IMPACT EVALUATION OF SCENARIO WITH LOCAL CURRENCIES DSGE MODEL

KATERINA GAWTHORPE

University of Economics, Prague, Department of Microeconomics,
W. Churchill Sq. 4, Prague, Czech Republic
email: xzimk04@vse.cz

ABSTRACT:

This paper presents a dynamic stochastic general equilibrium model developed to conduct a monetary analysis of a scenario with local currencies. The popularity of the alternative currency initiatives has remarkably increased during the last three decades. Despite their widespread proliferation with thousands of them currently circulating, there is a lack of quantitative analysis. This absence worsens the ability of central banks to choose the most appropriate position towards such movement. Presented study proposes an impact evaluation of these initiatives with a unique New Keynesian version of DSGE model extended for capital and labor market along with comparison of different monetary policies from a side of the local currencies. Co-existence of multiple currencies enters the model in the form of a Dixit-Stiglitz index. Simulation of the model suggests a positive effect of the alternative currencies in terms of increase of income but also inflation rate in absolute terms. This outcome appears to be highly sensitive to monetary policy from the side of issuers of the local currencies.

1. INTRODUCTION

The concept of alternative currencies barely recognized before 1980s has in the last three decades become well known in over fifty-eight countries. (John Turmel list cited in Gomez, 2010, p. 1672) Various researchers now tackle the idea about viability of this scenario with multiple currencies, which Hayek has already proposed in 1976. (For example see Greco, 2001; Colacelli & Blackburn, 2009; Camera & Craig & Waller, 2004; Collom, 2007 or Hogan, 2012) This relatively new grassroots movement might significantly help to mitigate inequality issues, unemployment, poverty, indebtedness of young generation (see Lietaer & Dunne, 2013; North, 2007, p. 87) as well as environmental devastation or harmful emissions (see Seyfang, 2004, 2006), but it might as well be just a momentary trend which becomes past in few decades. To navigate and precipitate the correct path for the future monetary policy with or without alternative currencies; central but also local authorities are in need of suitable tools for the impact evaluation of these currencies on an economy.

This study supplies such practical instrument in a form of a unique extended version of a New Keynesian Dynamic Stochastic General Equilibrium model (DSGE). The benchmark model subject to modification originates in the study of Galí (2008, chapters 3 and 6), which is the classical example of New Keynesian model assuming monopolistic competition in the market as well as wage and price stickiness. The new version of the

original model as constructed in this study enhances the basic model for new variables and parameters to allow the analysis of multiple-currency scenario.

The main divergence from Galí (2008, chapters 3 and 6) stems from the original definition of money index. A representative agent in this model opts between varieties of alternative currencies. This concept assimilates the influential article of Friedman (1956), who defines a portfolio of assets with different liquidity. Instead of the portfolio of assets, the model in this paper operates with the portfolio of currencies. The money index is then a bundle of differentiated alternative currencies defined in a similar fashion as the CES variable for the consumption bundle in the study Dixit & Stigliz (1977).

To derive money demand for these currencies in comparison to money demand for the national currency, the utility of a representative agent in its additive form is not only a function of consumption and labor supply but also of money variables. Derivation of nominal variables also has to take into account the existence of money index. While, the price and the wage setting behavior is dependent on the currency choice as well, one can find comparable New Keynesian Phillips curve to other New Keynesian models although extended for the inclusion of alternative currencies.

Final simulation of the log-linearized equations illustrates potential evolution of variables for the alternative-currency model but also for the benchmark model to allow a comparison. The outcome of the simulation outlines the dynamics of macroeconomic aggregates in response to monetary policy shock, shock into the number of alternative currencies and network externality shock. The resulting plots allow an interesting discussion about the effect of the currencies on economic growth and stability.

Next to the inquiry about the importance of the alternative currencies for local economies, the model in this study displays the effect of different monetary policies from the side of the issuers of the community currencies. Namely, if the regulator follows Taylor rule, profit maximization or does not provide any monetary policy.

In the end, the outcome of this study determines the most efficient monetary policy rule for the authorities influencing a local currency initiative as well as provides a discussion about the importance of the alternative-currency movement.

The structure of the paper is as follows. In the beginning, the literature review gives an outline of the preceding literature on this topic. The subsequent part pertains to the construction of the DSGE model followed by the description of the parameter estimates. Finally, the discussion of the simulation outcomes is provided. The conclusion of the paper can be found at the end of the study.

2. LITERATURE REVIEW

The construction of the new version of the model follows theoretical as well as empirical studies on the topic of alternative currencies. Researchers define the alternative currencies to be complementary to a legal tender. (See Collom, 2011, Seyfang, 2006b); Guargaard, 2012; Seyfang and Longhurst, 2013; Pfajfar, D., Sgro, G., & Wagner, W., 2012) Subsequently, the label for the alternative currencies is commonly complementary, cooperative or local.

The general aim of these currencies is to build a prosperous resilient local economy filled with strong interrelations among individuals, to support neighborliness

and mutual aid. (Collom, 2011, North 2007 cited in Seyfang and Longhurst, 2013, p.66; Cahn, 2001). Personal interactions, social networks and the level of trust are in turn the main components of social capital.

As social capital is becoming more and more threatened in the presence of socio-economic shifts, the local currencies are viewed as a promising option. (For the topic of social capital see Cavaye, 2001) The studies of North (2007), Linton (cited in North, 2007, p. 87), Seyfang & Longhurst (2013, p. 65) and Collom (2011) suggest a positive effect of the complementary currencies in the U.S. on the social capital.

The potential of the currencies to meet the goal of the social-capital promotion motivates individuals to use these alternative media of exchange. (Seyfang, 2003) Therefore, agents demand these currencies not for the currencies themselves but rather for their ultimate objective to stimulate social capital.

Example of the Szolnok Kor supports this idea. The administrators of this local currency in Hungary facilitated various fairs where individuals met face-to-face. Once the social network for trading was established, individuals stopped viewing the Kor as valuable and indulged into direct barter. (North, 2007, p. 115) The ability of the local currency to encourage inter-linkages among individuals showed to be more valuable than the currency itself. The currency rather served as a tool for the social-capital enhancement.

Local currencies then seem to rise the utility of agents through the variable of social capital. Following this intuition, it will be the social capital instead of the alternative currency variable which will enter the utility function of a representative agent. The social capital in turn will be defined as a function of local currencies.

Besides the hope for deepening social relations, the size of the demand for a local currency also depends on other variables. The following paragraphs then provides the background behind the other variables, which seem to affect the demand for an alternative currency.

In the beginning, the alternative-currency demand is a function of variables, which also affects legal tender such as aggregate demand in the economy or nominal interest rate. The inclusion of nominal interest rate and output variable conforms the textbook Euler equation. (see Galí, 2008, chapters 3 and 6)

Nevertheless, there are more factors one has to consider while analyzing the alternative currency demand. Dowd and Greenaway (1993) describe costs for switching between multiple currencies. Alternative currencies are limited in scale and relatively new, these features worsen using these media in exchange. Additional costs to demand currency not fully circulating in order to persuade traders to accept it in payment or to provide additional clause into contracts to account for its uncertainty will enter the model in the form of Adjustment costs variable.

The adjustment costs are in turn dependent on the size of the currency membership. The more individuals are willing to accept the currency, the easier it becomes using the currency for transactions. The dependence of the demand on the size of the currency membership is called network externality. Issing (2000, p. 17-18) confirms the significance of the variable in a currency demand equation.

The size of the adjustment costs also depends on the risk connected with holding on an alternative currency. Inflation rate worsens the uncertainty about its future prices. Similarly, the studies of Colacelli and Blackburn (2009), Greco (2001) and Camera, Craig and Waller (2004) and Gawthorpe (2015) understand the price stability as another significant factor to opt for an alternative currency. Inflation rate then represents other variable influencing the money demand for the alternative currencies. All these above-mentioned variables will reveal to enter the final money demand for a complementary currency in the presented DSGE model.

Given the above-analyzed demand for a currency, firms select optimal prices and wages. Literature and data provide evidence for the relationship between the number of users of an alternative currency and price/wage setting behavior.

While the size of the membership for this grassroots movement has significantly increased, the local currencies in the United States are still less demanded than the national currency even within the local communities. Individuals express their lower preference for the local currencies by demanding lower relative prices as customers and higher relative wages as employees in respect to these variables denominated in the national currency.

The link between the lower prices and alternative currencies has been also examined in the study of Jayaraman and Oak (2002). The exchange rate ratios between a local currency and the dollar confirms the pattern of requesting lower prices for the prior one. While the prices on goods appear at the first glance the same for the dollar and local currency denomination, the exchange rate ratio for these types of currencies differ. For example, Davis Dollars' organizers have changed its exchange rate to attract more businesses to the ratio 1 Davis dollars for 97 cents for exchanges to 500 DDS (davisdollars.org). To allure customers for the currency BNotes, new members can acquire 11 BNotes for $10. (baltimoregreencurrency.org) To obtain the BerkShares, a shopper visiting a bank in the Berkshire County, pays 95 dollars to receive 100 BerkShares. (berkshares.org). Exchange rate between local currencies and the dollar shows to favor the latter currency.

The higher preference of the national currency also motivates the regulators of the community currencies to set lower interest rate on offered loans in a local currency relatively to those in the national currency. For example, the WIR bank issuing the alternative currency WIR in Switzerland provides such practice. The model should therefore find the above outlined relationship between the demand for an alternative currency and prices, wages but also interest rate.

In terms of the legal form of the administrators in charge of the alternative currencies, the NGOs appear as the most frequent initiators. (Seyfang & Longhurst, 2013, p.67) The non-profit organizations usually do not attempt to directly regulate money supply but only keep record of the members' accounts. To create credit one needs to provide desired G&S. For example, to earn credits in the alternative currency LETS one has to provide demanded work; to supply a TimeBank currency in the United states it is necessary to work required number of hours. There is no influence of money supply from a third party. Money supply then fully depends on money demand. (Andrei, 2015) The

model will approximate this scenario by letting money supply flexibly evolve with money demand without any ad-hoc nominal interest rate rule for alternative currencies.

Recently, local authorities have also started to tend to manage a local movement to support their community. (Sárdi et al., 2013; Seyfang 2002) One could then question a scenario where these authorities follow the same rule for their currency to secure price and economic stability alike the central institution. In this case, the monetary policy will appear in the model as Taylor rule for the national but also alternative currencies.

The last examined interest-rate rule in this study will be the pursue of a pure profit-maximizing objective. The reason for examining this rule is the success of the alternative currencies called Scrips during the Great Depression in the United States. Various initiators started their issuance. Individuals and merchants belonged among the founders of Scrips. (Greco, 2001, p. 58) This fact motivates the impact evaluation of the private objective to maximize profit. Analysis of these three varieties of monetary policies incorporated into the DSGE model will allow a comparison of the impact of the different policy objectives on aggregate variables.

Based on this literature review, the next section describes a detailed construction of the crucial equations subject to simulation.

3. MODEL

This section outlines the construction of the New Keynesian model extended for the introduction of alternative currencies. The derivation of the model is comparable to its original version from Galí (2008, chapters 3 and 6). Monopolistic competition for the firm and labor sector, price and wage stickiness are all common features for both models.

In contrast to the study of Galí (2008, chapter 3 and 6), the model in this section incorporates capital accumulation and assumes the circulation of alternative currencies. These currencies are assumed to be complementary to each other such as the literature-review part indicates. These differentiated money units take in the model a form of money index similar to the Dixit-Stiglitz (1977) index for the consumption basket. The alternative currencies enter the utility function through the social capital variable as suggested in the literature review. Subsequently, the formulation of other nominal variables must take into account price denomination in the various currencies.

Based on these specifications, an optimal currency for price-setting and wage-setting behavior is derived. In the end of the model, the issuers of alternative currencies are assumed to follow one of the three monetary-policy rules: Taylor rule, profit maximization or no regulation of interest rate. The central authorities issuing legal tender follow Taylor rule as commonly assumed. (See Galí, 2008, chapters 3 and 6)

Altogether, the model in this study divides into the parts for households, firm, labor market, monetary policy and shocks.

3.1. HOUSEHOLDS

In the economy with multiple currencies, a continuum of identical and infinitely-lived households choose in each period t a path over consumption, labor supply, money aggregate for dollars but also required level of social capital, which is function of alternative currencies, to maximize their infinite stream of utility in the following form:

$$E_t \sum_{t=0}^{\infty} \beta^t U_t = E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\kappa} \left\{ bSK_t^{\frac{\omega-1}{\omega}} + (1-b) \frac{M_t}{P_t}^{\frac{\omega-1}{\omega}} \right\}^{\frac{\omega(1-\kappa)}{\omega-1}} + \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\upsilon}}{1+\upsilon} \right] \tag{1}$$

$$SK_t = \epsilon \frac{D_t}{P_t} \tag{2}$$

$$E_t \frac{D_t}{P_t^D} = \left(\int_0^1 E_t(i) \frac{d_t(i)}{P_t^D(i)}^{\frac{\varepsilon_d-1}{\varepsilon_d}} di \right)^{\frac{\varepsilon_d}{\varepsilon_d-1}} \tag{3}$$

in this equation the relation 0< β <1 holds. Beta represents the subjective inter-temporal discount factor. The beta parameter equals $\frac{1}{1+\varpi}$, where ϖ depicts the subjective rate of time preference.

The utility of an individual household is an increasing function in respect to the consumption C_t, the money balances M_t/P_t, the social capital SK_t and decreasing function in respect to the labor supply L_t. Parameters κ, σ and υ stand for elasticity of substitution between particular variables. Parameter omega signals elasticity of substitution between money balances standing for legal tender and social capital. Social capital is then a function of the bundle of differentiated local currencies D_t/P_t. The reason for such indirect introduction of local currencies follows other studies mentioned in the literature review, which document the importance of local currencies for social-capital building. Individuals use these local currencies as a complement to legal tender as they provide additional functions legal tender is weak of satisfying, such as the creation of network between individuals, community building, neighborliness and other factors promoting social capital.

This bundle of local currencies is the Dixit-Stiglitz aggregate composed of varieties of local currencies. (See Dixit & Stiglitz, 1977) The individual local currencies are assumed to complement each other. (See the Literature Review)

While all the local currencies seem to share the goal for building stronger networks, they might complement each other by differing in other objectives. For example, time banking focuses on facilitating social help mostly for retired, marginalized or disabled individuals; LETs, a mutual credit system, aims to mediate any otherwise missing exchanges and systems like Nu Spaarpas target pro-environmental objectives. (Seyfang, 2006) The differentiation in objectives for alternative currencies from environmental goal to weakening the power of chain stores enables them to circulate alongside. The parameters omega and epsilon indexed "d" signal the degree into which the local currencies complement the legal tender but also the magnitude with which local currencies complement each other.

In this model, the CES representation is not only present for the money aggregate but also for the consumption aggregate. Following the study of Galí (2008, chapter 3 and 6) each household makes a decision over the composition of a consumption basket consisting of heterogeneous final goods. The CES as presented in Dixit and Stiglitz (1977) as well as in Galí (2008) is as follows:

$$C_t = \left[\int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{4}$$

where C_t represents an aggregate consumption index of all the differentiated final goods produced in the economy. This index consists of i-th varieties of final goods, $i \in [0,1]$. Parameter epsilon stands for the elasticity of substitution between various final goods.

A representative household then maximizes the utility function (1) in respect to the budget constraint:

$$C_t P_t + Q_t \frac{B_{t+1}}{P_t} + \frac{F_t}{P_t}(1 + AC_t^l) = \frac{B_t}{P_t} + \frac{F_{t-1}}{P_t} + W_t L_t \tag{5}$$

The variables of interest in this equation from the left-hand side are the aggregate consumption index C_t and the aggregate price index P_t:

$$P_t = \left(\int_0^1 \left(\int_0^1 E_t(j) P_t(i,j) dj \right)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}. \tag{6}$$

This index consists of prices denominated in j-th varieties of currencies, $j \in [0,1]$. All prices are denominated in the legal tender; therefore exchange rate $E_t(j)$ takes place in the currency index.

The pricing rule for every heterogeneous consumption good *i* is then:

$$P_t(i) = \int_0^1 E_t(j) P_t(i,j) dj \tag{7}$$

The total consumption expenditure then follows the New Keynesian Model:

$$C_t P_t = \int_0^1 C_t(i) P_t(i) di. \tag{8}$$

Real bonds represent the next variable in the budget constraint. This variable is subject to disaggregation in the form:

$$Q_t \frac{B_{t+1}}{P_t} = \int_0^1 \frac{1}{1+i_t(f)} \frac{B_{t+1}(f)}{P_t(f)} E_t(f) df \tag{9}$$

The bond variable in time *t+1* accrues nominal interest rate i_t. By definition, the bond variable is a bundle of bonds denominated in a currency f, $f \in [0,1]$. The currency f stands either for the alternative currency d_t or the legal tender variable M_t.

The last left-hand side variable is an aggregate nominal money stock F_t:

$$F_{t-1} = \int_0^1 E_t(f)F_{t-1}(f)df \tag{10}$$

The money stock composes of differentiated currencies, alternative currencies as well as legal tender. All currencies are multiplied by the nominal exchange rate, which enables denomination of the money variable in the national currency.

The nominal money stock appears in the budget constraint in multiplication with adjustment costs AC_t^l in the following form:

$$F_t\left(1 + AC_t^l\right) = \int_0^1 E_t(f)F_t(f)\left(1 + AC_t^l(f)\right)df \tag{11}$$

The adjustment cost variable AC_t^l affects individual's demand for a currency f:

$$AC_t^l = \left[\frac{\psi_a l_t(f)}{2}\left(\frac{\theta_t(f)F_t(f)}{F_{t-1}(f)}\right)^2\right]Y_t, \theta \in (0, \infty) \tag{12}$$

This definition of adjustment costs follows the paper of Falagiarda & Marzo (2012), who uses a similar variable for bonds called transaction costs.

The variable in this study presents an impediment for portfolio adjustment in the case of currencies. Steady-state value for the adjustment costs is assumed to be non-zero, generating a non-zero demand for currencies in the long - run. These costs include information costs as well as costs of carrying transactions in scenario with multiple currencies. One can also interpret these costs as switching costs (Gawthorpe, 2014), costs of switching the established currency for a new less common one. In that case individuals suffer from attempts to use not yet well-established currency for mediating exchanges. Higher adjustment costs pertain then to a less common currency where individuals suffer from the difficulties stemming from its lower acceptance.

The adjustment costs variable differs from the transaction costs of Falagiarda & Marzo (2012), by inclusion of new variables affecting the scenario with alternative currencies. Network externality represents such variable, which affects adjustment costs for currencies. Network externality denotes the willingness of an individual to accept a currency based on its current membership. The higher is the inclination of others to accept the currency f in payment, the lower are the costs for carrying transactions. In case an individual keeps only legal tender, this variable appears as zero.

In detail, the network externality variable weighs particular currencies according to the size of their velocity:

$$\theta_t F_t = \int_0^1 \theta_t(i)E_t(i)F_t(i)\,di. \tag{13}$$

Next, an inclusion of the variable *l* into the adjustment cost identity illustrates the dependence of adjustment costs on the number of alternative currencies in an individual's currency index. Increase in the number of different currencies causes carrying transactions to become more cumbersome and inefficient. The number of alternative currencies negatively affects the adjustment costs variable. A representative household then faces higher costs when demanding these new alternative currencies.

Adjustment costs in real terms using simple mathematical operation appear as:

$$AC_t^l = \left[\frac{\psi_{al}}{2} \left(\frac{\theta_t M_t \pi_t}{M_{t-1}} \right)^2 \right] Y_t \qquad (14)$$

Similarly, for a currency (j) adjustment costs reveal to be:

$$AC_t^l(j) = \left[\frac{\psi_{al}}{2} \left(\frac{\theta_t(j) M_t(j) \pi_t(j)}{M_{t-1}(j)} \right)^2 \right] Y_t \qquad (15)$$

The last variable of interest from the right-hand side of the budget constraint is the labor supply variable L_t. The above definition of a price index results in the subsequent total labor income where L_t depicts labor supply in time t.

$$W_t L_t = \int_0^1 E_t(i) W_t(i) di \qquad (16)$$

Based on these definitions, individual households maximize their lifetime utility stream (1) in respect to the budget constraint (5). Solving the optimization problem with an assumption of common transversality conditions for all types of currencies and bonds:

$$\lim_{t \to \infty} \beta^t \lambda_t y_t = 0$$

$$\text{for } y_t = d_t, M_t, B_t$$

yields the general Euler equation in the log-linearized form:

$$c_t = E_t(c_{t+1}) - \frac{1}{\sigma} (i_t - E_t\{\pi_{t+1}\} - \rho), \qquad (17)$$

money demand equation for legal tender:

$$\frac{M_t}{P_t} = \left(\frac{1 + i_{t+1}^M}{(1 + AC_t^M(i))(1 + i_{t+1}^M) - 1} \right)^\omega C_t^{\sigma\omega} \left(\frac{1-b}{X_t} \right)^\omega \qquad (18)$$

as well as money demand for an individual alternative currency:

$$\frac{d_t}{P_t^D} = \left(\frac{1+i_{t+1}^D}{(1+AC_t^D(i))(1+i_{t+1}^D)-1}\right)^{\varepsilon_d} \frac{C_t^{\sigma\varepsilon_d}}{E_t} \left(\frac{b}{X_t D_t \epsilon SK_t^{1/\omega}}\right)^{\varepsilon_d} \quad (19)$$

where   stands for the first bracket in the utility function consisting of social capital and money aggregate variables.

X_t

Derivation for the labor supply variable in combination with the Euler equation results in the log-linearized equation:

$$w_t = \sigma c_t + \varphi n_t \quad (20)$$

3.2. FIRMS

Individual firms in this model compete on a market dominated by the market structure of monopolistic competition. Therefore, the continuum of firms indexed as $i \in [0,1]$ produce differentiated products. Following Galí (2008, p. 42) these firms face an identical isoelastic demand schedule:

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} C_t \quad (21)$$

Concerning price-selection behavior for the heterogeneous products, the model assumes firms to follow the Calvo-rule pricing. (Calvo, 1983) Every period the fraction of 1- θ companies reset their price optimally, the rest of them sets prices equal to lagged inflation. However, before the fraction of firms can draw such pricing decision, individual firms have to select bundle of currencies in which they wish to denominate their prices.

Therefore, the next part divides into two sections: first, a representative firm follows an optimization problem to select optimal currency and in the second stage, it makes a decision about the optimal price denominated in the pre-selected currency in the situation of staggered-price setting.

3.2.1. CURRENCY PRICE SELECTION

Every firm in this model selects an optimal currency j according to its profit maximization problem, where the firm aims to minimize its costs for every period (see McCandless, 2008, p. 263).

The firms maximize the following profit function

$$\Pi_t(i) = P_t(i)Y_t(i) - TC_t(i) \quad (22)$$

where the first variable stands for the currency index:

$$P_t(i) = \left(\int_0^1 P_t(i,j)^{1-\frac{1}{\vartheta}} dj\right)^{\frac{\vartheta}{\vartheta-1}} \quad (23)$$

and the total price for goods of a firm *i* is a bundle of prices denominated in differentiated currencies *j*. The parameter "ϑ" illustrates the elasticity of substitution between currencies used for a price denomination. The continuum of prices denominated in differentiated currencies lies on an interval $j \in [0,1]$.

The last variable in the profit function denotes total costs. To derive the total costs function it is necessary to define the production function. The production function for every firm in nominal terms equals:

$$P_t(i)Y_t(i) = A_t K_t(i)^\alpha L_t(i)^{1-\alpha} \tag{24}$$

with identical technology level A_t for all firms. This variable exogenously evolves over time. This production function allows the formulation of the nominal cost function as:

$$TC_{t+k}(i) = \frac{\omega_{t+k}(i)}{(1-\alpha)a_{t+k}} \left(\frac{ir_{t+k}(i)(1-\alpha)}{\omega_{t+k}(i)\alpha} \right)^\alpha Y_{t+k}(i) \tag{25}$$

In the above equation $\omega_t(i)$ illustrates nominal wage and $ir_t(i)$ nominal interest rate for the firm *i*:

$$\omega_t(i) = P_t(i)w_t(i) = \int_0^1 E_t(j)P_t(i,j)w_t(i,j)dj \tag{26}$$

$$ir_t(i) = P_t(i)r_t(i) = \int_0^1 E_t(j)P_t(i,j)r_t(i,j)dj \tag{27}$$

These identities express equality between the variable in nominal terms and real variable multiplied by price in the currency *j* and transformed into the legal tender with a help of nominal exchange rate.

The maximization of the profit function (22) with respect to the above-derived identities results in demand for the currency "j" by a firm "i":

$$P_t(i,j) = \left((1-\alpha)\frac{w_t(i,j)}{\omega_t(i)} + \alpha\frac{r_t(i,j)}{ir_t(i)} \right)^{-\vartheta} P_t(i)^{1+\vartheta} \tag{28}$$

The intuition behind this equation is as follows. Individual firms are willing to set lower prices in a preferable currency and pay higher wages for their employees to compensate them for getting paid in a currency, which workers might not prefer and vice versa. The intuition behind this equation follows real-life evidence as described in the literature review.

3.2.2. PRICE SETTING BEHAVIOR

After the firm has already selected the composition of the currency bundle, it proceeds to the next stage where it decides about the optimal price denominated in various currencies.

The existence of the price stickiness allows only firms re-optimizing in period t to select the price $P_t^*(j)$ according to the profit maximization problem:

$$\max \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left(P_t^* Y_{t+k,t} - \Psi_{t+k}(Y_{t+k/t}) \right) \right\} \tag{29}$$

subject to the demand constraint

$$Y_{t+k/t} = \left(\frac{P_{t+k}}{P_t^*} \right)^{\varepsilon} C_{t+k} = \left(\frac{P_{t+k}(j)^{\frac{1}{1+\vartheta}} \left((1-\alpha)\frac{w_{t+k}(i,j)}{\omega_{t+k}(i)} + \alpha\frac{r_{t+k}(i,j)}{ir_{t+k}(i)} \right)^{\frac{\vartheta}{1+\vartheta}}}{P_t^*(j)^{\frac{1}{1+\vartheta}} \left((1-\alpha)\frac{w_t(i,j)}{\omega_t(i)} + \alpha\frac{r_t(i,j)}{ir_t(i)} \right)^{\frac{\vartheta}{1+\vartheta}}} \right)^{\varepsilon} C_{t+k} \tag{30}$$

This equation originates in the isoelastic demand schedule (21), where the aggregate prices are substituted for the equation as derived in the currency selection part (28).

The log-linearized solution to the profit maximization problem (29) subject to the demand constraint (30) is:

$$p_t^*(j) + \vartheta \left((1-\alpha)\frac{w_t(i,j)}{\omega_t(i)} + \alpha\frac{r_t(i,j)}{ir_t(i)} \right) = (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t (p_{t+k}(j) \tag{31}$$

$$+\vartheta \left(\frac{\bar{P}}{\bar{P}(i,j)} \right)^{-\frac{1}{\vartheta}} \left[(1-\alpha)\frac{\bar{w}(i,j)}{\bar{\omega}} (w_{t+k}(j) - w_{t+k}) + \alpha\frac{\bar{r}(i,j)}{\bar{ir}} (r_{t+k}(j) - r_{t+k}) \right]$$

$$+(1+\vartheta)[(1-\alpha)w_{t+k} + \alpha r_{t+k} - a_{t+k}])$$

Given the log-linearized aggregate price dynamics alike the Galí (2008, p43) version for every currency:

$$\pi_t(j) = (1-\theta)\left(p_t^*(j) - p_{t-1}(j) \right), \tag{32}$$

the final New Keynesian Phillips curve assuming in equilibrium equality $Y_t(i) = C_t(i)$ equals for real interest rate:

$$\Pi_t^P(j) = \beta E_t \Pi_{t+1} + \kappa \tilde{y}_t - \beta\vartheta \left(\frac{\bar{P}}{\bar{P}(i,j)} \right)^{-\frac{1}{\vartheta}} \left((1-\alpha)\frac{\bar{w}(i,j)}{\bar{\omega}} [\Pi_{t+1}^w - \Pi_{t+1}^w(j)] \right. \tag{33}$$

$$\left. + \alpha\frac{\bar{r}(i,j)}{\bar{ir}} [\Pi_{t+1}^r - \Pi_{t+1}^r(j)] \right) + \vartheta(1-\beta\theta)\vartheta \left(\frac{\bar{P}}{\bar{P}(i,j)} \right)^{-\frac{1}{\vartheta}} \left((1-\alpha)\frac{\bar{w}(i,j)}{\bar{\omega}} \right)$$

$$(w_{t+k}(j) - w_{t+k}) + \alpha \frac{\bar{r}(i,j)}{\bar{ir}}(r_{t+k}(j) - r_{t+k}) \Bigg)$$

and for nominal interest rate:

$$\Pi_t^P(j) = \beta E_t \Pi_{t+1}(j) + \kappa \tilde{y}_t - \beta \vartheta \left(\frac{\bar{P}}{\bar{P}(i,j)}\right)^{-\frac{1}{\vartheta}} \left((1-\alpha)\frac{\bar{w}(i,j)}{\bar{\omega}}[\Pi_{t+1}^w - \Pi_{t+1}^w(j)] \right. \qquad (34)$$

$$\left. + \alpha \frac{\bar{r}(i,j)}{\bar{ir}}\left[\Pi_{t+1}^{ir} - \Pi_{t+1}^{ir}(j) + \Pi_{t+1}(j) - \Pi_{t+1}\right]\right) + \vartheta(1-\beta\theta)\vartheta\left(\frac{\bar{P}}{\bar{P}(i,j)}\right)^{-\frac{1}{\vartheta}}\left((1-\alpha)\right.$$

$$\left. \frac{\bar{w}(i,j)}{\bar{\omega}}(w_{t+k}(j) - w_{t+k}) + \alpha \frac{\bar{r}(i,j)}{\bar{ir}}(r_{t+k}(j) - r_{t+k})\right)$$

where

$$\kappa = \frac{\lambda(1+\vartheta)(\sigma+\varphi)(1-\alpha)}{(1+\alpha\varphi)}$$

$$\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$$

The variables Π_{t+1}^{ir} and Π_{t+1}^r stand for inflation rate for nominal interest rates and real interest rates respectively. The variable Π_{t+1}^w illustrates wage inflation.

In this model not only prices are sticky. Wage-setting behavior is assumed to face rigidities as well. The next section concerns such wage selection procedure.

3.3. LABOR MARKET
This model operates in a staggered-wage environment. In similarity to the article of Erceg et al. (2000), the wage stickiness is modeled comparable to the price stickiness. Next, also wages can be denominated in different currencies.

Therefore, this section again divides into the two stages for wage determination problem. In the first stage, a representative agent selects optimal currency denomination for his wage and in the next stage, he makes decision over optimal size of the wage denominated in the pre-selected bundle of currencies.

3.3.1. CURRENCY WAGE SELECTION
Individual firms make a decision over the currency denomination for wages for their employees. In this manner, firms encounter the preferences of households over wage denomination. The optimization problem stays alike the one in the beginning of the model.

A representative agent maximizes the utility function (1) subject to the budget constraint (5). To derive the optimal currency for wages, the alternative currency index

$$E_t \frac{D_t}{P_t^F} = \left(\int_0^1 E_t(j) \frac{d_t(j)^{\frac{\varepsilon_d - 1}{\varepsilon_d}}}{P_t^F(j)} \, dj \right)^{\frac{\varepsilon_d}{\varepsilon_d - 1}} \tag{35}$$

holds. However, not only the alternative currency index but also money aggregate M_t/P_t is disaggregated to account for money acquired as wages.

$$E_t(j) \frac{f_t(j)}{P_t^F(j)} = \left(\int_0^1 \xi_t(k) \frac{f_t(j)^{\frac{c-1}{c}}}{P_t(j)} \, dk \right)^{\frac{c}{c-1}} \tag{36}$$

where f_t stands for alternative currencies d_t as well as for the legal tender M_t. The parameter $\xi_t(k)$ enables to differentiate between various sources of received money. This disaggregation enters the original utility function (1).

The intuition behind the identity is following. Every currency $f_t(j)$ can be identified as a continuum of currencies obtained from various sources "k". By other words, when an individual holds money, part of it initiates as wages, the other part comes from other origins.

The parameter $\xi_t(k)$ then stands for the share of currency k obtained from a particular source ξ_t. In case, the money had an origin as wage, the total money variable is multiplied by $\xi_t(k)$ labeled as ϖ_t. This variable $\varpi_t(d)$ indicates the proportion of total currency received as wages in the currency d_t.

Earnings in the budget constraint are also disaggregated to introduce money variable into the wage variables:

$$w_t^d L_t = \varpi_t(d) \frac{F_t}{P_t} \tag{37}$$

$$w_t^M L_t = \varpi_t(M) \frac{F_t}{P_t} \tag{38}$$

Derivation of the utility function given the budget constraint subject to the share of currency j obtained as wages: $\varpi_t(j)$ results in the following equation:

$$\frac{w_t^d}{w_t^M} = \left(\frac{b}{1-b} \frac{\epsilon M_t^{\frac{1}{\omega}}}{d_t^{\frac{1}{\varepsilon_d}} D_t S K_t} \right)^c \tag{39}$$

its log – linearized version is:

$$w_t(d) - w_t(m) = \frac{c}{\omega} M_t - \frac{c}{\varepsilon_d} d_t - cD_t - cSK_t - cE_t. \tag{40}$$

This outcome corresponds to the intuition from the literature-review part of the paper, individuals are willing to accept lower wages in more demanded currency.

3.3.2. OPTIMAL WAGE SETTING

In this second stage, an agent selects w_t^* in wage-staggered environment. This part assimilates the one from Galí (2008, chapter 6).

Maximization of the utility function (1) rewritten for time t+k for a household which sets its wage in period *t*:

$$E_t\{\textstyle\sum_{k=0}^{\infty}(\beta\theta_w)^k U\big(C_{t+k/t}, N_{t+k/t}\big)\} \tag{42}$$

subject to the constraints

$$L_{t+k/t} = \left(\frac{w_t^{d*}(j)\frac{d_t(j)^{\frac{c}{\varepsilon_d}}D_t^c SK_t^c}{M_t^{\frac{c}{\omega}}}}{w_{t+k}^{d*}(j)\frac{d_{t+k}(j)^{\frac{c}{\varepsilon_d}}D_{t+k}^c SK_{t+k}^c}{M_{t+k}^{\frac{c}{\omega}}}} \right)^{-\varepsilon_w} L_{t+k} \tag{43}$$

$$C_{t+k/t}P_{t+k} + Q_{t+k,t+k+1}\frac{B_{t+k+1}}{P_{t+k}} + \frac{F_{t+k}}{P_{t+k}}\big(1 + AC_{t+k}^l\big) = \frac{B_{t+k/t}}{P_{t+k}} + \frac{F_{t+k-1}}{P_{t+k}} + w_t^* L_{t+k/t} \tag{44}$$

where the budget constraint remains identical to the original one for time *t+k* for *k* = 0,1,2… with consideration of sticky wages (See Galí, 2008, chapter 6), leads to the log-linearized wage inflation dynamics:

$$\Pi_t^w(j) = \beta E_t\{\Pi_{t+1}^w(j)\} - \frac{\lambda_w}{1+\varepsilon_w}\hat{\mu}_t^w - \frac{1-\varepsilon_w\varphi}{1+\varepsilon_w\varphi}\lambda_w(\tfrac{c}{\varepsilon_d}d_t(j) + cD_t + cSK_t - \tfrac{c}{\omega}M_t) \tag{45}$$

where

$$\hat{\mu}_t^w = w_t - mrs_t - \mu^w$$

The output gap enters the wage inflation equation in the similar way as in the New Keynesian Phillips curve:

$$\hat{\mu}_t^w = \hat{w}_t - \left(\sigma + \frac{\varphi(1-\alpha\sigma)}{1+\varphi\alpha}\right)\tilde{y}_t \tag{46}$$

Final assumption concerns the identity with a link between wage gap, price inflation, wage inflation and the natural wage as in Galí (2008, p. 127)

$$\hat{w}_t = \hat{w}_{t-1} + \pi_t^w - \pi_t^p - \Delta w_t^n \tag{47}$$

In the equation $\widehat{w}_t = w_t - w_t^n$ stands for the difference between real wage and the natural real wage respectively.

The resulting wage inflation equation is:

(48)

$$\Pi_t^w(j) = \beta E_t\{\Pi_{t+1}^w(j)\} + \kappa_w \tilde{y}_t - \frac{\lambda_w}{1+\varepsilon_w}\widehat{w}_t - \frac{1-\varepsilon_w\phi}{1+\varepsilon_w\phi}\lambda_w(\frac{c}{\varepsilon_d}d_t(j) + cD_t + cSK_t - \frac{c}{\omega}M_t)$$

where

$$\kappa_w = \lambda_w \frac{1}{1+\varepsilon_w}\left(\sigma + \frac{\varphi(1-\alpha\sigma)}{1+\varphi\alpha}\right)$$

$$\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w}$$

One can notice the similarity between the wage inflation dynamics in this study and Galí (2008, chapter 6) version. The main difference stems from the inclusion of an alternative currency and national currency variables. A raise in the demand for the alternative currency relatively to the national one has deflationary tendencies on wages.

This outcome corresponds to the preceding section as well as to the result of the firm sector. The more is an alternative currency demanded in respect to a legal tender, the lower relative wages denominated in the alternative currency employees demand.

The last sector modelled in this study regards the banking sector and the monetary policy individual issuers of various currencies decide to follow.

3.4. MONETARY POLICY

The central authority issues the national currency M_t. Since central banks commonly intend to keep inflation rate and output stable, the monetary policy for the issuing institution takes the form of the famous Taylor rule:

$$i_t(M) = \rho + \phi_\pi \Pi_t^P(M) + \phi_w \Pi_t^w(M) + \phi_y \hat{y}_t + v_t \qquad (49)$$

where the index M signals inclusion of the variables for the national currency.

Differentiated alternative currencies on the other hand are commonly regulated by different entities. This paper aims to compare various monetary policies alternative-currency issuers might follow.

Firstly, the issuers are assumed to follow the same Taylor rule with an ambition of constrained evolution of inflation rate for the alternative currency j and output:

$$i_t(j) = \rho + \phi_\pi \Pi_t^P(j) + \phi_w \Pi_t^W(j) + \phi_y \hat{y}_t + v_t \quad (50)$$

Higher demand for an alternative currency followed by increase of inflation rate (see NKPC) results in increase in nominal interest rate. This outcome confirms the intuition, that regulators of less demanded currency offer cheaper loans. (See www.wir.ch)

Secondly, the institutions which initialize the circulation of alternative currencies are assumed to make in period t decision about nominal interest rate to maximize their expected profit. The expected profit abstracted for total costs is a function of demand for the alternative currency multiplied by interest rate on the loaned money:

$$\max \Pi_t^j = (1 + i_t^D) d_t \quad (51)$$

where d_t is the money demand for the alternative currency as calculated in the equation (19). For simplicity I assume that the $i_t^D = E_t(i_{t+1}^D)$.

Maximizing the profit function with respect to the nominal interest rate variable results in:

$$i_t^D = -\frac{AC_t^D(i) - \varepsilon_d}{1 + AC_t^D(i)} \quad (52)$$

in log-linearized form:

$$i_t^D = -\frac{1 + \overline{AC^D}}{AC^D - \varepsilon} \widetilde{ac_t^D} \quad (53)$$

The last equation shows a negative relationship between log-linearized nominal interest rate and the deviation of the adjustment costs from its steady state. An increase in adjustment costs reduces the demand for an alternative currency. Issuing institution has to react by dropping nominal interest rate on loans. Oppositely, when the alternative currency gains on popularity, the issuers can afford to rise their interest rates without deterring potential users of their currency.

Finally, the most common scenario is that alternative currencies circulate without upper regulation of interest rates. Private/public initiators of the alternative currencies then continue to "only" administrate the project and market it. Money supply then flexibly copy money demand.

To set nominal interest rate for the alternative currency j I apply Fisher equation:
$$i_t(j) = r_t(j) + E_t(\Pi_{t+1}^P(j)) \quad (54)$$

assuming that the Fisher equation is relevant also for the national currency interest rate as determined by the Taylor rule (49):

$$i_t(M) = r_t(M) + E_t(\Pi_{t+1}^P(M)) \quad (55)$$

Since real interest rate depends on real variables it should stay similar for both equations. Therefore, we can write:

$$i_t(j) = i_t(M) + E_t(\Pi^P_{t+1}(j)) - E_t(\Pi^P_{t+1}(M)) \tag{56}$$

Nominal interest rate for the alternative currency j equals the nominal interest rate for the national currency and difference between inflation rates for the respective currencies. This last relation shows the positive relation between demand for an alternative currency and its nominal interest rate. The higher the demand for the currency is the higher is expected inflation rate such as the NKPC indicates, subsequently the nominal interest rate rises relatively to the nominal interest rate for legal tender. Alike the relation for the Taylor rule also here institutions in charge of regulating an alternative currency tends to set lower interest rate in respect to the legal tender if the alternative currency is less demanded.

3.5. SHOCKS

Nominal interest rate for the legal tender and for the alternative currency where its regulator follows the Taylor rule, face monetary policy shock. The exogenous component of the interest rate v_t is assumed to follow an AR(1) process:

$$v_t = \rho_v v_{t-1} + e^v_t \tag{57}$$

where $\rho_v \epsilon (0,1)$ and e^v_t is a zero mean white noise process. The expansionary monetary policy then relates to a negative realization of e_v.

Final two shocks apply to the existence of alternative currencies. Namely, they affect the adjustment cost variable. There is the shock into the number of currencies:

$$l_t(j) = \rho_l l_{t-1}(j) + e_l \tag{58}$$

where $\rho_l \epsilon (0,1)$ and e^l_t is a zero mean white noise process.
And network externality shock

$$\theta_t(j) - \theta_t = \rho_t(\theta_{t-1}(j) - \theta_{t-1}) + e^t_t \tag{59}$$

where $\rho_t \epsilon (0,1)$ and e^t_t is a zero mean white noise process.
See the Appendix for the Log-linearized version of the simulated equations.

4. PARAMETER ESTIMATES

The parameter estimates for the model simulation assimilates one from Galí (2008, chapter 3 and chapter 6). The parameters for the alternative currency variables are hard to estimate due to the lack of empirical data. The parameters of interest pertain to the degree into which alternative currencies are in relation to each other. Following the literature review, these parameters have been selected to account for the complementary characteristics of alternative currencies. The values for these parameters are available on the figure one in the Appendix.

Since all of the necessary parameters except the degree of complementarity are alike the Galí version (2008, chapter 6), the simulations of the model provide a valuable comparison between the scenario with and without complementary currencies. Figure two till four display the output of the simulation. The following section provides discussion of the illustrated dynamics.

5. DISCUSSION OF THE RESULTS
5.1. ONE OR MULTIPLE CURRENCIES?

In the beginning, it is interesting to note the differences between the version with and without the circulation of complementary currencies. For this purpose, note the plots for the monetary policy shock in the Appendix.

Concerning the monetary policy shock, the scenario with more domestic currencies displays lower negative reaction in terms of output, output gap and nominal interest rate. On the other hand, price and wage inflation displays higher deflationary tendencies in this scenario relatively to the situation with only one currency.

By other words, the existence of complementary currencies could help smoothen out recessionary periods caused by restrictionary monetary policy. The study of Stodder (2009) supports such evolution with the case study for the WIR currency in Switzerland. According to Stodder (2009), the WIR currency has helped to stabilize Swiss economy.

Counter-cyclical evolution of the WIR currency apparently helps to provide additional medium of exchange in times of deficiency of circulating Swiss Franc. (see also Gawthorpe, 2015) The variable for relative demand of an alternative currency in respect to the national one "m_j" in response to the monetary policy shock confirms such pattern. During periods of money shortages caused by negative monetary policy shock the variable "m_j" indicates higher demand for alternative currencies. Additional finances in the form of complementary currency units help to provide lower susceptibility of an economy to this type of shock. Economy with the multiple currencies appears as more resilient.

Shock into the number of alternative currencies and network externality shock provide additional evidence in analyzing the question of alternative currencies. Increase in number of alternative currencies negatively affects money demand for these currencies due to their higher adjustment costs. By other words, cumbersomeness from using more currencies presents a burden for individuals to use alternative currencies as a mediator for transactions. In detail, the lower demand causes deflationary tendencies for prices denominated in the complementary medium of exchange but also legal tender. Decrease in expected inflation along with the adjustment-cost burden to select otherwise most preferable currency slowdowns production and in the end the aggregate output.

Network externality shock illustrates the increase in demand for an alternative currency in respect to the rise of its current membership. Granovetter (1978) describes this shock for money demand in general. The more individuals hold onto a currency the more are others allure to keep it as well given the main function of the currency to serve as a medium of exchange. This shock then positively affects money demand for the alternative currency. In turn, a representative agent is willing to pay relatively more for products denominated in the alternative currency, which causes the inflation rate to grow. Inflation rate for the national currency rises as well due to the lower demand for

the legal tender. Subsequently, output gap as well as output increases. Higher nominal interest rate caused either by an issuing institution following Taylor rule or by simple Fisher equation result in return of aggregate variables to their steady states.

In sum, increase in money demand for a complementary currency in respect to national one has an unambiguously positive effect on the aggregate product. The more is an alternative currency demanded, the lower relative wages employees request and the higher relative prices are consumer willing to pay for a product denominated in such currency. The lower costs on labor along with revenue raises from sold more expansive products positively affect firms, which in turn expand production. However, the advantages stemming from circulation of the multiple currencies are highly sensitive to the adjustment costs variable. Increase of this variable negatively affects individual money demands and in result output.

The raise in the number of alternative currencies can trigger such negative evolution. However, the effect of this variable enters the model rather ad hoc. Intuitively, the more individuals become accustomed to circulation of multiple currencies, the less an issuance of a new currency might affect the dynamics. Also individuals satisfied with the currently circulating media of exchange or too risk-averse to accept new ones might not accept new ones at all. In that case, increase in number of alternative currencies would not have effect on an economy. Last but not least, suitable institutions could help to smoothen the entrance of the new currency. Individuals could then use existing media without perceiving higher cumbersomeness of transactions.

Finally, evidence suggests beneficial outcome of local currencies for local economy per se. According to their proponents, these currencies promote localization, reduce unemployment, help to build social capital, give advantage to local companies over chain stores, improve resilience of the local economy and its independence on national monetary policy. (See Seyfang & Longhurst, 2013; Collom, 2011; North, 2007; Lietaer & Dunne, 2013) While the national monetary policy is commonly unambiguously modeled as Taylor rule, the monetary policies for alternative currencies differ. The next part aims to analyze the effect of various monetary policies for the complementary currencies on economic variables.

5.2. DIFFERENT MONETARY POLICY RULES

This section compares three types of monetary policies from the side of alternative currency issuers.

The first situation of the profit maximization from the side of a local issuer of a currency perhaps represents the reason why some central authorities fear local currencies. Low regulation of these local issuers allow them to follow their own ambition to generate revenue without consideration of the long-run effect of such scheme on an economy or national currency.

The revenue of these private subjects is assumed to depend on the demand for their currency as well as interest rate charged on private loans. Simulation but also simple observation of this idea from the model section shows destabilizing tendencies for the aggregate variables.

Intuition behind such unfavorable dynamics starts with analyzing the equation (53) for the monetary policy of private issuers in comparison to the Taylor rule of central authority. Negative monetary policy shock causes drop of output followed by deflationary tendencies. Central institution following Taylor rule tends to stabilize such situation by pressing the interest rate downwards. The reduction of nominal interest rate results in an inflation-rate growth, which in effect results in return of all the aggregate variables to their steady-state values.

On the other hand, the private issuer is motivated to rise nominal interest rate on loans as lower inflation rate for the local currency diminishes adjustment costs. Unfortunately, increases in nominal interest rate leads to even deeper deflationary tendencies further destabilizing economy. By other words, aggregate variables further deviate from their steady-states. Central/local authorities are therefore recommended to discourage attempts to create such private schemes with primarily private profit-maximizing objectives.

Secondly, local government might initiate the local-currency project to support local economy. (Sárdi et al., 2013, Seyfang, 2002) The concentration on the prosperity of local economy inspires to study the potential case where these authorities target price and economic stability. Taylor rule could then withstand as an appropriate solution not only for central institutions but also for the local ones. The effect of this simulated scenario on the evolution of individual variables is depicted by the dotted line.

Finally, local currencies commonly emerge as grassroots movements by non-profit organizations. (Seyfang & Longhurst, 2013, p.67; North, 2007) Subsequently, very frequent situation is the absence of any intervention trying to regulate money supply. (For example LETs currency, time banks or for example green dollars in New Zealand) Money supply then flexibly reacts to demands for the currencies to fulfill required transaction. This scenario is reflected in the Appendix by the full line.

The plots in the Appendix illustrate the comparison of the two last-mentioned monetary policies for alternative currencies, namely the absence of interventions and Taylor rule. Output, output gap and inflation rate are less responsive to these shocks when local issuers of complementary currencies follow the Taylor rule. Response of the aggregate variables to the monetary policy shock is more comparable for both analyzed situations, namely the scenario with Taylor rule and the scenario without monetary interventions. Scrutiny of the network externality shock, shock into the number of alternative currencies but also monetary policy shock suggests the Taylor rule as the best analyzed monetary policy rule to secure business - cycle smoothening. In sum, the Taylor rule appears as more suitable for stabilizing individual variables after a shock.

In detail, the stabilization process of the economy without the presence of monetary policy regulating alternative currencies requires variables to react stronger to a shock. It is especially the adjustment costs variable, which is very sensitive to the type of the monetary-policy rule and causes the divergences between the two displayed scenarios.

Overall, except profit-maximizing objective, the Taylor rule and no presence of monetary rule seem to be both favorable monetary policies for a local economy.

6. CONCLUSION

This study provides the very first model for impact evaluation of the complementary currency scenario in the United States by applying the method of the DSGE modelling. The derived model offers the step-by-step procedure for interested researches to incorporate the features of community currencies into any other DSGE model. The construction of the model follows previous studies examining local currency movements.

In correspondence to the literature review, derived demand for alternative currencies shows to be a function of adjustment costs, network externality variable, inflation rate as well as nominal interest rate and aggregate output. The two latter variables enter also demand for the national currency, as tradition Euler equation in other studies displays as well.

Lower demand for local currencies in respect to the national currency leads individuals to request lower prices on G&S but also interest rate on loans denominated in an alternative currency and higher wages. The lower valuation of alternative currencies in respect to the national one proved by examples in the literature review explains such dynamics.

Next to deriving relations between economic variables in presence of complementary currencies, this study allows the comparison of different monetary policies managed by alternative-currency issuers. The most common scenario where founders of community currencies do not regulate money supply displays relatively higher susceptibility to the studied shocks. Local authorities with an ambition to launch a local currency initiative to keep resilience of the local economy should opt to follow the Taylor rule. Also in the situation with alternative currencies, this rule seems to be the best suited for keeping economy more stable.

From the perspective of output-evolution, the alternative currency scenario helps to reduce negative effects of monetary policy shock on economic activity. Finally, demand for alternative currencies shows to be beneficial on its own for economic prosperity. The simulation of the model displays positive effect when demand for community currencies rises. The evolution of the variable, which suffers in the presence of the multiple currencies is the dynamics for inflation rate. Inflation rate drops relatively more in effect to the monetary policy shock. In sum, central and local authorities viewing economic growth as of the highest importance should support the local currency movement while keeping in mind the potential reduction of price stability.

Future research could try to incorporate the features for alternative currencies as defined in this study into other models to more closely approximate the American economy. Subsequently, the model in this study assumes closed economy, opening the economy in the model as well as incorporation of fiscal sector could help to support the results of this article. Finally, an empirical study for the impact of local currencies on social capital could help to establish more precise link between these two variables.

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APPENDIX

SIMULATED LOG-LINEARIZED DSGE MODEL

The main equations for calibration are Euler equation in equilibrium $C_t = Y_t$, dynamic IS equation:

(61) $$\tilde{y}_t = E_t(\tilde{y}_{t+1}) - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - r_t^n)$$

(62) $$r_t^n = \rho + \sigma\psi_{ya}E_t(\Delta a_{t+1})$$

where $\psi_{ya} = \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$

(63) $$\tilde{y}_t = y_t - y_t^n$$

In the line with Galí (2008, p. 48):

$$mc_t = w_t - mpn_t$$

Substitution of the Euler equation for the real wage and marginal product of labor from the production function gives:

$$mc = \left(\sigma + \frac{\alpha + \varphi}{1 - \alpha}\right) y_t^n - \frac{1 + \varphi}{1 - \alpha} a_t - \log(1 - \alpha)$$

(64)
$$y_t^n = \psi_{ya} a_t + \xi_y$$

where $\xi_y = -\frac{(1-\alpha)(\mu - log(1-\alpha))}{(\sigma(1-\alpha)+\varphi+\alpha)}$

Log-linearized local currency demand equation in relation to legal tender demand is:

(65)
$$\hat{m}_t(j) = -\omega \, \widehat{ac}_t(j) - \frac{\varepsilon_d}{\omega} SK_t - E_t - \varepsilon_d D_t$$

where $\hat{m}_t(j) = d_t(j) - M_t$ and $\widehat{ac}_t(j) = ac_t^d(j) - ac_t$.
Price choice equation:
(66)
$$p_t^m - p_t^d = \vartheta(w_t^d(j) - w_t^M)$$

Log-linearized adjustment costs equation

(67) $\quad \widehat{ac}_t(j) = 2(\theta_t(j) - \theta_t) + 2(\Pi_t^p(j) - \Pi_t) + 2(\hat{m}_t(j) - \hat{m}_{t-1}(j)) + (l_t(j) - l_t)$

Price Inflation dynamics:

(68) $\Pi_t^P(j) = \beta E_t \Pi_{t+1}(j) + \kappa \tilde{y}_t - \beta \vartheta \left(\frac{\bar{P}}{\bar{P}(i,j)}\right)^{-\frac{1}{\vartheta}} \left\{(1 - \alpha) \frac{\bar{w}(i,j)}{\bar{\omega}} [\Pi_{t+1}^w - \Pi_{t+1}^w(j)] + \right.$

$\alpha \frac{\bar{r}(i,j)}{\bar{ir}} [\Pi_{t+1}^{ir} - \Pi_{t+1}^{ir}(j) + \Pi_{t+1}(j) - \Pi_{t+1}] \right\} + \vartheta(1 - \beta\theta)\vartheta \left(\frac{\bar{P}}{\bar{P}(i,j)}\right)^{-\frac{1}{\vartheta}} \left[(1 - \right.$

$\left. \alpha) \frac{\bar{w}(i,j)}{\bar{\omega}} (w_{t+k}(j) - w_{t+k}) + \alpha \frac{\bar{r}(i,j)}{\bar{ir}} (r_{t+k}(j) - r_{t+k}) \right]$

where

$$\kappa = \frac{\lambda(1 + \vartheta)(\sigma + \varphi)(1 - \alpha)}{(1 + \alpha\varphi)}$$

$$\lambda = \frac{(1 - \theta)(1 - \beta\theta)}{\theta}$$

Wage Inflation Dynamics:

(69) $\quad \Pi_t^W(j) = \beta E_t\{\Pi_{t+1}^W(j)\} + \kappa_w \tilde{y}_t - \frac{\lambda_w}{1+\varepsilon_w}\hat{w}_t - \frac{1-\varepsilon_w\phi}{1+\varepsilon_w\phi}\lambda_w(\frac{c}{\varepsilon_d}d_t(j) + cD_t + cSK_t -$
$\quad \frac{c}{\omega}M_t)$

where

$$\kappa_w = \lambda_w \frac{1}{1+\varepsilon_w}\left(\sigma + \frac{\varphi(1-\alpha\sigma)}{1+\varphi\alpha}\right)$$
$$\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w}$$
$$\hat{w}_t = \hat{w}_{t-1} + \pi_t^w - \pi_t^p - \Delta w_t^n$$

Wage currency selection rule:

(70) $\qquad w_t^d(j) - w_t^M = \frac{c}{\omega}M_t - \frac{c}{\varepsilon_d}d_t - cD_t - cSK_t = c\widehat{ac}_t(j)$

where $\widehat{ac}_t(j) = ac_t^d(j) - ac_t$

Traditional Taylor rule for national currency M:

(71) $\qquad i_t(M) = \rho + \phi_\pi\Pi_t^P(M) + \phi_w\Pi_t^W(M) + \phi_y\hat{y}_t + v_t$

Taylor rule for alternative-currency regulators:

(72) $\qquad i_t(j) = \rho + \phi_\pi\Pi_t^P(j) + \phi_w\Pi_t^W(j) + \phi_y\hat{y}_t + v_t$

Monetary policy rule for community currency issuers following profit-maximization:

(73) $\qquad i_t^D = -\frac{1+\overline{AC^D}}{AC^D - \varepsilon}\widetilde{ac}_t^D$

No monetary policy intervention for alternative currencies:

(74) $\qquad i_t(j) = i_t(M) + E_t(\Pi_{t+1}^P(j)) - E_t(\Pi_{t+1}^P(M))$

Monetary policy shock:

(75) $\qquad v_t = \rho_v v_{t-1} + e_t^v$

Shock into the number of currencies:

(76) $\qquad l_t(j) = \rho_l l_{t-1}(j) + e_l$

Network externality shock

(77) $\qquad \theta_t(j) - \theta_t = \rho_t(\theta_{t-1}(j) - \theta_{t-1}) + e_t^t$

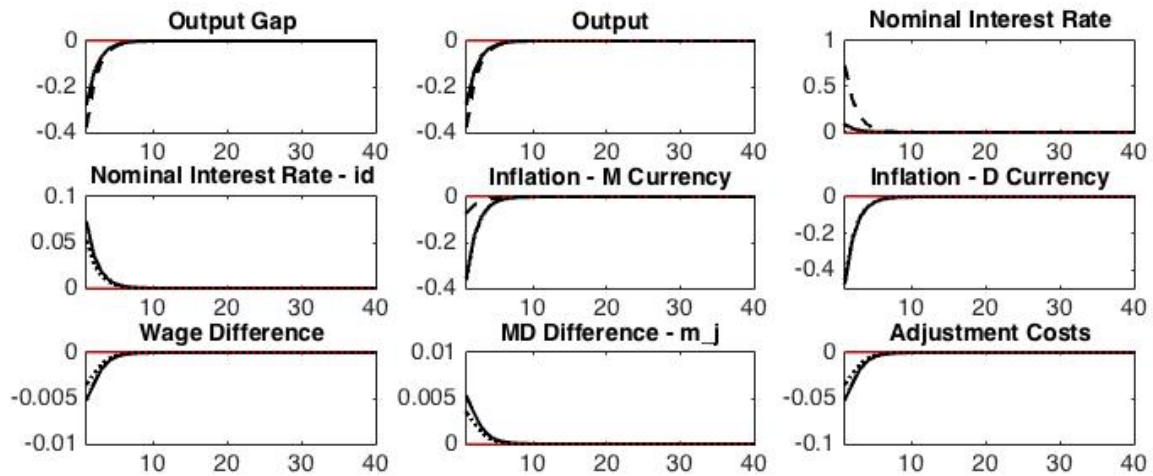Figure 1: **PARAMETER ESTIMATES**

α	β	ρ	σ	ω	φ	ε_d	ε	ε_w	ϑ
1/3	0.99	$-\log\beta$	1	0.1	1	0.1	6	6	0.5

θ	θ_p	θ_w	ϕ_π	ϕ_w	ϕ_y	η	ρ_v	ρ_a	ρ_l
2/3	2/3	3/4	1.5	0	0.5/4	4	0.5	0.9	0.9

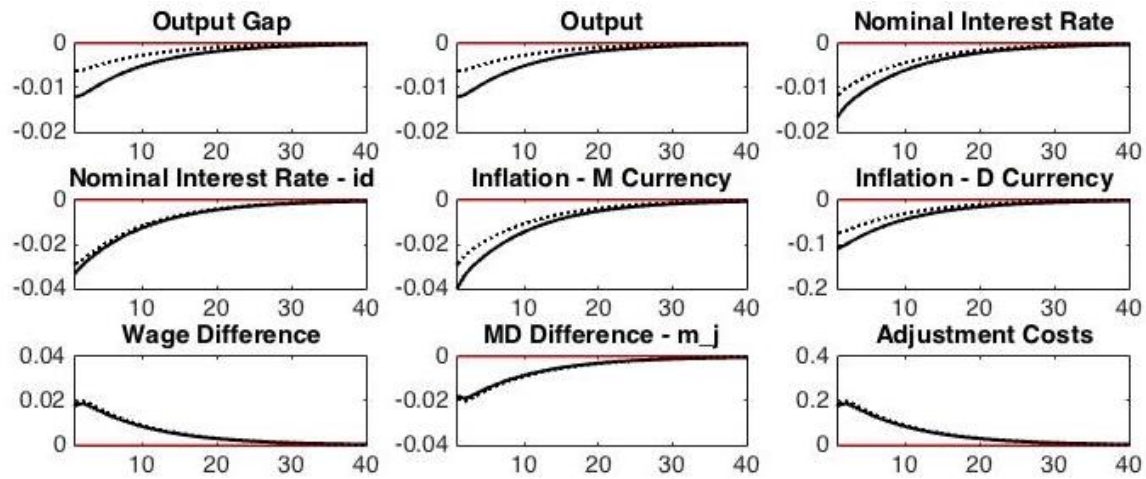| ρ_t	c
0.9	0.1

Figure 2: **MONETARY POLICY SHOCK**

Source: Author's calculation.
The dashed line epitomizes the variables for the version without alternative currencies as constructed by Galí (2008, chapter 6). The full line depicts the scenario with alternative currencies without any regulation of their supply. Finally, the dotted line stands for the situation of complementary currencies where their issuers follow Taylor rule.

Figure 3: **SHOCK INTO THE NUMBER OF ALTERNATIVE CURRENCIES**

Source: Author's calculation.
The dashed line epitomizes the variables for the version without alternative currencies as constructed by Galí (2008, chapter 6). The full line depicts the scenario with alternative currencies without any regulation of their supply. Finally, the dotted line stands for the situation of complementary currencies where their issuers follow Taylor rule.

Figure 4: **NETWORK EXTERNALITY SHOCK**

Source: Author's calculation.
The dashed line epitomizes the variables for the version without alternative currencies as constructed by Galí (2008, chapter 6). The full line depicts the scenario with alternative currencies without any regulation of their supply. Finally, the dotted line stands for the situation of complementary currencies where their issuers follow Taylor rule.