The Dynamic Model, Based on the Quantity Theory of Money Plus the Velocity of Money Circulation: Factor Analysis of the Inflation in USA During 1960-2024

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Abstract: The model for factor analysis of inflation is presented and applied to the inflation in USA during 1960-2024. GDP deflator is decomposed into three growth rates: M2, velocity M2V and real GDP. The subject is impact of money supply and velocity to the CPI and GDP deflator. As a result **–** the dynamic model is proposed for the factor analysis. Some results of regressions are exposed to check relations between CPI, GDP deflator and those factors. The scientific novelty – the velocity of money circulation may play key role in inflation. Velocity depends on two basis trade-offs: expected risk and return on deposits and expected risk and return in financial markets. Velocity is generally stable and tends to decrease when inflation factors are anchored.

When a central bank control prime rate and ignore money supply, the market price for capital is distorted. Then three factors may come into play: an increase in inflation expectations due to increase of money supply; an increase of the money velocity due to inflation expectations; a decrease of real GDP growth due to a high prime rate. All three factors accelerate inflation and all are ignored by New Keynesian models, currently employed by central banks. Therefore, it is proposed to improve management of inflation by replacing the New Philip's curve with the factor model based on money supply, money velocity and real GDP growth.

Keywords: Demand for money, Monetary policy, GDP deflator, DSGE, JEL: E4, E32, E41.

1. INTRODUCTION AND REVIEW

The paradigm of "neutrality" of the money supply is well known from classical economy and now is the mainstream concept for monetary policy[1], widely accepted in a "weak" form and debated in the "strong" form[2]. Now this paradigm dominates through DSGE models, employed by central banks. However, Friedman and Schwartz (Friedman, M, Schwartz A.J. 1963) proved that an increase in the money supply historically was a prerequisite (in Granger's sense) for an increase in output. The main argument for the "neutrality" of the money supply - there are no statistical evidences of its influence to economic growth, or structural changes in wealth (Woodford, M. S. 2003, Mishkin, F.,2007). But the impact of money supply on inflation is the cornerstone of the quantity theory of money (Friedman, M. 1989).

The current paradigm of central banks is – in developed countries with the current inflation management inflation is "well anchored" (Mishkin, F., 2007), and not linked to the money supply (Adam K., Padula M. 2011). But when inflation is high and unstable (not "well anchored") increase of money supply matters and may increase inflation due to a rise in expectations, as happened particularly in some South American countries (Kehoe, Timothy J., Nicolini J.P. 2021), and etc.

However, the contemporary evidences for that impact may be observed even in developed countries (EU and USA): the post-pandemic surges in inflation at 2020-2022. As that question was raised by Isabel Schnabel[3]: "whether the increase in excess money growth in 2020 was an early and sufficiently strong warning sign that risks to medium-term price stability?". And: "after 2,5 years following the outbreak of the pandemic, the sum of currency in circulation and overnight bank deposits in the euro area, referred to as M1, increased by over 30%", but "inflation accelerated from 1.2% to 9.1%, peaked at 10.6% in October 2022" [4].

Isabel Schnabel's aphorism "inflation is not always and everywhere a monetary phenomenon" (rephrasing of the opposite famous Milton Friedman's aphorism) is obviously true (if ignore change of the velocity). If inflation is low and stable, it may be not sensitive to the short-term fluctuations in the money supply (Kiley, M., 2015). But in the long-term run evidences are different (De Grauwe P., Polan M., 2005). As stated in the same lecture: "both cross-sectional and time series evidence has for a long time provided strong support in favor of a stable long-run relationship between money and prices" [5].

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[1] https://financefacts101.com/understanding-the-neutrality-of-money-a-comprehensive-guide-for-institutional-investors/

[2] https://www.investopedia.com/terms/n/neutrality_of_money.asp

[3] Isabel Schnabel (Member of the Executive Board of the ECB) Lecture "Money and inflation" 2023 URL: https://www.ecb.europa.eu/press/key/date/2023/html/ecb.sp230925_1~7ad8ef22e2.en.html#footnote.8

[4] Ibid

[5] Ibid

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The same as in the EU COVID-19 inflation surge was observed in the USA where combined US federal budget deficit during 2020-2022 was about $6 trillion (approximately equal to annual expenses) (Cochrane, J.H. 2023). It was covered mainly by credit emission: FRS purchased T-bonds almost for that entire deficit and M2 increased approximately by the same $6 trillion (Zhukov P.E., 2023). Eventually that was the cause for inflation peak about 10%. And to fight that inflation surge special law "Inflation Reduction Act" [6] was adopted. Then the M2 money supply decreased (at 2022-2023 by about $0.8 trillion per year) and inflation returned to a normal level.

That happened in the USA and EU - developed countries with “well anchored” inflation, managed with Taylor’s rule and DSGE. Besides, COVID-19 inflation surge happened in many countries (see tab. 17) by the same reasons.

So, first outcome: even in developed countries with “well anchored” inflation huge credit emission caused by budget deficit may cause inflation surge. Second outcome – that may happen if size of the emission is above critical. Third outcome: with proper measures of the Central Bank and government this surge may be oppressed during several months and inflation returns to a normal level.

But the question arises – what would happen if that size credit emission caused by budget deficit sustained during some years? Fortunately, neither FRS nor ECB did undertake that experiment. But some of central banks did – *e.g.*, in Argentine, Turkey and many other countries in the past (Friedman, M., 1989).

The Sargent-Wallace (Sargent T., Wallace N.,1973) model shows that if the state's debt grows faster than GDP, then there comes a moment “T”, when the state is no longer able to sell debt in financial markets and is forced to finance the deficit by central bank purchase. Economic agents foresee that and include their expectations in both current and future inflation. The similar model of hyperinflation, which is based on the expansion of the money supply, was proposed first in the work of Cagan (Cagan P.D., 1956) and then developed in the work of Bruno and Fisher (Bruno M., Fischer S. 1987).

All the three models were developed for the case of high inflation inspired by huge money supply caused by massive credit emission in order to finance huge budget deficit. A limitation of the Sargent-Wallace, Cagan, and Bruno-Fisher models is the assumption that velocity of money is constant.

Now in a situation when the debt in many countries (*e.g*. USA, Japan ant some of EU countries) is growing at an alarming rate, the Sargent-Wallace model looks relevant. For example, in Japan, the "T" moment in the Sargent-Wallace model has already achieved, so the Bank of Japan finances government expenditures through credit emission. However, inflation stays low, despite the devaluation of the yen. The reasons for this paradox seem to be the high level of public confidence in the Bank of Japan and the high level of savings[7].

Krugman (Krugman, P., 2000) considered Mises's and Keynes's monetary theories for the question of money long-term influence to the economy. Krugman discusses the Keynesian idea that interest rates are determined by money demand and supply. But that is not the case when interest rates are set up by the central bank as it is nowadays. Then Krugman highlights that money supply is affecting real variables and economic cycles, not merely inflation in the long run both public and private debt dynamics matter.

Evidently, excessive money supply is rather symptom of fiscal policy. Specifically for Latin American countries comprehensive analysis presented in the monograph, edited by Kehoe, T.J., Nicolini J.P. (Kehoe, T.J., Nicolini J.P., 2017). This study covered economic history of eleven major Latin American countries during 1967-2017. The question is: why those countries had persistent economic problems. And the answer is: poorly designed and implemented fiscal and monetary policies caused stagnation, devaluations, sovereign debt defaults, banking crises and extremely high inflation.

Before 2004, the FRS and ECB (and many other central banks) conducted long-term planning of the growth for M1 and M2. And both FRS and ECB used prime rate as the key tool for the short-term policy (Mishkin, F.S., 2007, 2011), (Ireland, P., 2007), (Woodford, M. S., 2003).

But after 2004, most central banks in developed countries have declared inflation targeting based on direct control of the prime rate, with the Taylor rule (8) (Mishkin, F.S., 2011), (Woodford, M. S., 2011), (Yellen, J., 2019).

DSGE models were employed by FRS[8] and other central banks to forecast inflation and output (Chirichiello G., 2024). Commonly these models are based on the New Keynesian economics (Galí J.,

[6] https://www.irs.gov/inflation-reduction-act-of-2022

[7] https://www.project-syndicate.org/commentary/koichi-hamada-assesses-the-progress-that-japanese-prime-minister-shinzo-abe-s--three-arrows--strategy-for-economic-revitalization-has-made-so-far

[8] https://www.newyorkfed.org/research/policy/dsge#/overview

2018). There is one (but not only) problem with DSGE models – the predictions may be good in equilibrium (stability), but not so good if equilibrium is changing (Christiano L.J., Eichenbaum M. S., and Trabandt M. 2018), (Cai M,, Del Negro M., Giannoni M.P, etc, 2019).

Particularly, DSGE models failed to predict crises, including crisis of 2007-2008 (Stiglitz J. E., 2018). The technical reason is – the mathematical basis of a DSGE model fails when distributions shift (Hendry and Mizon 2014). But real cause is deeper – fails the part of basic theory (based on unrealistic assumptions).

So far, eventually some new concepts were considered to explain these crises and the paradox of zero interest rates after 2008 (Cochrane J. H. 2011, 2022), (Garcıa-Schmidt, Woodford Mariana and Michael, 2019), (Gariın, J., Lester R, and Simson E. 2018), etc. And the possible effects of “shotgun wedding” of fiscal policy with monetary policy (Bassetto M., Sargent T., 2020) are considered as the feasible and disturbing especially after inflation peaks at 2022 (despite the mainstream paradigm of the “neutrality” of money supply).

The main reason for the shift in the monetary policy of the central banks perhaps was not just theoretical “neutrality” of credit emission for inflation (which is very questionable). The practical reason - central banks can’t strictly control M1, M2, or M3 (*e.g*., Ireland, P., 2007). However, the prime rate is exactly factor which central banks can set in a directive manner. The main problem with that way to manage inflation - consequences are not always predictable (Stock J., Watson M. 2007, 2011). Prime rate is the price for money (time value). Directive setting of any prices may harm economy (*e.g*., distort structure of investments).

The new original fiscal theory of the price level was proposed recently by T. Sargent and M. Bassetto (Bassetto M., Sargent T., 2020) and different variant by J. Cochrane (Cochrane, J. H. 2023). In the both variants monetary and fiscal policy described through sequences of government IOUs (bonds and money). And both variants of the fiscal theory consider the cases of quantitative easing and low interest rates since the Great Recession of 2007-2008.

Initial premises of the model of Cochrane looks relevant to the Sargent-Wallace model of inflation and to the “shotgun wedding” of the fiscal and monetary policy in the M. Bassetto and T. Sargent work. The difference is - in the J. Cochrane model inflation is determined by future surpluses of the federal budget. That is hardly plausible both intuitively and empirically. But still the basic idea of J. Cochrane's argument looks plausible: long term inflation depends on ability of a government to balance budget and finance deficit. And budget deficit financed by central bank may cause high inflation and even hyperinflation.

As the outcome: there are two principally different ways to increase money supply by central bank. The first way is to increase (decrease) money supply by lending banks to support their liquidity. In this case, an increase (decrease) in the money supply should not affect inflation or entail a threat to stability. The reason may be not only that inflation is stable and "well anchored", but even more so that banks usually cannot afford excessively risky loans. The exception (which support the rule) may arise if the government (through its agencies), buys risky loans from banks. That was exactly the case with MBS in the United States before the Great Recession of 2007-2008.

But the second (and very much different) case is when the government finances the budget deficit through credit emission. The direct sale of government bonds to the central bank is commonly prohibited by law. But the government may issue bonds while the same volume of bonds is purchased by the central bank through the open market operations (this way is legal).

That is the case of real “shotgun wedding” of fiscal and monetary policies. This case, increase in the money supply leads to a massive appearance of unsecured money among the firms and population, which is almost guaranteed to lead to higher inflation even with the use of modern monetary regulation. This case DSGE models may fail to forecast, Taylor’s rule may not help and “well anchored” inflation may turn into high inflation and even into hyperinflation.

2. THE QUANTITY THEORY OF MONEY, IS-LM MODELS AND THE DYNAMIC MODEL FOR FACTOR ANALYSIS OF INFLATION

The classical identity of exchange (1) (sometimes referred as “Irwin Fisher equality”) (Friedman, M. 1989), (Mishkin, F.S. 2010), etc. is the basis of the quantity theory of money. It describes the equality of the demand for money on the right side (nominal GDP) and the supply of money on the left side (money supply multiplied by the velocity of circulation).

$$MV = PY \tag{1}$$

The identity of exchange (1) may be represented in a form of IS-LM model by M. Keynes and J. Hicks. The main difference is that the model (1) assumes equilibrium of demand for money (right side) and supply of money (left side) at a certain time t, while the IS-LM model assumes equilibrium in the markets, depending on the interest rate. But if both sides of (1) depends on interest rate, it may be considered as intersection of IS and LM curve in the IS-LM model. For that purpose, the velocity V(r) must be independent of (1), as definition of V as PY/M defines just intersection of IS=LM.

For the common presentation in real (or constant) prices:

IS(r)= Y(r), LM(r)= M(r)V(r)/P(r)

In the traditional IS-LM model, IS - real money income, and LM - function of real demand for money (see Figure **1**):

Here, Y is the real total money income (which roughly corresponds to GNP), r is the real interest rate, and L(Y,r) is the real money balances.

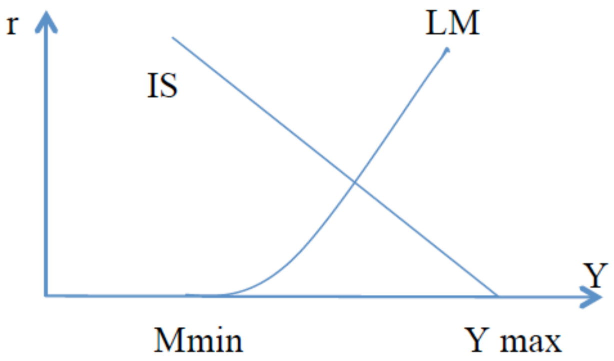

Figure 1: The classical IS-LM model for the real GDP and money supply.

In the classical Keynesian approach, LM is divided into two parts:

LM(Y, r) = LM1(Y) + LM2(r)

LM1 (Y) is a function of the transactional demand for money, which depends (according to Keynes) only on real disposable income.

LM2 (r) is a function of speculative demand for money associated with investments in deposits and short-term bonds and depends only on real interest.

The reality is more complicated. First question: which monetary aggregate is considered in LM? Second question: are there other factors that affect income and demand for money? Besides, even if consider LM in short term, the transaction demand for money may depend on interest. If consider L(Y,r) as a function of two independent variables Y and r, then it is a hyper surface, not curve. But given the dependence of Y on r is known (IS curve), it is a curve.

If LM represents just cash and on call deposits (M1), then it should be a decreasing (not increasing) function of the interest rate. In this case, the slope and intersection of IS and LM curves may be different of Figure **1**. But assuming that LM is an increasing function of interest rate (in the original sense of the Keynes-Hicks model), it may be understood not as M1, but rather M2 (common monetarist treatment), so includes deposits in banks. And probably even investments in short-term bonds of high reliability may be added.

When real interest rate grows, investments in deposits become more attractive, and investments in stocks or real assets less attractive (high real price of borrowings is not favorable for real business). So, M2 may increase but velocity V decrease (as money is frozen in deposits). Finally, it is not quite clear, whether LM=MV increase or decrease with increase of prime rate (increase is more likely). But certainly, cross section of LM and IS exists – it follows from the identity (1).

The same may be assumed for investments in short-term bonds. Yield on long-term bonds depends to a greater extent on the expectation of future interest rates, which are currently unknown.

If represent identity (1) in the form of the IS-LM model, the alternative approach is possible: to interpret nominal IS, LM as a function of the nominal interest rate (in current prices). So, another form (different of common) may be proposed for the nominal GDP and the nominal effective money supply MV:

IS*(r)= PY(r), LM*(r)= M(r)V(r)

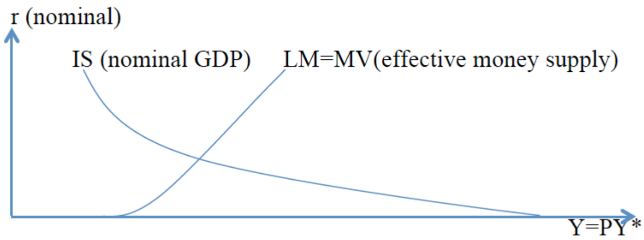

Figure 2: IS-LM model for the nominal GDP and money supply.

In the common approach, inflation obviously cannot be included in the model. But in the alternative approach IS represent nominal GDP (money income), and LM represent nominal effective money supply, taking into account the velocity of money. The equilibrium nominal interest rate at the intersection of the nominal IS and LM curves (Figure **2**), may be linked to a current price level.

Then, given (1): how increase of nominal money supply affects inflation? The answer may be given on the basis of factor analysis – changes in the money supply, taking into account changes in the velocity of money circulation.

The identity of exchange (1) and both these IS-LM models are static because there is no transmission from current period of time to the future one. So, to find the dynamics of the inflation, (1) must be transformed into dynamic form.

First, introduce the time “t” into (1):

M (t)V(t)= P(t) Y(t) (2)

Then write down the relative increments of the variables at time “t”:

∂M(t) =(M(t)- M(t-1))/M(t-1) (growth rate of the money supply M)

∂V(t) =(V(t)- V(t-1))/V(t-1) (growth rate of the velocity V)

∂P(t) =(P(t)- P(t-1))/ P(t-1) (growth rate of the price level P)

∂Y(t) =(Y(t)-Y(t-1)))/Y(t-1) (growth rate of the real GDP Y) (3)

The simplest way to determine V(t) may be just to divide P(t)Y(t) to the M(t) (see (2)). Nominal GDP and real GDP may be found in economic statistics, but they are not always linked to the P(t) (price level) in the identity (2). Money supply M(t) may be found in the statistics of central banks. Inflation may be measured by CPI (consumer inflation) or by the GDP deflator alternatively. Those values usually are different. However, by observations below (see Tab. 1-7) the average values for the considered intervals in 1960-2024 are very close.

In the monetarist tradition commonly is assumed that the velocity of money (V) in the (2) is constant or change insignificantly (Friedman, M. 1989). But today this assumption is not considered as realistic. As a matter of fact: no significant relationship was found in the annual regressions (see Tables **8-10** below) between the growth of the money supply M2 and either the GDP deflator or CPI. But with adjusting for velocity, this outcome may turn to the opposite.

Definition 1. The growth of effective money supply - g(M) is the money supply growth 1+∂M(t), adjusted for the 1+ ∂V(t):

g(M(t)) = (1+ ∂M(t))(1+ ∂V(t)) -1 (4)

Definition 2. The total growth of effective money supply - total g(M) is the money supply growth 1+∂M(t), adjusted for the 1+∂V(t) and the 1+∂Y(t):

total g(M) =(1+∂M(t))(1+∂V(t))/(1+∂Y(t)) -1 (5)

The dynamic model (2)-(5) may provide some answers for questions: dependence of inflation on money supply, GDP growth, interest rates and exogenous shocks. Let's prove one simple lemma and two theorems[9].

Lemma Given assumption (2), derivative of relative change of aggregate demand (nominal GDP), is equal to sum of the same derivatives for M(t) and V(t).

Proof: The derivative of relative change of GDP is:

∂(P(t) Y(t)/(P(t) Y(t)))/∂t = ∂(M(t)V(t)/(M(t)V(t)))/∂t = (6)

∂/∂t ln((M(t)V(t)) = ∂/∂t ln M(t) +∂/∂t ln V(t) =

∂(M(t) /M(t))/∂t +∂(V(t) /V(t))/∂t

The lemma has been proved.

Theorem 1 Given the variables M(t), V(t), P(t), Y(t) are linked by the (2), the g(M) is equal to the growth of the nominal GDP.

Proof: Follows from the definition (4) and Lemma (*e.g*. taking integral of the left and right side of (6)). *The theorem has been proved.*

Theorem 2 Given the variables M(t), V(t), P(t), Y(t) are linked by the (2), the total (g(M)) is equal to the GDP deflator.

Proof. By virtue of the definition 2 (5):

total growth of the effective money = (1+ ∂M(t))(1+ ∂V(t))/(1+ ∂Y(t)) -1

Taking logarithm of the (1) at moments t and t-1 get:

ln P(t) = ln M(t) + lnV(t) – ln Y(t)

ln P(t-1) = ln M(t-1) + lnV(t-1) – ln Y(t-1) (7)

Taking into account (3):

ln P(t) = ln(P(t-1)) + ln(1 + ∂P(t))

ln M(t) = ln(M(t-1)) + ln(1 + ∂M(t))

ln V(t) = ln (V(t-1)) + ln(1 + ∂V(t))

ln Y(t) = ln (Y(t-1)) + ln(1 + ∂Y(t))

Subtracting the second equation from the first equation (6), we get:

[9] These theorems fix exact mathematical relations between economic variables. Any exact mathematical relation this sort may seem trivial. But we need that sort relations for the rigorous analysis and comprehension.

$\ln(1 + \partial P(t)) = \ln(1+ \partial M(t)) + \ln(1+ \partial V(t)) - \ln(1+ \partial Y(t))$

Next, apply the exponent and subtract 1 from the right and left sides:

$\partial P(t) = (1+ \partial M(t))(1+ \partial V(t))/(1+\partial Y(t)) -1$

The theorem has been proved.

Since nominal GDP is the total income of firms and households, its growth is equal to growth of the national income. Theorem 1 may be presented in another form: assuming that national income is received in the form of money, we get that it is equal to the increase in M, taking into account the velocity of circulation.

The concept of total effective money supply will further be used for the factor analysis of inflation based on (2), similarly to the Du-Pont formula:

ROE = NI/Eq = (NI/S)(S/A)(A/Eq) = ROS TOA DL

Here NI is net income, Eq is equity, S is sales, A is assets, ROS is return on sales (by net profit), TOA is asset turnover, DL is debt leverage.

Similarly, to the Du-Pont formula, the model (2)-(5) is designed to estimate the contribution of each component to the changes in inflation. And the contribution of the of ∂V (velocity) sometimes prevails over contribution of the ∂Y (real GDP) and even $\partial M(t)$ (money supply).

Further, the ratios (2)-(5) are considered as the dynamic model for the factor analysis of the money supply and inflation, referred as “model (2)-(5)”.

The next question is: what kind of money aggregate should be understood by the supply of money M in (1)? Using supply of money by central bank as a benchmark, the most adequate aggregate is the monetary base M0. But M0 hardly is a proper money aggregate, especially for USA, as the main part of dollar notes is circulating outside USA. Considering supply of money available in the commodity and financial markets, more adequate aggregates may be M1, M2 or M3. But M1 is too narrow, too volatile and depends on financial technologies.

Then the best option may be M2 - the amount of cash and all money in bank accounts. It has clear economic sense – M2 is the part of the national wealth stored in the form of money. Broader aggregates (like M3) may include bonds, foreign currencies, crypto currencies and other instruments. But they are not so relevant, as not commonly used for settlements in a domestic market. And the ratio of M2 growth to GDP is the share of national income (GDP) of the current period (year, quarter), which the population and firms keep in the form of cash and deposits.

In the model (2)-(5), it is necessary to abandon the common assumption that the velocity of money circulation is constant, since its changes may carry important information. It follows from (1) that the inverse of V(M2) (hereinafter referred to as M2V) is the ratio of M2 to nominal GDP (GDP capitalization). But that is true only for the intersection of IS and LM in the Figure **2**.

Thus, a decrease (increase) in M2V means an increase (decrease) in the ratio of monetary assets of firms and households to GDP.

The economic stagnation decreases the return on real assets and shares. And the possibility of financial crisis increases risks. Bonds also may be affected by stagnation, because of default risk, but less then shares (as they have lower beta). Also bonds with duration higher than 1 are the subject of interest rate risk. Then bonds can’t be qualified as pure financial asset (as J. Cochrane and many other authors do). So, bonds (even T-bonds) theoretically are rather in the intermediate position between monetary assets and real assets.

Therefore, if real return on real and financial investments goes higher, than money flows from deposits into financial markets and so M2V increases.

On the contrary – monetary assets (M2) depend only of real interest rate. If real return on investments in monetary assets increases, share of M2 in national income increases and so M2V decreases. Therefore, M2V depends on two factors:

- expected inflation and real interest rates on deposits;

- expected risk and return in financial markets (including bond markets).

3. NEW KEYNESIAN MODELS WITH TAYLOR`S RULE - IS IT POSSIBLE TO REPLACE THE NEW PHILIPS CURVE WITH THE FACTOR MODEL?

FRS, ECB and many other central banks (including the Bank of Russia) now use the direct control over interest rate and the inflation targeting is declared as a main principle (*e.g*. Woodford M.S, 2010). Commonly it is considered that DSGE models based on the new Keynesian theory provide satisfactory forecasting results when the economy is in a state of “dynamic equilibrium” (*e.g*. Chirichiello G. 2024). But in a stressful situation equilibrium may be broken and the applicability of DSGE models is not evident at least (*e.g.* Stiglitz J. E. 2018).

The relevance of DSGE models to statistical data is provided commonly by adjusting (fitting) some discretional parameters: *e.g.* "calibration" constants and proxy variables (*e.g.* Christiano L. J., Eichenbaum M.S., and Trabandt M. 2018). With any serious shock DSGE models tuned to "dynamic equilibrium" may fail or lead to uncertainty (*e.g.* Cai M,, Del Negro M., Giannoni M.P, etc, 2019).

The long period of zero rates observed in 2008-2018 is not aligned with the logic of DSGE models - under such policy inflation should raise rapidly. But in fact inflation in USA and EU was stable (Michelson-Morley, Fisher, Occam., 2018), (Mertens, T., Williams J., 2019).

The classical version of the new Keynesian theory may be presented in the form of three components (*e.g.* Galí J., 2019) - the Taylor rule (8) for the interest rate, the New Keynesian Phillips Curve for inflation expectations (9), and the new dynamic IS curve (10). First consider the Taylor's rule in a simple form:

$$R(t) = R^* + \pi^*(t) + \phi_\pi (\pi(t) - \pi^*(t)) + \Psi \text{ GDP gap } (t) \quad (8)$$

Here π(t) is the inflation rate (GDP deflator) expected (or observed) at the year t, π*(t) is the target inflation rate, R* is the assumed equilibrium ("natural") real interest rate, GDP gap (t) – the difference between natural logarithm of nominal GDP and natural logarithm of potential GDP:

$$\text{GDP gap } (t) = y(t) - y^*(t)$$

Here y(t) is the natural logarithm of nominal GDP, y*(t) is the natural logarithm of potential GDP determined by the linear trend.

At $\phi_\pi = 0$, the interest rate is equal to the nominal equilibrium rate, increased (decreased) by GDP gap. The Ψ is a gauge coefficient, which is estimated from empirical data. The role of the last component is - if nominal GDP is higher than potential, then the interest rate should increase in order to slow down the economy, but if it is lower, then it is reduced in order to accelerate growth.

The coefficient ϕ_π may be set by discretion of central bank (defining more or less tight monetary policy). If $\phi_\pi = 1$, the prime rate by (8) will be equal to the assumed "natural" real interest rate plus inflation adjusted to GDP gap (with gauge coefficient Ψ). But to manage inflation in theory is recommended $\phi_\pi > 1$, and even higher: $\phi\pi > 1.2$ (in theory if $\phi\pi < 1$ inflation may be unstable). However, in the original form Taylor rule (1993) was:

$$R(t) = \pi(t) + 2\% + 0.5\, y(t) + 0.5(\pi(t) - 2\%)$$

where R(t) – central bank prime rate, π (t) is the rate of inflation over the previous four quarters, and y(t) = 100% (Y - Y*)/Y* is the percent deviation of real GDP from a potential GDP (in Taylor's version y = 2.2%).

Next (second) component of the DSGE is the New Keynesian Phillips curve (9) (derived by Roberts in 1995) for the expected inflation at the year t.

$$\pi(t) = \beta\, Et\,\{\pi(t+1)\} + \Psi^* \text{ GDP gap } (t) + v(t) \quad (9)$$

Here, *Et*{π(t+1)} is the expected inflation at the year t+1, β is the long-term discount factor for 1 year (in theory it is not related to the R(t) and R*), y(t) is the logarithm of the nominal GDP (same as in (8)), and the coefficient Ψ* relates to the sensitivity of inflation to the GDP gap. In the theory the higher GDP push inflation higher and that is supported by numerous empirical researches.

Note: that is the logarithm of the nominal GDP (but not real) in the (8) and (9). Certainly, if inflation rises, the nominal GDP increases, because inflation may be the part of that increase. But theoretical explanation is very different: incomes grow and there is an opportunity for prices to rise. The constant Ψ* in the (9) (may be the same to the Ψ in the (8)) is determined through the dynamic Calvo pricing model (also very theoretical):

$$\Psi^* = \Upsilon\, h\, [1 - (1 - h)\, \beta]/(1 - h)$$

Here h is the probability of a price change, ϒ is the calibration coefficient.

Calvo model is consistent with the Keynesian concept of "sticky prices". So (9) may reflect inflationary processes better than the classical ("Ricardian") theory of supply and demand (AS-AD model). Equation (9) may (or may not) include a "stochastic shift" - the component v(t).

The third component of the new Keynesian theory is the "dynamic IS curve" (10), which describes the effect of the interest rate on output. Also, it is called the "Euler equation of households" (as if any of households use it?):

$$\text{GDPgap } (t) = Et\{\text{GDPgap}(t+1)\} - \sigma^{-1} [R(t) - R^* - Et\{\pi(t+1)\}] + v(t) \quad (10)$$

Here GDP gap (t) is current GDP gap, *Et*{GDP gap(t+1)}is expected GDP gap, E_t{π(t+1) is expected future inflation (as in (9)), and σ^{-1} is the calibration coefficient linking the GDP gap and the interest rate

R(t) (minus expected inflation $E_t\{\pi(t+1)\}$ and R*), v(t) is the stochastic deviation of GDP.

In order to make system (8)-(10) complete some assumptions for *Et* π(t+1)} should be applied. If those assumptions are based on (9) and (10), the case may be considered as "anchored expectations" (opposite to "adaptive expectations").

In general, "anchored expectations" means, that markets expectations about future inflation stay stable and do not react to external economic shocks or monetary shocks, rapid surge in the money supply or actual current inflation.

Equations (8), (9), (10) are the basis of the new Keynesian theory and DSGE models (possibly with some additions from AS-AD models) (Christiano L.J., Eichenbaum Martin S., Trabandt M., 2018), (Chirichiello G.), 2024. For example, model may be obtained by determining the expected inflation $E_t\{\pi(t+1)\}$ from the Phillips curve (9) and substituting it into the "dynamic IS curve" (10).

The key element of DSGE is the New Keynesian Phillips curve (9). It sets "rational expectations" of "anchored expectations" of inflation. The positive slope of the New Keynesian Phillips curve (9) was checked and confirmed on empirical data by many authors (Lansing, K., 2009), (Mavroeidis, S., Plagborg-Moller M., Stock J. 2014), (McLeay, M., Tenreyro S. 2020), (Jorgensen, P., Lansing K., 2020, 2024), (Lansing, K., Nucera F., 2025) etc. However, the "rational expectations" in (9) may be affected by an extraction problem (Keen, B. 2010). It may depend on the stage of business cycle and in the 1970s and early 1980s, rising inflation related to weaker economic activity, due to "poorly anchored inflation expectations" (Kozicki S., Tinsley P., 2012). It means that before early 1980s Phillips curve had negative slope, but after that its slope had been changed to positive. Michael T. Kiley (Kiley, M., 2016) shows a high sensitivity of New Keynesian models outcomes to choices about price dynamics and the nature of monetary policy.

John H. Cochrane (Cochrane J.H., 2011, 2023) argues, that application of the Taylor's rule (8) may not necessarily anchor inflation expectations and even may pose expectations of explosive inflation (case of "adaptive expectations").

And near the ZLB (Zero Lower Bound), some of forecast behavior (may lead to de-anchoring of inflation expectations (Lansing, K., 2021).

The issue of the slope of the Phillips curve (determined by Ψ in (9)) has been discussed since the Janet Yellen's speech (Yellen, J., 2019). Based on statistical data, chief of FRS has expressed an opinion that the slope of the Phillips curve has now become "flatter", meaning that the dependence of inflation on unemployment (or the GDP gap) in (9) has decreased (or even vanished). But some authors (*e.g.* Jorgensen, P., Lansing K., 2024) has objected to this opinion and defended the New Keynesian theory. However: as (9) is linked with nominal GDP, it may not so much explain inflation, as just include good part of it.

The "monetary" concept of "adaptive" (not "anchored") expectations also is considered *e.g.*, in the fiscal theory of inflation (Cochrane J.H., 2022, 2024). In this case, the Phillips curve (9) may not be applied and expected inflation may be based on interest rates. This case raising interest rates sometimes may mean not lower inflation, but higher inflation (Lester G.R, Sims E., 2018). The reason is - persistent inflation target changes and price flexibility enhance the likelihood of Neo-Fisherian effects. So, an increase of the inflation target may cause an increase of the nominal interest rate in the short run.

And there may be an uncertainty in the new Keynesian model (8), (9), (10) in the case of "adaptive" or "irrational" (so not based on (9)) inflation expectations (Adam, K., Padula M, 2011), (Berardi, M. 2024), (Cochrane J.H., 2024).

Could "adaptive" inflation expectations lead to hyperinflation in the new Keynesian model (8), (9), (10)? At least one mechanism ("Fisherian") may be assumed. If market agents assume financial instability, inflation expectations *Et*{π(t+1)} in (9) may grow in accordance with I. Fisher's formula, where nominal interest rate is equal real rate plus expected inflation:

$$E_t\{\pi_{t+1}\} = R(t) - R^* + e(t) \quad (11)$$

Here, R(t) - R* is the difference between the interest rate and the real equilibrium interest rate (R* can be estimated on the basis of expected GDP growth), and e(t) stands for "monetary policy shock" by Central Bank. Then, positive relationship between inflation and Central Bank Rate follows (9):

$$\pi_t = \beta\,(R(t) - R^* + e(t)) + \Psi \text{ GDP gap } (t) + v(t)$$

Let's assume that the GDP gap (t) is zero (full employment) in the case of adaptive expectation (11) (Fisher's formula). Then from (11), an increase in the interest rate by the (8) automatically leads to an increase of current inflation - by the same amount, plus e(t) - the "monetary policy shock" (with a discount β). If the GDP gap is greater than zero, the current inflation increases more. In the case of (11), applying (8) may lead to an inflationary spiral, if $\beta+\phi_\pi \geq 1$.

When inflation expectations are “well anchored”, wage and price setters do not revise their long-term inflation forecasts even if they observe temporary changes in inflation. This usually happens when there is strong confidence in the central bank’s commitment to its inflation target.

However, if the prime rate is too much higher than the reasonable limits (expected inflation plus the real rate), then it may harm economic development due to (10), and also stimulate inflation expectations. Another concern is increase in money supply. It is not accounted in the model (8), (9), (10), but it may provide very good basis for hyperinflation (Friedman, M. 1989), etc.

The quantity theory of money is essentially incompatible with the new Keynesian model and DSGE models in their typical (standard) form. Control of the money supply on the basis of DSGE is practically impossible, since usually money supply is not part of DSGE (in explicit form).

Another problem with (8), (9), (10) – the setting of prime rate on directive manner (by central bank) may distort market equilibrium. Consider loans as commodity, necessary for investments: why the price for loans should be established by monetary authorities? Wouldn’t be the better option for central bank to manage money supply and let money markets to establish a price for loans?

One of the possible variants to insert money supply shocks into DSGE models may be to replace new Keynesian Phillips curve (9) with more practical equation from the (4):

$$P(t) = \text{total } g(M(t)) = (1+ \partial M(t))\,(1+ \partial V(t))/\,(1+ \partial Y(t))-1 \quad (12)$$

Here ∂M(t) - growth rate of nominal money supply M, managed by central bank, ∂V(t) growth rate of the velocity V, ∂Y(t) growth rate of the real GDP.

It may seem that (12) contradicts to the New Keynesian Phillips curve (9), as in (9) inflation grows when GDP grows; while in (12) dependence is the opposite – inflation decreases with increase of ∂Y. But there is no real contradiction, as (9) is based on increase of nominal GDP, which by the Theorem 1 is equal to g(M(t)). And nominal GDP certainly depends on inflation.

Real GDP growth may push inflation down, as it comes from the model (2)-(5) and empirical data (below). So, there are at least two lacks of the New Keynesian curve (9): it doesn’t account for the growth of money supply ∂M(t) and it doesn’t account for the real GDP growth ∂Y(t).

To make the model (10)-(12) complete additional equations required for ∂V(t). From the IS curve (10) for g(t) (nominal GDP) and Theorem 1:

$$g(t+1) = -\,[GDPgap(t) - Et\{GDPgap(t+1)\} - \sigma^{-1}(R(t) - R^{*} - Et\{\pi(t+1)\})]/GDPgap(t)$$

$$\partial V(t) = (1+ g(t))/(1+ \partial M(t)) -1 \text{ (by the Theorem 1)} \quad (13)$$

Equation for the ∂Y(t) may be provided by the same IS curve for real GDP:

$$\partial Y(t) = (1 + g(t))/(1+ E_t\{\pi_{t+1}\}) -1 \quad (14)$$

In the model (10) – (14) two parameters may be managed by central bank: interest rate R(t) and ∂M(t) - growth rate of nominal money supply. Evidently these parameters are interdependent: if central bank control interest rate R(t) with (8) then ∂M(t) should be function of R(t), inflation π(t) and real GDP growth ∂Y(t).

But if central bank control money supply ∂M(t), then R(t) should be function of investment opportunities which may be defined by expected real GDP growth. Theoretically central bank can’t control both of R(t) and ∂M(t). But in reality, flexible management of R(t) may be combined with flexible management of ∂M(t), observing data for g(t), ∂Y(t) and inflation. All these parameters are currently observed by central banks. The point of the model (10)-(14) is to add ∂M(t) on the panel for the purpose of inflation targeting. The New Keynesian Philip’s curve (9) is deleted from the new combined model (10)-(14) because it doesn’t include money supply, money velocity and real GDP growth.

4. EMPIRICAL RESEARCH: THE FACTOR ANALYSIS OF INFLATION AND MONEY SUPPLY IN THE UNITED STATES FOR DATA IN THE PERIOD 1960-2024

Further provided results of factor analysis based on the quantity factor model (2)-(5) with the annual data for 1960-2024 next after the period 1867-1960 (Friedman, M, Schwartz A.J. 1963). Tables **1-7** provide the annual data for the factor analysis of GDP deflator and CPI. The factors are: money supply M2, real GDP in 2017 prices (Y), velocity (M2V), growth rate of M2 (∂M2), growth rate of M2V (∂M2V), real GDP growth (∂Y), effective growth g(M2) (growth of the nominal GDP), GDP deflator (∂P), consumer inflation (CPI), FRS rate (FR).

The main part of statistics for the Tables **1-7** was obtained from the St. Louise Fed database[10]: GDP

[10] https://fred.stlouisfed.org

Table 1: The period 1 low inflation and high growth 1960-1965

Year	M2 bln$	GDP bln$	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
1960	314	543	1.73	5.3	-2.5	-0.7	2.7	3.4	1.5	2.9
1961	338	574	1.70	7.4	-1.7	7.6	5.7	-1.8	1.1	2.0
1962	365	611	1.67	8.2	-1.8	3.6	6.3	2.6	1.2	2.8
1963	395	649	1.64	8.2	-1.8	6.2	6.3	0.1	1.2	3.2
1964	428	696	1.63	8.2	-0.9	5.5	7.2	1.6	1.3	3.6
1965	462	760	1.64	8.1	1.1	8.5	9.3	0.7	1.6	4.1
Average	384	639	1.7	7.6	-1.2	5.1	6.2	1.1	1.3	3

(NA000334Q), M2 (M2SL), Y (GDPC1), FR (BOGZ1FL072052006Q). Quarterly data have been brought to the annual basis. Annual CPI data are obtained from the World Bank database[11]. The other variables - M2V, ∂M2, ∂M2V, ∂Y, g(M2), ∂P were calculated. Note that under the conditions (2), g(M2) must be equal to the growth of the nominal GDP and the total g(M2) must be equal to the GDP deflator (Theorems 1, 2).

The conditions (2) are not always satisfied automatically, since M, V, P and Y may be obtained by different sources. With the statistical data cited above, equation (2) holds. But it is also possible to choose another data for the GDP deflator in such a way that equation (2) may not hold, which means theorems 1,2 do not hold. For example, there are another data in the St. Louise Fed data base for the GDP deflator: A191RI1Q225SBEA and NGDPDSAIXUSQ. But these data do not agree with each other and with the GDP deflator calculated on the basis of NA000334Q and GDPC1[12].

4.1. The Period 1 1960-1965 low Inflation and High Growth (after 1960)

The period 1960-1965 was the time of recovery from the late 1950s recession and a boom in the economy. Unemployment declined from 6% in 1960 to 4% by 1965. Overall, the period 1 was a time of strong economic expansion driven by fiscal stimulus (Kennedy-Johnson tax cut of 1964) and money supply.

Factor analysis. In the period 1 the money supply M2 grew at a high rate (average 7.6%), but real GDP also grew (average 5.1%) close to the g(M2) (average 6.2%). At the same time, the velocity M2V decreased (except 1965) from 1.73 to 1.64 (average -1.2% per year). CPI (consumer inflation) in the period 1 was below 2% (average 1.3%). The ∂P (GDP deflator) (average 1.1%) differs of CPI at every year, while almost the same in average (see Table **1**). The Fed rate slightly rose during the period (from 2.9% to 4.1%), remaining above inflation, which may be assumed as a cause for the gradual decline in the M2V rate from 1.73 to 1.64.

At the same time, as real GDP grew by an average of 5.1% (∂Y), the attractiveness of stocks was increasing. Highest ∂Y (8.5%) was observed in 1965 and eventually M2V rate slightly increased in that year.

4.2. Period 2 1966-1970 of Economic Growth ∂Y is Slowing Down with Moderate Inflation and Slight Increase in the M2V

The period 2 (1966-1970) was marked by slowing down economic growth (except 1968) and increasing inflation. The federal government tried to curb high deficits caused by Great Society programs and the Vietnam War spending. The tax surcharge in 1968 turned the federal deficit into a surplus, but slowed down the economic growth (from 4,5% in 1968 to 0,3% in 1969).

Factor analysis. For the period 2 (see Table **2**) CPI increases in from 3% to 5.8% with increase of M2V in 1966 (4.3%) and 1969 (3.7%). The related peaks of ∂P (5.7% and 7.1%) were oppressed by substantial increase of FR (6% average and 8.5% in 1969). The average numbers for this period are: 6.5% for ∂M2, 2.9% for ∂Y, 4.3% for CPI, 4.6% for ∂P, and 6% for FR. In the period 2, 1969 stands out - with the very low ∂Y (0.3%), CPI rises to 5.5%, and ∂P rises to 7.1%.

The FR was higher than CPI, in 1969 the difference increased to 3%. CPI and ∂P were unstable – this can be explained by comparing the g(M2) and ∂P (due to the theorems 1 and 2, they differ by the ∂Y). The volatility of inflation may be explained both by the volatility of the ∂Y and ∂M2V.

[11] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG

[12] https://fred.stlouisfed.org

Table 2: The period 2 (1966-1970) of slowdown and substantial increase in inflation with a slight increase in the M2V rate

Year	M2 bln$	GDP bln$	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
1966	482	826	1.72	4.2	4.3	2.9	8.8	5.7	3.0	5.2
1967	527	874	1.66	9.5	-3.4	3.8	5.8	1.9	2.8	4.3
1968	569	961	1.69	7. 9	1.8	4.5	9.9	5.2	4.3	5.7
1969	590	1033	1.75	3.6	3.7	0.3	7.4	7.1	5.5	8.5
1970	633	1093	1.73	7.3	-1.4	2.7	5.8	3.1	5.8	6.6
Average	560	958	1.7	6.5	1.0	2.9	7.6	4.6	4.3	6

Usually the money growth ∂M2 (average 6.5%) is divided between ∂Y and ∂P. But sometimes ∂M2V plays decisive role. *E.g.*, at 1969 ∂M2 was just 3.6%, while ∂P was 7.1% and CPI 5.5%. That is explained by the unusual increase in the ∂M2V 3.7%. The Assuming cause is inflation expectations due to slowdown of ∂Y and increase of inflation risks. A similar unusual increase in ∂M2V (4.3%) was in 1966. Probably increase of FR in 1969 (8.5%) helped to curb inflation as M2V decreased at 1970 (-1.4%).

4.3. Period 3: 1971-1982: Two Major Recessions and High Inflation

The period 3 in US economy often is referred as the "Great Inflation". That was a time of high and volatile inflation, stagflation, and economic instability.

There were many causes assumed: end of the gold standard in 1971 (Nixon Shock), two oil crises (price shocks), aggressive fed rate hikes, but most of all - two recessions. The first recession in 1974 is considered as a "deep one" and the second in 1981-1982 is considered as "severe global recession" (or maybe even two recessions: a brief one in 1980 and a severe one from 1981 to 1982).

In 9 from 12 years of the period 3 the economic growth (∂Y) was very low, but except 1972, 1975 and 1978. And as inflation was very high as well, then most part of the period 3 may be qualified as "stagflation".

The first recession in 1974 marked with the drop in real GDP (-2.3%), and it was after stagnation in 1973 (0.6%). The reason certainly was the oil crisis of 1973-1974 (a fourfold increase in oil prices from October 1973 to March 1974 due to the politically caused embargo of Arab countries).

The second recession marked with the drop in real GDP (-2.2%) observed at 1981. But it was just the first stage of the severe global economic downturn, so

Table 3: The period 3 of two major recessions ("Russian Roller Coasters" of 1971-1982) - unstable economic growth and two peaks of inflation

Year	M2 bln$	GDP bln$	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
1971	718	1190	1.66	13.4	-4.0	3.5	8.9	5.2	4.3	4.6
1972	810	1314	1.62	12.9	-2.2	7.6	10.4	2.6	3.3	4.6
1973	860	1453	1.69	6.1	4.3	0.6	10.6	9.9	6.2	9.1
1974	906	1575	1.74	5.4	2.8	-2.3	8.4	10.9	11.1	10.3
1975	1027	1734	1.69	13.3	-2.8	6.2	10.1	3.7	9.1	5.6
1976	1165	1914	1.64	13.5	-2.8	3.2	10.4	6.9	5.7	5.1
1977	1280	2135	1.67	9.8	1.5	4.1	11.5	7.1	6.5	5.7
1978	1372	2435	1.78	7.2	6.4	6.5	14.1	7.1	7.6	8.2
1979	1483	2692	1.82	8.1	2.3	1.4	10.6	9.0	11.3	11.4
1980	1607	2933	1.82	8.4	0.5	1.6	8.9	7.2	13.5	14.1
1981	1770	3252	1.84	10.2	0.7	-2.2	10.9	13.4	10.3	15.5
1982	1959	3390	1.73	10.7	-5.8	1.4	4.3	2.8	6.1	12.0
Average	1246	2168	1.7	9.9	0.1	2.6	9.9	7.2	7.9	8.9

Table 4: Period 4 of moderate but unstable inflation (1983-1991)

Year	M2 bln$	GDP bln$	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
1983	2138	3747	1.75	9.1	1.3	8.6	10.5	1.8	3.2	9.2
1984	2332	4108	1.76	9.1	0.5	4.6	9.6	4.9	4.3	10.2
1985	2502	4410	1.76	7.3	0.1	4.1	7.4	3.1	3.5	8.1
1986	2744	4624	1.69	9.7	-4.4	2.7	4.8	2.1	1.9	6.8
1987	2847	4943	1.74	3.8	3.0	4.2	6.9	2.5	3.7	6.7
1988	2992	5346	1.79	5.1	2.9	4.3	8.2	3.7	4.1	7.8
1989	3167	5730	1.81	5.9	1.3	2.8	7.2	4.2	4.8	9.2
1990	3288	6004	1.83	3.8	0.9	-1.0	4.8	5.8	5.4	8.0
1991	3381	6238	1.84	2.8	1.0	2.9	3.9	1.0	4.2	5.5
Average	2821	5017	1.8	6.3	0.7	3.7	7.0	3.2	3.9	7.9

called “the 1981 recession”[13]. That recession had multiple causes, including the 1979 energy crisis and rising Fed rate - up to 20 percent at the 1981.

The limited growth of the money supply in1981-1982 is commonly considered as the possible reason for the “severe recession”. However, the association of the 1981 recession with a "contraction" in the M2 money supply is not supported by statistics (see tab. 3). In reality the ∂M2 in 1981 and 1982 increased to 10.2% and 10.7% (while ∂P in the 1982 was just 2.8%).

CPI was above 10% during 1979-1981 but decreased to 6.1% at 1982. The decrease of inflation in 1982 is linked with a 5.8% decrease in the M2V. That may be explained by the of increase of FR and decrease of inflation risks.

With the factor analysis of the ∂P the increase in the ∂P (average 7.2%) during the two "Russian roller coasters" (stagnation plus recession) in the 1973-1974 and in the 1979-1981 may be explained by significant increase in the money supply (average 9.9%) accompanied by low and unstable ∂Y rates (average 2.6%).

The average ∂M2V for the period 3 1971-1982 was near zero (0.1%). But ∂M2V accelerated markedly in the periods preceding the "Russian rollercoasters" of high CPI (4.3% in 1973 and 6.4% in 1978). The most likely – because of expected inflation risks.

4.4. Period 4 1983-1991: Inflation was Moderate, but Volatile

In the period 1983-1991 there were signs of recovery and expansion. This period was called as "Morning in America" by President Ronald Reagan, reflecting economic optimism and expansion. “Reaganomics” played a central role. There were tax cuts, deregulation, and increased defense spending. Commonly considered that despite rising deficits, that was period of economic expansion, accompanied with declining inflation, and stronger business confidence. However, this period includes one slight recession (-1%) in the 1990. In the 1982 unemployment was 11%, and ∂Y was 1.4%. But in the 1983 GDP growth rose to 8.6%, unemployment fell to about 8.2%, and ∂P to 1.8% (see Table **4**).

Factor analysis. The main contribution to inflation was made by the growth of the money supply ∂M2 (average 6.3%). The observed ∂Y (average 3.7%) was good, except 1990. The M2V increased from 1.75 to 1.84, but the average ∂M2V was not essential (0.7%). Then inflation was moderate (average ∂P 3.2%), except the peak in 1990 (4.8%) caused by the short recession.

However, in the 3 years 1986-1988 ∂M2V was quite remarkable (-4.4% in 1986 and 3% in 1987-1988). In those years ∂M2V made a significant contribution to the volatility of the ∂P. In the 1986 ∂M2V (-4.4%) decreased inflation, related to the high ∂M2 (9.1%), but in 1987-1988 ∂M2V was added up to the moderate ∂M2.

4.5. Period 5 1992-2007 - Inflation is Low and Stable

The next fifth period (1992-2007) (see Table **5**) covers 16 years. That period is commonly characterized with the relative stability and growth – so called "Great Moderation." During this time, inflation was low and there was moderate economic expansion, avoiding the booms and busts. There were just two

[13] https://documents1.worldbank.org/curated/en/185391583249079464/pdf/Global-Recessions.pdf

Table 5: A period of relatively low and stable inflation (1992-2007)

Year	M2 bln$	GDP bln$	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
1992	3419	6604	1.93	1.1	4.7	3.3	5.9	2.5	3.0	3.5
1993	3475	6957	2.00	1.6	3.7	3.4	5.3	1.9	3.0	3.0
1994	3492	7386	2.11	0.5	5.6	3.5	6.2	2.6	2.6	4.4
1995	3648	7730	2.12	4.5	0.2	2.6	4.7	2.0	2.8	5.8
1996	3835	8191	2.14	5.1	0.8	4.3	6.0	1.6	2.9	5.3
1997	4056	8695	2.14	5.8	0.3	4.9	6.1	1.2	2.3	5.5
1998	4403	9195	2.09	8.5	-2.6	4.8	5.8	0.9	1.6	5.3
1999	4668	9786	2.10	6.0	0.4	4.2	6.4	2.1	2.2	5.0
2000	4978	10365	2.08	6.7	-0.7	2.2	5.9	3.6	3.4	6.3
2001	5461	10651	1.95	9.7	-6.3	1.3	2.8	1.4	2.8	3.5
2002	5812	11042	1.90	6.4	-2.6	1.7	3.7	2.0	1.6	1.6
2003	6082	11637	1.91	4.6	0.7	4.3	5.4	1.0	2.3	1.1
2004	6431	12404	1.93	5.7	0.8	3.9	6.6	2.6	2.7	1.5
2005	6730	13261	1.97	4.7	2.2	3.2	6.9	3.6	3.4	3.4
2006	7119	13964	1.96	5.8	-0.4	1.6	5.3	3.7	3.2	5.0
2007	7518	14650	1.95	5.6	-0.7	1.4	4.9	3.5	2.9	4.9
Average	5070	10157	2.0	5.1	0.4	3.2	5.5	2.3	2.7	4.1

years of slowdown 2001-2002, related to the dot-com bubble and the aftermath of the 9/11 attacks. But this period ended abruptly: next was financial crisis at 2007-2008 (the “Great Recession”, or “subprime MBS crisis”).

It was caused by the bubble in housing market, various high risk securities (like subprime MBS, CDS, etc.) and fueled by low interest rates and by the government-backed enterprises. The government purchased risky mortgage loans from the banks through the government-backed enterprises, like Fannie Mae (Federal National Mortgage Association) and Freddie Mac (Federal Home Loan Mortgage Corporation). These entities either held these loans in their portfolios or pooled them into mortgage-backed securities (MBS).

Factor analysis. The average values were low: ∂M2V (0.4%), CPI (2.7%), ∂P (2.3%). The ∂M2 was moderate (average 5.1%) and largely offset by ∂Y (average 3.2%). Based on the fluctuations in ∂M2V, it is possible to distinguish the short period of instability in 1992-1994, when ∂M2V was 3,7-5.6% per year, and the stable period of 1995-1997, when annual changes in ∂M2V were insignificant.

During the periods 1998-2000 and 2001-2002 M2V decreases (-2.6% in 1998 and -6.3% in 2001). In both cases it is related to financial crises – the Asian crisis of 1998 and the dot.com stock market crisis of 2000 (see Table **5**). So, most likely cause – market risks increases and money flow away from security markets into money markets. That may explain why despite the high growth rates of the M2 money supply (8.5% in 1998 and 9.7% in 2001), ∂Y and CPI declined.

Fed rate was lower than inflation in the 2002-2004, but in the 2005-2007 fed rate increased (3.4%-5%), while inflation was moderate (2.9%-3.4%). Probably that was related to assessed financial instability and inflation expectations. Eventually ∂M2V% steps down from 2.2% at 2005 to -0.4% at 2006 and -0.7% at 2007.

4.6. Period 6 2008-2019 from the Great Recession to COVID-19

This period begins with the Great Recession: severe recession triggered by financial crisis and housing bubble burst. The Great Recession begins at Dec 2007 and lasts by June 2009 (at least). But recovery featured slow GDP growth and high unemployment goes during early 2010s, with full job recovery only by 2014.

The period ended with the next major economic shock at the start of 2020 - COVID-19 pandemic. Then shock of the COVID-19 pandemic caused a sharp and sudden contraction in economic activity.

Commonly is stated, that “the US experienced the longest economic expansion in its history from 2009 through 2019”. But actually the 2008-2009 deepest recession (-3.2%) was followed by the rather moderate compensatory growth only at 2014 (4%) (see Table **6**).

Table 6: Period of low growth and low inflation after the Great Recession before the COVID-19 pandemic (2008-2019)

Year	M2 bln$	GDP bln$	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
2008	8289	14634	1.77	10.3	-9.4	-3.2	-0.1	3.2	3.8	1.6
2009	8478	14558	1.72	2.3	-2.7	1.7	-0.5	-2.2	-0.4	0.2
2010	8845	15211	1.72	4.3	0.1	2.0	4.5	2.4	1.6	0.2
2011	9751	15795	1.62	10.2	-5.8	2.6	3.8	1.2	3.2	0.1
2012	10498	16368	1.56	7.7	-3.7	1.7	3.6	1.9	2.1	0.1
2013	11118	17027	1.53	5.9	-1.8	1.7	4.0	2.3	1.5	0.1
2014	11789	17799	1.51	6.0	-1.4	4.0	4.5	0.5	1.6	0.1
2015	12506	18405	1.47	6.1	-2.5	1.8	3.4	1.6	0.1	0.2
2016	13301	18952	1.42	6.4	-3.2	2.1	3.0	0.9	1.3	0.4
2017	13883	19900	1.43	4.4	0.6	3.3	5.0	1.6	2.1	1.1
2018	14446	20836	1.44	4.1	0.6	1.9	4.7	2.7	2.4	1.9
2019	15417	21697	1.41	6.7	-2.4	1.3	4.1	2.8	1.8	2.1
Average	11527	17599	1.6	6.2	-2.6	1.7	3.3	1.6	1.8	0.7

Factor analysis. The average variables for the period 6: ∂Y only 1.7%, which is almost 2 times lower than the previous period 5, ∂M2V -2.6%, and the growth of the money supply ∂M2 6.2% (1,1% higher than the 5.1% in the previous period 5).

But CPI (1.8%) and ∂P (1.6%) were about 30% lower than for the previous period 5, due to a significant decrease in the M2V rate (from 1.77 at 2008 to 1.41 at 2017). As the maximum decrease of ∂M2V (-9.4%) occurred at 2008, it was evidently due to the shift of investment from real assets to monetary assets.

Another significant decline of M2V occurred in the period 2011-2012 (-5.8% in 2011 and -3.7% in 2012) and continued in 2013-2016. At the period 6, the Fed rate from the 2008 and until 2017 was near zero (changes from 0.16% at 11.2008 to 0.79% at 01.2017), After 2017, the Fed rate began to rise (gradually).

Therefore, the most likely reasons for the decline in the M2V were the consequences of the Great Recession, so an increase in the preference for monetary assets due to higher risks of securities and lower economic growth.

4.7. Period 7 2020-2024 - the Consequences of the COVID-19 Pandemic

The last period 2020-2024 (Table **7**) was marked by turbulence: the COVID-19 pandemic in 2020-2022, its aftermath and recovery in 2023-2024.

After 2019 started the sharp recession caused by the pandemic. However, even in 2021 the recovery (4%) was substantial. Personal consumption expenditures were major driver of the economy after COVID-19 pandemic.

Factor analysis. Overall, for the period 7 average annual numbers were: 3.7% for the ∂P, 2,6% for the ∂Y and 7.4% for the ∂M2. There was a very unusual sharp peak in ∂M2% in 2020 (25.6%) and a significant peak in 2021 (11.5%).

That size of monetary expansion (about $6 trln. in 2020-2021, like add one year US fed. budget

Table 7: Period 2020-2024 (post-COVID-19)

Year	M2 bln $	GDP bln $	M2V	∂M2%	∂M2V%	∂Y %	g(M2)%	∂P%	CPI %	FR%
2020	19360	21572	1.11	25.6	-20.8	1.8	-0.6	-2.3	1.2	0.2
2021	21586	24303	1.13	11.5	1.0	4.0	12.7	8.3	4.7	0.1
2022	21205	26526	1.25	-1.8	11.1	2.3	9.2	6.7	8.0	2.0
2023	20773	28084	1.35	-2.0	8.1	2.9	5.9	2.9	4.1	5.1
2024	21520	29534	1.37	3.6	1.5	2.1	5.2	3.0	2.9	5.1
Average	20889	26004	1.2	7.4	0.2	2.6	6.5	3.7	4.2	2.5

Table 8: Linear approximation of the ∂P (GDP deflator) by factors of model (2)-(5): ∂M2, ∂M2V, ∂Y

Coefficient	value	Stand. error	p-value	Comment
R^2	0.977	0.45	4,7E-50	Valid
a	0,15369	0,161487	0,344996!	Invalid!
b1 (∂M2)	0,948121	0,024325	8,08E-45	Valid
b2 (∂M2V %)	1,07882	0,023005	1.46E-49	Valid
b3 (∂Y)	-1,00043	0,026899	1.26E-43	Valid

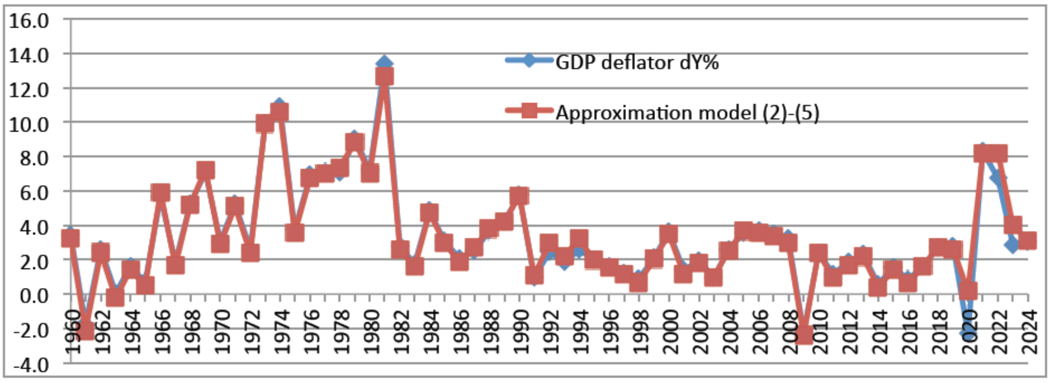

Figure 1: Linear approximation of the ∂P (∂P) by factors of model (2)-(5): ∂M2, ∂M2V, ∂Y.

expenses) caused growth of ∂P (8.3% at 2021 and 6.7% at 2022) and CPI (4.7% at 2021 and 8% at 2022). At 2020 the effect of credit emission was weakened by a decrease of M2V (-20.8%) (growth of cash deposits).

In 2021 the ∂M2V was low (1%) and the increase of ∂M2 pushed inflation at full scale. Then at 2022 and 2023 ∂M2V grew (11.1% and 8.1%). That increase inflation while ∂M2 was negative (-1.8% in 2022 and -2% in 2023). The most likely it was caused by sense of financial instability, high inflation expectations.

But since 2023 Inflation Reduction Act [14] was implemented, M2 money supply was limited and Fed rate hikes to 5.1% (2023-2024). Then, in 2024 with moderate ∂M2 (3.6%) CPI declines to 2.9% and ∂M2V to 1.5%.

4.8. The summary of factor analysis (Tables 1-7)

Factor analysis of CPI and the ∂P (see Tables **1-7**) shows that the complex dependence of CPI inflation and the ∂P on a variety of external factors may be reduced to the dependence on three factors: changes in M2, M2V, and real GDP.

And changes in the M2V may play the most significant role in the time of financial instability and high inflation expectations. In the time of recession priority may shift to the real GDP. As noted above, changes in the M2V depend on firms' and households' assessments of the risks and return on deposits versus the risks and return of investments in stocks, bonds, and real assets.

5. REGRESSION ANALYSIS OF INFLATION (CPI) AND GDP DEFLATOR (∂P) IN THE UNITED STATES FOR 1960-2024, THE QUESTION OF THE SLOPE OF THE PHILLIPS CURVE

In this section, there are results of the CPI and the ∂P regression analysis of the model variables (2)-(5), first at annual intervals and then at quarterly intervals.

5.1. Linear Approximation of the GDP and Inflation Deflator with (2)-(5)

Multiple regression of the ∂P on variables ∂M2, ∂M2V, ∂Y (Table **8**) shows a very high degree of coincidence. That is not surprising, since the regression takes into account all 3 factors affecting ∂P, in accordance with theorem 1. The note: free term "a" with a high probability (0.345) is equal to zero.

Figure **1** shows that the linear approximation of the ∂P by the factors of model (2)-(5) ∂M2, ∂M2V, ∂Y is quite accurate, except some points (for example, 2020). However, there are discrepancies during periods of CPI peaks. If a logarithmic approximation were used, then the coincidence would be complete by the theorem 1. In the "value" column of Table **8**, may be seen the sensitivity of ∂P to factors ∂M2, ∂M2V, ∂Y – it is close to 1.

[14] https://www.irs.gov/inflation-reduction-act-of-2022

Table 9: Linear approximation of consumer inflation (CPI) by factors of model (2) - (5): ∂M2, ∂M2V, ∂Y

Coefficient	value	Stand. error	p-value	Comment
R^2	0.66	1.63	2.35E-14	Valid
a (CPI)	0,605535	0,584418	0,30423!	Invalid!
b1 (∂M2)	0,805697	0,088032	4.72E-13	Valid
b2 (∂M2V %)	0,853404	0,083255	6,86E-15	Valid
b3 (∂Y)	-0,71311	0,097347	6,39E-10	Valid

Multiple regression – CPI dependences on the variables ∂M2, ∂M2V, ∂Y (see Table **9**) also shows the high relevance (R^2=0.66). Unlike ∂P, this is not explained by theorems 1 and 2, and the discrepancies are not related to the linear nature of the approximation. Similar to the regression for ∂P, the p-value for "a" is 0.345, so high probability that the free term "a" is zero.

For clarity, Figure **2** shows a linear approximation of the CPI according to the model (2)-(5) (based on linear regression). For period 1 (1960-1965) and period 2 (1966-1970), the approximation predicts higher volatility and slightly higher CPI (with a difference of 1-2%, except for 1966, 2.6%).

Significant discrepancies are visible for the period 3 of the two "Russian roller coasters" (see Table **3**), where linear approximation underestimates CPI.

After 1982 estimates are close to observed inflation – the differences are usually less than 1%, except for 2021-2022, where the approximation shows a peak in inflation 1 year ahead of schedule.

Outcome. The linear approximation of CPI (consumer inflation) with (2)-(5) model seems to be generally satisfactory, except for some periods of high inflation.

5.2. Regressions of CPI on Variables: ∂M2, ∂M2V, ∂Y, g(M2), ∂P and FR Based on Annual Intervals for 1960-2024

In the Table **10** there are represented results of the regressions of consumer inflation (CPI) on the variables of the (2)-(5) model: ∂M2, ∂M2V, ∂Y, g(M2), ∂P (∂P) and FR (on annual intervals for 1960-2024).

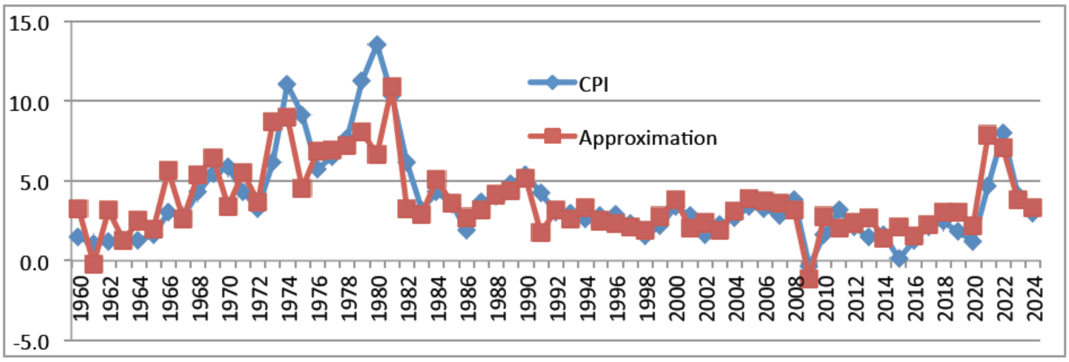

Figure: 2: Linear approximation of consumer inflation (CPI) by factors of model (2)-(5): ∂M2, ∂M2V, ∂Y.

Table 10: Regressions of the CPI on ∂M2, ∂M2V, ∂Y, g(M2), FR and ∂P

Variable	R^2	Stand. error	p – value (regression)	a (p-value)	b (p-value)	Comment
∂M2	0.005	0.028	0.56!	0.03 (4.6E-06)	0.05(0.56!)	Invalid!
∂M2V	0.1	2.6	0.01	3.8(1.9E-17)	0.2 (0.01)	Doubtful
∂Y	0.07	2.6	0.037	4.7(3.6E-12)	-0.31(0.04)	Doubtful
g(M2)	0.35	2.23	2.1E-07	0.26 (0.7, invalid)	0.54 (2.1E-07)	Doubtful
FR	0.53	1.9	5.0E-12	1.06 (0.01)	0.56 (5E-12)	Valid
∂P	0.64	0.017	9.7E-16	0.012 (2.1E-4)	0.75(9.7E-16)	Valid

First result - with a 56% probability, the correlation between ∂M2 and CPI is zero. In other words, annual inflation (CPI) is highly likely independent of annual fluctuations in the money supply if other factors hold.

The dependence of inflation on ∂M2V and ∂Y is doubtful. Although formally the regression is significant (the independence hypothesis is refuted), the level of dependence is too small (R^2 is 0.1 and 0.07). Therefore, the causal relation cannot be confirmed.

A certain relationship may be seen between ∂P and FR, but the standard error is 1.9, which means that R^2 is instable in partial samples. An important result is the significance of the "b" coefficient (5E-12), and the standard error of 0.07 indicates its stability. The positive dependence of CPI on FR may mean just that the Fed tends to raise rates when inflation rises. The coefficient "b" (0.56) may show the average sensitivity of CPI to changes in FR (or vice versa).

5.3. CPI Regression Analysis with 1 and 2 Year Lags

The CPI regression on ∂M2 with a shift of t, t-1, t-2 shows the absence of a significant dependence with lags over annual intervals (while there is a weak dependence with a lag of 2 years).

The lagged regression of the CPI on FR (see Table **11**) shows that there is no significant dependence on the previous year t-1 and the dependence on t may mean that the Fed usually raises FR when the CPI increases.

The results for regression CPI on ∂P (Table **11**) shows that the free term "a" is not valid (p-value 0.19, st. error 1.03). However, this dependence cannot be ignored, since it is theoretically justified - changes in ∂P can outpace the CPI and affect it with a delay, presumably not exceeding 1 year. In addition, as already noted, in all the periods considered (see Tables **1**-**7**), the average values of ∂P and CPI were very close (almost coincided).

The results for the lagged g(M2) are significant (although the st. error for R^2 is 1.88). Note that by the theorem 2, g(M2) is equal to the growth of nominal GDP (aggregate demand). The linear relationship has a positive slope for both t (0.27) and t-1 (0.49), with the dependence on t-1 being higher (Table **11**). The CPI positive dependence on the g(M2) means it increases with the growth of aggregate demand (nominal GDP). That may be explained by the positive slope of the Phillips curve. But the Phillips curve does not take into account the aggregate demand of period t-1 (this issue will be considered later for the ∂P).

5.4. Regression of ∂P on ∂M2, ∂M2V, ∂Y, g(M2), FR

The results of the regressions of ∂P on ∂M2, ∂M2V, ∂Y, g(M2), FR (Tab. 12) are much similar to the results of the same CPI analysis (Table **10**). With an 89% probability, the correlation between ∂M2 and ∂P is zero. That means no dependence (Table **12**) holding other factors constant.

The dependence of ∂P on ∂M2V and ∂Y (separately) is doubtful as well as for CPI, and values are close to those for CPI. Similar to CPI, the regression is formally significant (the independence hypothesis is refuted), but the relationship is too small: R^2 is close to zero, and Stand. Error has a high value (Table **12**).

Same with CPI, a valid dependence for ∂P may be set with FR. The standard error 2.3 for R^2 means that it may be inconsistent in partial samples. The p-value (0.07) for the "a" coefficient (0.89) is slightly higher than the threshold, but the standard error (0.08) indicates stability. The "b" coefficient (0.51) is very close to the similar coefficient for CPI (0.56).

Dependence of ∂P on g(M2), as for CPI, is valid, while free coefficient "a" is doubtful (p–value 0.15). However, the coefficient "b" - the slope of the Phillips curve is more important, and this coefficient (0.68) is valid (p-value 4.25E-10) and a low st. err. (0.09). Thus, a positive slope of the Phillips curve for the nominal

Table 11: Multiple regression of annual CPI values on ∂P, FR and g(M2) with the lag of 1 year

Variable	R^2 (p–value, st. error)	a (p-value, st. error)	b (p-value, st. error)	Comment
∂P (t)	0.86 (5E-27, 1.03)	0.29 (0.19!, 0.22)	0.58 (5E-18, 0.047)	Doubtful! (a=0?)
∂P (t-1)	-	-	0.46(5E-14, 0.047)	Valid
FR(t)	0.54 (3E-11,1.88)	1.14 (0.06. 0.4)	0.7(6E-06, 0.14)	Valid
FR (t-1)	-	-	-0.15 (0.27!, 0.14)	Doubtful
g(M2) (t)	0.55 (3E-11, 1.88)	-1.14 (0.08. 0.63)	0.27 (0.006, 0.09)	Valid
g(M2) (t-1)	-	-	0.49 (2E-06, 0.09)	Valid

Table 12: Regression analysis of the dependence of the ∂P (∂P) on ∂M2, ∂M2V, ∂Y, g(M2), FR

Variable	R^2	Stand. error	p – value (regression)	a (p-value)	b (p-value)	Comment
∂M2	0,0003	2,95	0,89	3.44 (1.3E-05)	-0,01(0,89)	Invalid
∂M2V	0,19	2,65	2.8E-04	3.45(2.17E-15)	0.298 (2.8E-04)	Doubtful
∂Y	0,156	2,7	0,001	4.9(1.6E-12)	-0,5(0,001)	Doubtful
g(M2)	0,46	2,15	4.2E-10	-0,9 (0,15!)	0.67 (4E-10)	Valid
FR	0,39	2,3	2.7E-8	0,89 (0,07)	0.51 (2.7E-8)	Valid

GDP (but not real GDP as in the theory) may be confirmed.

5.5. Multiple Regressions of ∂P on ∂M2 with lags of 1 and 2 Years Plus on FR and g(M2) with a Lag of 1 Year

Regression of the ∂P on ∂M2V with t-1 and t-2 lags shows independence with probabilities greater than 77% and 60%. But in contrast to CPI (Table **11**), multiple lagged regression of ∂P on FR (Table **13**) shows a valid dependence on both t and the previous year t-1. For FR (t) relation is positive (b=1.2), fot FR (t-1) relation is negative b =-0.57. It means that Fed increase FR if ∂P increases and increase of FR may push down ∂P next year.

Next of the interest are the valid results of multiple regression of ∂P on g(M2) with lag 1 year (Table **13**). A positive dependence on g(M2) (t) (b=0.27) and on g(M2) (t-1) (b=0.49) are certainly confirmed.

Conclusions on the slope of the Phillips curve.

Overall, the results confirm the positive slope of the Phillips curve, but for the nominal GDP, not real GDP as in the theory. Besides, in the standard Phillips curve there is no dependence of ∂P on the aggregate demand at t-1.

5.6. Quarterly regressions of the ∂P on aggregate demand g(M2)

The Table **14** shows results of the ∂P regression on aggregate demand over the quarterly intervals for 1960-2024. The results prove that at quarterly intervals, the values of the ∂P coincide very well with changes in aggregate demand (R^2=0.905, p-value = 3.9E-136, St. err.=0.01). The regression of residuals by aggregate demand shows that there is no correlation with probability 1. So, the regression results are correct (despite autocorrelation of some data, as it shown below).

There is autocorrelation of g(M2) quarterly data (Table **15**). The correlation of aggregate demand in quarter “t” with quarters “t-1, t-2, t-3” is a natural phenomenon.

As may be seen from the Table **16** and Table **14**, accounting information of g(M2) at the quarters t-1 increases R^2 from 0.905 to 0.913 (adding 0,88% to the accuracy measure). So, the main part of information of

Table 13: Multiple Regression of Annual Values ∂P on, FR and g(M2) with a Lag of 1 Year

Variable	R^2 (p – value, st. error)	a (p-value, st. error)	b (p-value, st. error)	Comment
FR(t)	0.49 (5E-10, 2.1)	1.2 (0.009, 0.45)	1.02(1,7E-08,0.16)	Valid
FR(t-1)	-	-	-0.57 (0.005,0.16)	Valid
g(M2) (t)	0.55 (3E-11, 2)	-2 (0,004, 0,67)	0.27 (4.6E-06, 0.1)	Valid
g(M2) (t-1)	-	-	0,49 (0.002, 0.1)	Valid

Table 14: Quarterly regression of the ∂P on g(M2) for 1960-2024

Coefficient	Value	Stand. error	p-value	Comment
R2	0.905	0.01	3.9E-136	Valid
a	-0.0063	0.0007	1.168E-16	Valid
b	0.925	0.02	3.9E-136	Valid

Table 15: Quarterly regression of the g(M2) in quarter t on g(M2) quarters t-1, t-2, t-3 for 1960-2024

Coefficient	Value	Stand. error	p-value	Comment
R2	0.57	0.023	3.6E-46	Valid
a	0.035	0.0025	5.4E-34	Valid
b1 (t-1)	-0.504	0.054	6.2E-18	Valid
b2 (t-2)	-0.166	0.062	0.0077	Valid
b3 (t-3)	-0.502	0.054	6.16-18	Valid

Table 16: Regression of the ∂P on the g(M2) at the quarters t and t-1 over 1960-2024 (quarterly intervals)

Coefficient	Value	Stand. error	p-value	Comment
R^2	0.913	0.01	6.2E-139	Valid
a	-0.003	0.001	0.0005	Valid
b1 (t)	0.853679995	0.023	3.3-105	Valid
b2 (t-1)	-0.113692669	0.023	1.6E-06	Valid

aggregate demand is accounted in values for quarter "t" and autocorrelation does not affect the validity of the results in the Tables **14** - **16**.

6. COMPARING INFLATION IN USA AND OTHER COUNTRIES

From the data in Table **17**, may be seen that inflation in USA in 2000-2022 in average (2.26) is lower than the world average (4.03), China (3.29), and OECD (2.45) but higher, than in EU (2.14). However, for 2015-2022 it is different - inflation in USA in average (2.62) is higher than in China (2.21), OECD (2.47) and still higher, than in EU (2.10). It is lower than the world average (3.27), but the world average inflation for 2015-2022 is lower than for 2000-2022 and the same is true for China, OECD and EU. So, inflation in USA was growing faster, than in the world average and faster than in EU, OECD and China.

From the Table **17**, it may be concluded that the average inflation for 2015-2022 in African countries (East and South) is 5.66%, the group of low-income countries 5.6% and Brazil is 6.77% is higher, then in developed countries.

However, inflation commonly does not depend on the rate of economic growth, but rather on the monetary policy of central banks. For example, the average inflation for 2015-2022 in the group of developed countries (USA, EU, OECD) is similar for countries with rapid economic growth: 2.2% in China, 2.3% in Vietnam, 4% in India, except 7% in Brazil (see Table **17**).

Table **18** shows data on inflation in some CIS countries and high inflation examples of Turkey and Argentina are added to the panel. Here are countries with average inflation (up to 10% on average for 2015-2022), followed by four countries with very high inflation: Azerbaijan, Belarus Uzbekistan and Ukraine.

From the data in Table **18** may be seen that inflation is not determined by the country's participation in military conflicts or international sanctions. For example, inflation in Ukraine in peaceful 2015 was higher than in 2022, but high inflation was noted in Uzbekistan, Belarus, Turkey and Argentina, which are not involved in military conflicts. In Russia, inflation in 2021 was higher than in 2022 (the begin of the Special Military Operation).

Russia belongs to the group of countries with modest inflation (taking as a benchmark 10% for the average inflation during 2015-2022). Despite severe international sanctions, Russia stays in the intermediate position, between countries with low and modest inflation (tab. 17) and high inflation (Table **18**) - Kazakhstan, Azerbaijan, Kyrgyzstan, Uzbekistan, Belarus and Ukraine.

Besides Table **18**, there are only a few countries in the world with higher inflation in 2015-2022. This number includes troubled countries such as Syria, Lebanon, Haiti, Venezuela and world record holders Sudan and Zimbabwe, with galloping hyperinflation.

Combining the data of average inflation with data of average economic growth for 2000-2022 in a panel

Table 17: Inflation (GDP deflator %) during 2000-2022 in the group of countries with medium and low inflation (author calculations based on WB data[15])

Year	USA	EU	OECD	China	World average	Low Income	Africa	India	Vietnam
2000	2.27	2.74	3.17	2.06	4.94	9.85	11.12	3.64	3.41
2001	2.25	3.47	3.39	2.05	3.85	5.78	8.63	3.22	2.62
2002	1.56	3.27	2.94	0.60	3.53	2.81	9.37	3.72	4.70
2003	1.97	3.15	2.63	2.60	3.89	9.80	8.11	3.87	7.11
2004	2.68	2.67	2.91	6.95	5.45	11.10	9.84	5.73	8.43
2005	3.14	2.24	2.77	3.90	5.79	9.03	7.48	5.62	18.81
2006	3.09	2.90	2.84	3.93	5.50	7.46	8.48	8.40	8.57
2007	2.70	2.56	3.02	7.75	5.92	7.44	8.26	6.94	9.63
2008	1.92	2.86	3.14	7.80	7.85	9.21	11.46	9.19	22.67
2009	0.64	0.53	1.81	-0.21	2.12	3.65	8.66	7.04	6.22
2010	1.20	0.65	1.19	6.88	4.30	6.02	6.13	10.53	42.30
2011	2.08	1.61	1.88	8.08	5.60	11.25	10.07	8.73	21.41
2012	1.87	1.68	1.84	2.33	3.61	5.86	6.47	7.93	9.08
2013	1.75	1.28	1.66	2.16	2.24	4.77	5.84	6.19	4.04
2014	1.87	0.83	1.36	1.03	1.94	1.80	5.40	3.33	3.70
2015	1.00	1.04	1.32	0.00	2.26	6.50	5.55	2.28	-1.72
2016	1.00	0.86	1.07	1.41	1.96	4.78	7.00	3.24	1.82
2017	1.90	1.30	1.80	4.23	2.97	5.94	5.22	3.97	4.36
2018	2.40	1.84	1.96	3.50	2.71	4.44	4.32	3.88	3.63
2019	1.79	1.77	2.21	1.29	2.40	4.68	4.44	2.41	2.42
2020	1.30	1.69	1.91	0.49	1.91	3.17	4.79	4.75	1.47
2021	4.49	2.66	2.97	4.55	4.66	6.64	5.54	8.54	2.78
2022	7.04	5.68	6.53	2.25	7.26	8.62	8.39	8.23	3.86
Average 2000-2022	2.26	2.14	2.45	3.29	4.03	6.55	7.42	5.71	8.32
Average 2015-2022	2.62	2.10	2.47	2.21	3.27	5.60	5.66	4.66	2.33

regression, gives valid results (Table **19**). But the R^2 is very low (0.028) and coefficient “b” is very small (-0.002).

The panel built on the most expanded statistics of WB (Table **19**) leads to conclusion: the dependence of the average economic growth (∂Y) and the average GDP deflator (∂P) may be valid, but below rational benchmark.

CONCLUSIONS

When managing the Central Bank's interest rate according to Taylor's rule (8) without restrictions on the money supply, three factors may come into play:

- an increase in inflation expectations due to increase of money supply;

- an decrease in the money velocity due to rising inflation expectations;

- a decrease in real GDP growth rates due to a high interest rate.

All these factors accelerate inflation, and all three factors are blindly ignored by new Keynesian model and DSGE models, employed by Central banks.

As it was shown above on the example of USA history during 1960-2024, dynamics of GDP deflator may be decomposed into growth rate of three factors: M2, velocity M2V, and real GDP growth. The velocity of M2V depends by two factors: inflation expectations and interest rates on deposits (expected inflation risk and

[15] https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS

Table 18: Inflation (GDP deflator) in some CIS countries, Turkey and Argentina (author's calculations based on WB data[16])

	Georgia	Tajikistan	Moldova	Russia	Kyrgyzstan	Kazakhstan	Azerbaijan	Belarus	Uzbekistan	Ukraine	Turkey	Argentina
2000	5	23	27	38	27	17	12	185	47	28	49	1
2001	5	31	12	16	7	10	3	80	45	10	53	-1
2002	6	19	10	16	2	6	4	45	45	5	38	30
2003	3	27	15	14	4	12	7	31	27	8	23	11
2004	8	17	8	20	5	16	9	23	16	15	12	18
2005	8	10	9	19	7	18	15	19	21	24	7	10
2006	8	21	13	15	9	22	11	11	23	15	9	14
2007	9	27	16	14	15	16	21	13	23	23	6	15
2008	10	28	9	18	22	21	28	21	27	29	12	23
2009	-2	12	2	2	4	5	-19	9	17	13	5	15
2010	14	12	33	14	10	20	14	11	49	14	7	21
2011	9	13	8	24	22	21	23	71	22	14	8	24
2012	0	12	7	9	9	5	3	75	15	8	7	22
2013	1	4	4	5	3	9	0	21	12	4	6	24
2014	4	5	5	7	8	6	-1	18	14	16	7	40
2015	6	7	12	7	3	2	-9	16	10	39	8	27
2016	3	1	4	3	6	14	15	8	9	17	8	41
2017	8	10	6	5	6	11	16	9	19	22	11	26
2018	4	2	3	10	3	9	12	12	27	15	17	42
2019	5	4	5	3	10	8	0	9	18	8	14	49
2020	7	2	6	1	5	4	-7	12	11	10	15	40
2021	10	10	6	19	16	14	22	15	14	25	29	54
2022	9	6	19	16	17	20	37	14	14	34	96	69
Average 2015-2022	7	5	8	8	8	10	11	12	15	21	25	44

Table 19: Panel regression of the average economic growth % (∂Y) on the average GDP deflator % (∂P) during 1962-2023 for the 159 countries[17]

Coefficient	Value	Stand. error	p-value	Comment
R^2	0.028	1.8	0.034	Valid
a	5.62	0.15	3E-79	Valid
b (for ∂Y)	-0.002	0.001	0,035	Valid

interest rate), expected instability in financial markets and so expected risk and return on the market portfolio (expected market risk and return).

So, to improve management of inflation it may be good to change the new Keynesian Phillips curve (9) to another equation, based on inflation expectations, money supply, money velocity and real GDP growth, *e.g.*, like (12). It may be combined with additional models for the money supply, money velocity and real GDP growth (like the dynamic AS/AD models).

If M2 growth will be under control, inflation should decrease, and the equilibrium rate of the Central Bank will decrease accordingly. Or, to decrease high growth

16 https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS

17 https://data.worldbank.org

rate of the money supply (or V), the rate of the Central Bank may be higher. Assumption (12) may give similar or better results with DSGE models.

Based on the quantity theory of money and the fundamental uncertainty of the DSGE models, it would be better to limit the growth rate of the broad monetary base to the GDP growth rate plus target inflation, and to determine the refinancing rate at auctions. An increase of money supply may be just a result of bank loans from the central bank to support liquidity and that may be irrelevant to inflation (or little to do with it). But often it is a result of "Shotgun Wedding" of the monetary and fiscal policy. And this way is always relevant to inflation and even may undermine financial stability. In this case Milton Friedman's aphorism "inflation is always and everywhere a monetary phenomenon" may be applicable at 100%.

CONFLICTS OF INTEREST STATEMENT

The author has no conflicts of interest to declare.

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