Distinctive Features of the RIM Model of Russia

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The RIM[1] model of Russia shares its general structure and many features with the other dynamic interindustry models built with the Inforum software. We will describe here only some distinctive features of RIM, in particular its data base, its use of embodied technological progress in the productivity equations, investment equations, monetary aggregates, balance of payments, and a slightly embarrassing misadventure with the use of a saturation variable in the consumption functions.

The Data Base

RIM has 44 sectors as shown in the table on page 5 below and has a statistical base in series of input-output tables extending from 1980 to 2013 in both current and constant prices. Constructing such a series of tables covering ten years with a socialist economy, the breakdown of the old order and the gradual reorganization and subsequent growth of the new order was a daring and probably unique venture. Yet we believe that these tables are meaningful and form the best possible base for modeling the present and future Russian economy. They are consistent with the system of national accounts (SNA) and were made in this institute (IEF – RAS) primarily by Marat Uzyakov. The estimates were based on Russian IO flow tables in current prices and SNA definitions as published by Rosstat (the Federal State Statistics Service of Russia).

Embodied Technological Progress

In May of 2013, our Institute produced a position paper with the historically evocative title of "New Economic Policy" with the subtitle of "A Policy of Economic Growth." The paper argues that the Russian Government's finances are very sound and would allow a policy of promoting investment in the private sector without in the least risking that soundness. To quantify the benefits of increased investment, embodied technological improvement was incorporated into the production functions. Some results were described in the paper of Ksenia Savchishina at the 22nd Inforum Conference in 2014. We will explain here the thought process behind the equations.

The principal benefit to the economy of more investment in private industries is an increase in labor productivity, that is, of output per employed person. The relation between an industry's output (Q) and its employment (L) and capital stock (K) in year t may be written as

$$Q(t) = f(L(t),K(t),t).$$

We use the well-known Cobb-Douglas form with constant returns to scale:

$$(1) \qquad Q_t = Ae^{rt} L_t^{\alpha} K_t^{1-\alpha}$$

where Q, L, and K are all functions of t, time. Under the assumption that capital and labor are paid

1 The authors gratefully acknowledge important contributions from Clopper Almon, Sofiya Kaminova, Vadim Potapenko, Kseniya Savchishina, Georgiy Serebryakov, Marat Uzyakov, Rafael Uzyakov, Elena Uzyakova and Alexey Yantovskiy. The name of the RIM model, abbreviating “Russian Interindustry Model”, was suggested by Clopper Almon, our main helper and adviser. He is the original programmer of the software with which RIM is built and the author of many methodological approaches used in it. In suggesting the name, he doubtless had in mind that RIM (Рим) is also the Russian word for Rome, and that – after the fall of Constantinople – Moscow was proud to be known as the Third Rome.

in proportion to their marginal product, α is labor's share and 1- α is capital's share of the net product of the industry. A typical value of α is 2/3.

The term e^{rt} represents technical change that is "disembodied" in the sense that it happens whether or not there is investment in new plant and equipment. It may come about by an increasingly well-qualified labor force, or by learning by doing. A second type of technical progress may be embodied in new capital. This year's model of a machine may be more productive than last year's model but sell for the same price. Such an improvement is unlikely to be accounted for in the price deflator, so a "constant ruble" of this year's machine should count for more in the production than a "constant ruble" of last year's machine. This sort of technical progress is "embodied" in capital; an industry gets the benefit of it only if it invests.

While these two types of technical progress are conceptually distinct, it is virtually impossible to separate them statistically using only time-series data. Across establishments, however, there is a lot of variation in investment, and that variation makes it possible to separate the two types of technical progress. A 2001 Ph.D. thesis[2] at the University of Maryland by Daniel J. Wilson used the Longitudinal Research Database at the U. S. Bureau of the Census for just such a study. He found rates of embodied technical progress ranging from 0 up to some 20 percent per year for various industries, with 3 to 10 percent per year being typical values. Since these rates relate to machinery which is internationally traded, it is not unreasonable to suppose that similar rates would be found for post-Soviet Russia.

We will compute productivity-adjusted capital stocks for each RIM industry by using assumed rates of increase of embodied technical progress. Initially, we use the rate of 5 percent per year of growth of embodied progress. If we then find for some industry a disembodied rate, r, greater than 5 percent per year, we increase the assumed embodied rate. The employment equation for each industry is then found by solving (1) for L given Q and K.

We estimate the parameters of equation (1) by taking the logarithms of both sides and solving for log(L/K). First, divide both sides by K:

$$Q/K = Ae^{rt}(L/K)^{\alpha}$$

solve for $(L/K)^{\alpha}$

$$(L/K)^{\alpha} = (\frac{1}{A})e^{-rt}\left(\frac{Q}{K}\right)$$

and take logarithms of both sides

$$\alpha \log(L/K) = -\log A - rt + \log(Q/K)$$

and divide both sides by α to get

$$\log(L/K) = -\frac{\log A}{\alpha} - \frac{r}{\alpha}t + \frac{1}{\alpha}\log(Q/K).$$

This is the form we estimate by regression. Notice that we expect the coefficient of t to be negative while that of the last term should be something in the neighborhood of 1.5, corresponding to a value of α of 2/3.

We calculate the value of K first with an embodied productivity change of 5 percent per year and estimate the equation with a "soft" constraint that the coefficient on the last term should be

2 *Capital-embodied Technological Change: Measurement and Productivity Effects,* Daniel John Wilson, 2001. Available on the Inforum website.

about 1.5. If the assumed embodied technical progress implies negative disembodied technical progress -- as it does for about one third of the industries -- we reduce the embodied rate to zero. On the other hand, if the disembodied rate comes out strongly positive, we increase the embodied rate to give investment more credit for the progress. The final values of the rate of embodied technical progress are in the file productivity.ttl, shown on page 7 below, which also gives the assumed depreciation rates.

To calculate the capital stock we use the "cascading two-bucket" system, so called because of the analogy with a system of two buckets, one above the other and familiar to the readers of Almon's *The Craft of Economic Modelling.*

If we use the historical investment data for years before about 1992, we will probably over-estimate the capital stock because investment was largely limited to domestically produced machinery and equipment which was less productive, as history showed, than the world-class equipment which became available in the 1990s. If, on the other hand, we use only capital put in place after 1992, we would seriously underestimate the capital in use in the early years of the 2000 - 2012 period over which we will estimate the production function. We use, therefore, the device of adjusting a bucket beginning in 1992 by a unit bucket, also described in *The Craft.*

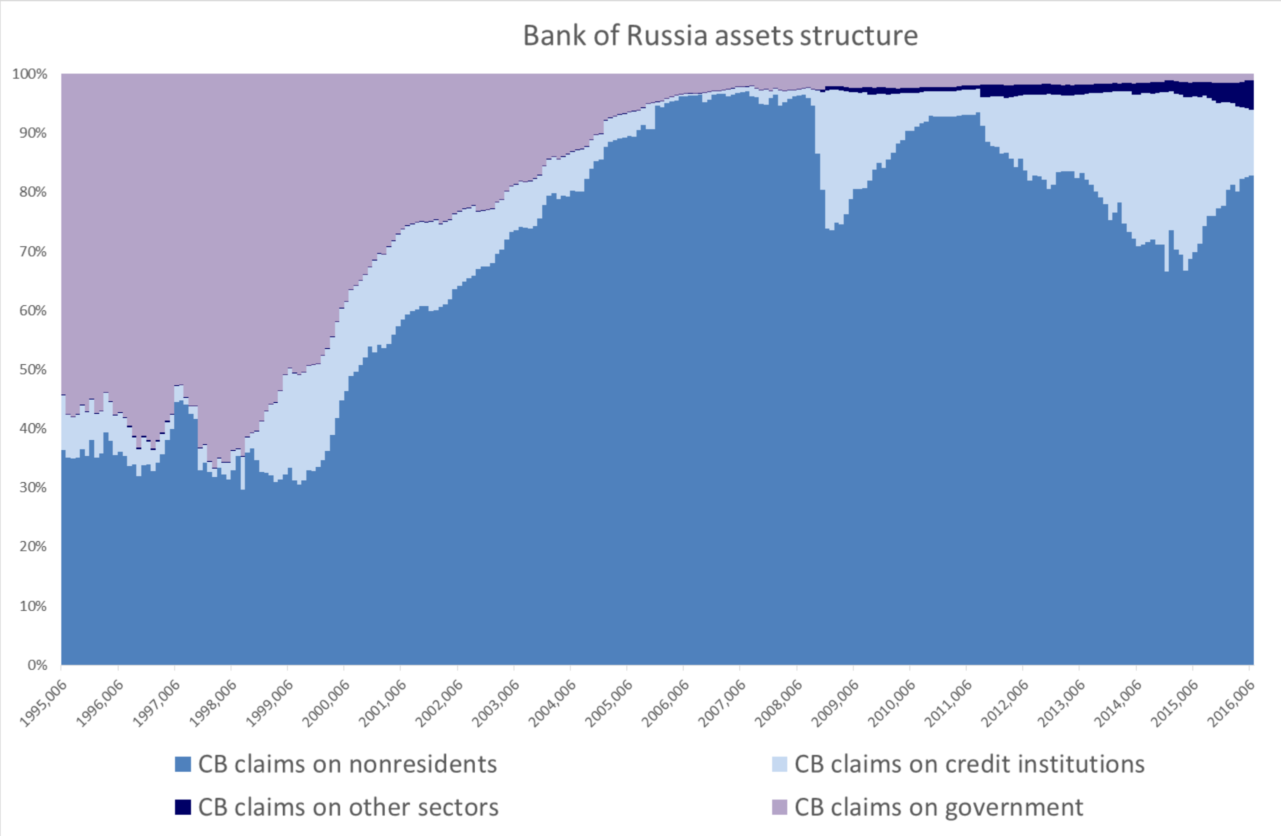
While the new employment equations can be used in RIM to make a forecast with given tax rates and investment equations, that is, as a business cycle forecasting model, they are of greatest benefit when the model is used to *envision a better future*. In this visionary mode, we use cta (constant term adjustment) fixes to add extra investment to that generated by the model's investment equations. We may also turn off the links from employment to Personal Disposable Income (PDI) and thus make PDI an exogenous variable. We can then experiment with the model to find the course of PDI that is, given our stimulus to productivity through investment, consistent with some specified high level of employment in future years.

The involvement of this Institute with the Inforum system comes from the vision of our former director Yuri Yaremenko. For him, forecasting was important because it involved envisioning a better future. Thus, this visionary use of the model is squarely within the tradition of the Institute.

The Balance of Payments and Money Supply

The balance of payments is more important in Russia than in many countries because, from the beginning of the 21st century, the Central Bank has based the money supply primarily on its holdings of foreign assets. Indeed, these assets have constituted 60 – 90 percent of the total assets of the Bank, as can be seen in the graph below, which shows the percentage composition of the Bank's assets from mid-1995 through 2015.

The lowest area is the share of foreign assets, the next higher area is the share of the debt of Russian banks and other credit institutions, the third area is the debt of Russian governments, including the central government, and finally, beginning in 2009, a small amount of debt of other Russian non-bank financial organizations.



During the 1990's the Central Bank had created a great deal of money by the purchase of Russian government debt, with consequent rapid inflation. In 1999, this policy was radically altered, and the Central Bank began basing the money supply more and more on its holdings of foreign assets, especially money or near money, a policy which brought inflation under control. The graph also shows the Bank's reaction to the crisis of 2008, when it significantly increased it purchases of the debt of Russian banks. It then cut back on these purchases for a few years but resumed them gradually after 2011 in conditions of economic slowdown. Beginning in 2009, it has purchased the debt of a few selected Russian non-bank financial companies.

After 1998, Russian exports of goods have exceeded imports in every year, while imports of services have steadily exceeded their exports. Russian investment abroad has exceeded foreign investment in Russia except in 2002-2003 and 2006 -2007. The balance on goods, however, has been strong enough the Russia – and the Central Bank in particular – has steadily increased its holding of foreign assets, so that after 2004 Russia became one of the leading owners of international monetary assets.

In forecasting, we assume that the Central Bank will continue its present polices and therefore the forecast of the balance of trade in goods and services – together with the balance on investment and government deposits with the Central Bank – affects, ruble for ruble, the monetary base. Of course, the monetary base is also influenced by Central Bank purchases or sales of other assets.

Exogenous variables in this part of the model include the exchange rate, government investment abroad and foreign government investment in Russia. Exports, of course, are related to foreign demands; but we hope that by the inclusion of RIM within the Bilateral Trade Model being developed at IRPET in Florence, we will not have to produce forecasts of these demands ourselves.

Investment Equations with Credit Conditions

We felt that the ease of obtaining long-term credit should influence fixed investment. After trying various representations of credit conditions, we settled on change in total outstanding long-term credit, where by long-term we mean for periods longer than three years. We deflated this difference to get a variable we called fiR. The investment equations for each industry then used the capital replacement in the industry, the current and two lagged values of the first difference of the industry's peak output, our fiR, and a variable representing profits in the industry. The coefficients on the first differences in peak output were softly constrained to maintain the capital-output ratio in the industry, and the profits variable was softly constrained. The fiR variable was not constrained and proved quite helpful in many industries, as is indicated by the variable's mexval, shown in the column on the right. In a few sectors, the coefficient turned out negative, so in those sectors the variable is not used.

Sector	fiR Mexval
1. Agriculture	37
2. Petroleum extraction	56
3. Natural gas extraction	41
4. Coal mining	15
5. Other fuels, incl. nuclear	neg
6. Ore and other mining	27
7. Food, beverages, tobacco	10
8. Textiles, apparel, leather	66
9. Wood and wood products	5
10. Paper and printing	1
11. Petroleum refining	4
12. Chemicals	52
13. Pharmaceuticals	24
14. Plastic products	neg
15. Stone, clay and glass products	22
16. Ferrous metals	40
17. Non-ferrous metals	neg
18. Fabricated metal products	neg
19. Machinery	7
20. Computers, office machinery	neg
21. Electrical apparatus	35
22. Radio, television, commo eq.	37
23. Medical, optical and precision instr.	4
24. Automobiles, trucks, buses	12
25. Ships and repair	80
26. Airplanes, rockets and repair	18
27. Railroad equipment and repair	55
28. Recycling	neg
29. Electric, gas and water utilities	43
30. Construction	24
31. Trade	9
32. Hotels and restaurants	50
33. Transport and storage	34
34. Communication	0
35. Finance and insurance	8
36. Real estate	45
37. Equipment rental	2
38. Computing service	0
39. Research and development	13
40. Other business services	0
41. Government, defence, soc ins	59
42. Education	87
43. Health services	44
44 Other social and personal services	78

Personal Consumption Expenditures

The equations for Personal consumption expenditures are all estimated in real terms on a per-capita basis, and by far the most important variable in nearly all of them is wages deflated by the consumption deflator. For some products, additional terms have been added.

Confession, they say, is good for the soul, and we have a confession to make. We thought that a sort of saturation variable could be useful, and we took as the saturation level the consumption of the corresponding product in the USA in 2011, measured in real terms per capita at the Purchasing Price Parity exchange rate. Our variable thus became

sat[i]= 1-(pceR[i][1]/popT[1])/pceRsaturation[i],

where pceR[i][1]/popT[1]) is the lagged value of the dependent variable of the regression equation. Thus, the variable shows how far Russia is from the "saturation" level. We expected a positive sign on this variable, but when we ran the regressions with – as usual – an intercept, we got mostly negative signs. That made us stop and think. Then we saw that the 1 at the beginning of the definition, when multiplied by a constant regression coefficient was just a constant and was absorbed into the constant term of the regression. Our carefully calculated pceRsaturation[i] was, after all, just a constant and was absorbed into the regression coefficient – so our labor in computing it was for naught. The variable that was left, -pceR[i][1]/popT[1]), was just the negative of the lagged value of the dependent variable. It is quite common for the lagged value of the dependent variable to be quite strong with a positive sign in a regression – but of course to be of little or no value for a long-term forecast. We had, in effect, introduced the negative of the lagged value, which, predictably got a strong negative sign, but had nothing really to do with the saturation idea which led us to introduce it. In fact, when we took the pceRsaturation[i] term out of the definition of sat[i], we got exactly the same R^2 and sum of squared residuals as with it. Live and learn.

It is now clear that, if we want to apply the saturation idea, we must use some sort of non-linear regression such as the logistic function

$$C_i(y) = \frac{L_i}{1 + e^{(a_i - b_i y)}}$$

where y is income per-capita, C_i is consumption per-capita of product i, L_i is precisely the saturation level we have already calculated, and a_i and b_i are positive constants to be estimated with non-linear regression. As y increases, the exponent of e in the denominator goes to -∞ and the whole denominator approaches 1.0 from above, so the whole right side rises asymptotically to L_i. G7 has two different methods of non-linear regression, and we may try using one or both of them to estimate a logistic curve. That adventure, however, has yet to be undertaken.

In some equations, money income was used instead of wage income. It is, however, computed from wage income by adding social transfers, property income, business incomes of households, and other income. In many equations, we used the price of the product relative to the PCE deflator. The signs were generally negative – and we kept the variable only if it had a negative sign – but with modest explanatory power. Also the exchange rate (rubles per dollar) divided by the consumer price index was used in a number of equations.

In certain equations we have introduced other, variables. For example, in the equation for Automobiles, a consumer credit variable and the exchange rate variable were strong explainers with the expected sign.

The Productivity.ttl File.

The second column is the rate of change of embodied technical change.
The third column is the rate of depreciation in each bucket of capital.

1	.05	.15	Agriculture
2	.05	.15	Petroleum extraction
3	.00	.15	Natural gas extraction
4	.05	.15	Coal mining
5	.05	.15	Other fuels, incl. nuclear
6	.00	.15	Ore and other mining
7	.05	.15	Food, beverages, tobacco
8	.05	.15	Textiles, apparel, leather
9	.05	.15	Wood and wood products
10	.00	.15	Paper and printing
11	.00	.15	Petroleum refining
12	.05	.15	Chemicals
13	.00	.15	Pharmaceuticals
14	.00	.15	Plastic products
15	.05	.15	Stone, Clay, and Glass products
16	.05	.15	Ferrous metals
17	.07	.15	Non-ferrous metals
18	.00	.15	Fabricated metal products
19	.07	.15	Machinery
20	.00	.15	Computers, office machinery
21	.00	.15	Electrical apparatus
22	.05	.15	Radio, television, communication equipment
23	.00	.15	Medical, optical, and precision instruments
24	.10	.15	Automobiles, highway transport equipment
25	.05	.15	Ships and repair
26	.05	.15	Airplanes, rockets, and repair
27	.00	.15	Railroad equipment and its repair
28	.00	.15	Recycling
29	.00	.15	Electric, gas, and water utilities
30	.05	.15	Construction
31	.05	.15	Trade
32	.07	.15	Hotels and restaurants
33	.00	.15	Transport and storage
34	.07	.15	Communication
35	.07	.15	Finance and insurance
36	.07	.15	Real estate
37	.08	.15	Equipment rental
38	.00	.15	Computing service
39	.00	.15	Research and development
40	.07	.15	Other business services
41	.05	.15	Government, defense, social insurance
42	.00	.15	Education
43	.00	.15	Health services
44	.05	.15	Other social and personal services