for Croatia. Based on these variables a dynamic simultaneous equation model has been estimated for 16 equation and variables. Permanent shocks are used to investigate growth policies.

The results show that permanent shocks tertiary education, R&D expenditures, number of researchers all enhance growth. Also a shock to world income growth has positive effects which phase out when the growth rate returns to that of the baseline.

All growth links work well in Croatia. However, they mostly go together with the rise of foreign imbalances. Permanent shocks to savings do not solve the problem. Permanent shocks to inward FDI improve the trade balance but curtail growth. As Croatia may want to increase R&D expenditure in order to correct the fall during 2004-2006 this could be done when the return to normal interest rates decrease investment, increase savings and create foreign surpluses.

All results should be taken with caution because the available data are extremely short and a time-series analysis has just become possible. When more data become available the model can be modified and tested again. For future modifications we would currently think of interest rates, migration, distinguishing between private and public R&D (see Soete et al. 2017) and perhaps sectoral arguments.

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