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NECESSARY AND SUFFICIENT CONDITIONS FOR FOREIGN TRADE BALANCE STABILIZATION BY MEANS OF DEVALUATION IN UKRAINE

Abstract

This paper defines a **necessary** and **sufficient** conditions of trade balance stabilization in Ukraine that, contrary to well-known Marshall-Lerner and Bickerdike-Robinson-Metzler conditions, is applicable to non-zero trade balance and to any elasticity of export and import. It also presents and analyses quantitative estimations of changes of physical volumes, prices and values of export and import after some devaluation.

For practical purposes the authors received the diapasons of elasticity of exports and imports, in which devaluation makes negative trade balance positive or zero.

Key words:

Trade balance stabilization, devaluation, necessary and sufficient conditions.

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Introduction

All-known conditions of foreign trade balance stabilization by means of devaluation identified and investigated by Alfred Marshall (1923) [6], Abba Lerner (1944) [5], Bickerdike (1920) [1], Metzler (1949) [7], Joan Robinson (1937) [8], R. Dornbusch (1976) [2] etc., are of qualitative character. They do not specify to what extend devalue national currency in order to bring a negative trade balance to zero.

Thus, these conditions are **necessary** for trade balance stabilization. To the best of our knowledge, **sufficient** conditions for achievement of zero trade balance, as a result of devaluation, were not derived.

Moreover, the known **necessary** conditions are valid only if trade balance is initially equal to zero. The Marshall-Lerner condition works with infinite supply elasticity only.

Classical studies of link between supply and demand for exports and imports, on the one hand, and their prices in a general form, on the other, do not allow deduction of sufficient conditions. This can be done only for specific functions. However, quantitative studies of devaluation's influence on foreign trade were carried out only at an empirical level when econometric models of export and import supply and demand were made (D. Warner and M. E. Kreinin (1983) [9], Lal A. K. and Lowinger T. C. (2002) [4]).

Our approach in this paper consists of theoretical studies for particular kind of export and import supply and demand functions.

Most of the contemporary studies do not solve this problem according to classical way. They use different modifications of monetary model of so called dependent economy (J. A. Frenkel and M. L. Mussa (1984) [10]). But in Ukraine interest rate is very high (30–60%) and its link with production level is almost absent.

Besides rate of inflation caused by devaluation usually differs from devaluation rate in transition period after devaluation only. During stationary period these rates are almost equal to each other. This is why real interest rate in stationary period is almost invariable.

These two reasons enabled to give us an opportunity to neglect monetary effect of devaluation and use a simplified approach.

First of all, we derived necessary and sufficient conditions for the most widespread classes of functions – linear and power (linear in variables' logarithms). This analysis is presented in the paper. Such an approach helped us to get following results:

1) We explicitly derived a relationship between export and import parameters like physical volumes, prices and values estimated in domestic and foreign currencies and also exchange rate.

2) We received quantitative estimations of these parameters' variations at certain devaluation for different export and import supply and demand elasticity.

3) We identified a factor for different combinations of elasticity either price or physical volumes that led to the larger changes of the exports and imports values.

4) We determined what elasticity (demand or supply) has stronger influence on change in exports and imports values in the result of devaluation.

5) We deducted **necessary** condition of trade balance stabilization without imposing restrictions concerning **zero balance** of payments and infinite price elasticity of export and import supply, which are required for validity of the Marshall-Lerner condition. Our necessary condition of trade balance stabilization, received for these specific functions, coincides with classical, if trade balance is zero.

6) We deducted the **sufficient** condition of trade balance's stabilization, also without imposing restrictions concerning zero balance of payments and infinite price elasticity of export and import supply. We do mean that if the **sufficient** condition is done, the balance deficit, which was before devaluation, becomes zero or planned proficit.

For practical purposes, we received the diapasons of elasticity of exports and imports, in which devaluation shown negative trade balance in positive or zero.

Usually monetary aspects of the problem are taken into account (dynamic considerations of saving and investment and so on). But in Ukraine the trade balance's dependence from these aspects is less. So, we simply neglect them.

Formulation of the sufficient condition for trade balance stabilization was done as follows:

1. Deduction of functional relationship between parameters of export and import (prices, volumes, values), on the one hand, and exchange rate and price elasticity for supply and demand on the other.

2. Deduction of the necessary condition for trade balance improvement.

3. Identification of the condition for price elasticity of import supply and demand, under which the reduction of imports value, caused by devaluation, is not less than τ_{VMI} level.

4. Estimation of the marginal level for decrease or increase in exports value τ_{VEI}, caused by devaluation, under which trade balance improves at the given level of decrease or increase in the value of import τ_{VMI}.

5. Identification of the condition for price elasticity ratio for export supply and demand, when a reduction in exports value caused by devaluation, is not higher than certain level τ_{VEl} if $\tau_{VEl} < 1$; or its increase is not lower, than τ_{Vlp} if $\tau_{VEl} > 1$. This is what a **sufficient** condition for trade balance stabilization, which results deficit in zero or proficit.

1. A relationship between Export and Import Parameters and Devaluation for Power Functions of Supply and Demand

1.1. Export

Export supply S_E is formed inside the country–exporter, so it depends on export price denominated in national currency P_E:

$$S_E = a(P_E)^b. \quad (1)$$

Export demand D_E is formed on foreign markets and depends on export price in foreign currency Q_E.

The latter corresponds with the price in national currency by the following ratio:

$$Q_E = P_E / r, \quad (2)$$

Where r is an exchange rate of national currency measured as the price of unit of foreign currency in national currency, for example, hryvnya/dollar.

Taking into account formula (2), a relationship between the export demand and the price has the following form:

$$D_E = c(P_E / r)^d. \quad (3)$$

Devaluation of national currency is presented as the level of national currency before devaluation r_0 and index of exchange rate I that in the base period is equal to $I = 1$, and in the current period it increases as:

$$r = r_0 I. \quad (4)$$

It is assumed that foreign markets establish equilibrium between demand for exports and its supply[1]. In this case, it is possible to equate expression (1) and (3) and to identify the export price, at which this equilibrium is established.

The equilibrium export price in national currency is equal to:

$$P_E = (c/a)^{\frac{1}{b-d}} (r_0 I)^{\frac{d}{d-b}}. \quad (5)$$

The equilibrium export price in foreign currency is equal to:

$$Q_E = (c/a)^{\frac{1}{b-d}} (r_0 I)^{\frac{b}{d-b}}. \quad (6)$$

Substituting expression (5) in formula (1), we receive the equilibrium physical volume of exports E:

$$E = S_E = D_E = a(c/a)^{\frac{b}{b-d}} (r_0 I)^{\frac{bd}{d-b}}. \quad (7)$$

The value of exports denominated in national currency is received by multiplication of (5) and (7):

$$V_E^P = a(c/a)^{\frac{1+b}{b-d}} (r_0 I)^{\frac{d(1+b)}{d-b}}. \quad (8)$$

Similarly, we obtain the value of exports in foreign currency:

$$V_E^Q = a(c/a)^{\frac{1+b}{b-d}} (r_0 I)^{\frac{b(1+d)}{d-b}}. \quad (9)$$

1.2. Import

Import demand D^M is formed inside the country–importer, thus it depends on the import price in national currency P_M:

$$D^M = e(P_M)^f. \quad (10)$$

The import price in foreign currency Q_M is linked to the price in national currency P_M as follows:

$$P_M^{\$} = P_M / r, \quad (11)$$

Where r is an exchange rate of national currency measured as the price of unit of foreign currency in national currency, for example, hryvnya/dollar.

[1] Non-equilibrium situation will be examined in other paper.

Relationship between import supply S^M and import price Q_M is established on the foreign markets and described by such function:

$$S^M = g(P_M^{\$})^h = g(P_M / r)^h. \quad (12)$$

It is possible to equate (10) and (12) under equilibrium condition between import demand and supply on the basis of this equation to identify the price of imports, at which this equilibrium is established:

$$P_M = (g / e)^{\frac{1}{f-h}} (r_0 I)^{\frac{h}{h-f}}. \quad (13)$$

The equilibrium import price in foreign currency is equal to:

$$P_M^{\$} = (g / e)^{\frac{1}{f-h}} (r_0 I)^{\frac{f}{h-f}}. \quad (14)$$

The equilibrium physical volume of imports is equal to:

$$D^M = S^M = M = e(g / e)^{\frac{f}{f-h}} (r_0 I)^{\frac{fh}{h-f}}. \quad (15)$$

The value of imports in national currency is equal to:

$$V_M = MP_M = e(g / e)^{\frac{1+f}{f-h}} (r_0 I)^{\frac{h(1+f)}{h-f}}. \quad (16)$$

The value of imports in foreign currency is equal to:

$$V_M^{\$} = MP_M^{\$} = e(g / e)^{\frac{1+f}{f-h}} (r_0 I)^{\frac{f(1+h)}{h-f}}. \quad (17)$$

Thus, proposed approach enables to find and study a dependence of export and import values in form of functions. It was hardly possible with classic approach.

Each of functions (5–17) has four parameters *a, b, c, d*, where *b* – price elasticity of exports' supply, *d* – elasticity of export demand, *a, c* – scale parameters[2].

We can reduce their number twice, if analyze a rate of these functions growth relatively to their values before devaluation (that is, at $I = 1$). It is necessary to normalize functions of export price, export volume and value of exports relatively their equilibrium values in base period (at point $I = 1$). From (5) follows that relative price of export in national currency is equal to:

$$P_E^O = (c / a)^{\frac{1}{b-d}} (r_0)^{\frac{d}{d-b}}. \quad (18)$$

The equation (5) and (18) indicate a rate of growth of exports price in national currency relatively to its value before devaluation:

[2] An elasticity of final parameter regarding its factor in situation, when dependency described by extent function, is equal to the extend parameter at the same factor.

$$\xi_E^P = P(I)/P(1) = I^{\frac{d}{d-b}}. \quad (19)$$

A rate of growth of exports price in foreign currency is following:

$$\xi_e^{\$} = Q_E/Q_E(1) = I^{\frac{b}{d-b}}. \quad (20)$$

A normalized function for the equilibrium physical volume of exports is following:

$$\varepsilon = I^{\frac{bd}{d-b}}. \quad (21)$$

A normalized function for the value of exports in national currency is following:

$$\varepsilon v = I^{\frac{d(1+b)}{d-b}}. \quad (22)$$

A normalized function for the value of exports in foreign currency is following:

$$\varepsilon v^{\$} = I^{\frac{b(1+d)}{d-b}}. \quad (23)$$

Thus, the elasticity of export price in national currency with respect to index of devaluation is equal to $d/(d-b)$. The correspondent elasticity of export price in foreign currency is equal to $b/(d-b)$, of physical volume of export is $bd(d-b)$, of export value in national currency is $d(1+b)/(d-b)$, and of exports value in foreign currency is $b(1+d)/(d-b)$. Similar method can be used for calculation of a value for imports.

These results coincide with formulas (8.5–10) by T. Durnburg (1989) [3].

Here we consider foreign trade of usual representative goods. These goods have a positive slope of supply curve (the curve that displays relationship between supply of exports or imports and price), and a negative slope of demand curve for exports or imports. In other words, price elasticity of exports supply *a, b* and imports supply *c* are positive ($a > 0$, $b > 0$, $c > 0$), and of exports and imports demand *d* and *f* are negative.

Similarly, for **linear functions of exports and imports supply and demand** $S_E = a + bP_E$; $D_E = c + dQ_E$; $D_M = e + fP_M$; $S_M = g + hQ_M$. have the following relationships:

The export price in national currency is:

$$\tau_{PE} = \frac{I(1+\beta)}{I+\beta}. \quad (24)$$

The export price in foreign currency is:

$$\tau_{QE} = \frac{1+\beta}{I+\beta}. \tag{25}$$

The physical volume of exports is:

$$\tau_E = \left[I\left(1-L_D^E\right)+-L_D^E+\beta\right]/(I+\beta). \tag{26}$$

The value of exports in national currency is:

$$\tau_{VE}^P = I(1+\beta)\left[I(1-L_D^E)+\beta(1-L_S^E)\right]/(I+\beta)^2. \tag{27}$$

The value of exports in foreign currency is:

$$\tau_{VE}^Q = \frac{(1+\beta)\left[I(1-L_D^E)+\beta(1-L_D^E)\right]}{(I+\beta)^2}. \tag{28}$$

The price of import in national currency is:

$$\tau_{PM} = \frac{I(1+\delta)}{\delta I+1}. \tag{29}$$

The price of import in foreign currency is:

$$\tau_{QM} = \frac{1+\delta}{\delta I+1}. \tag{30}$$

The physical volume of imports is:

$$\tau_M = \frac{\delta I(1-L_S)-L_D^M+1}{\delta I+1}. \tag{31}$$

The value of imports in national currency is:

$$\tau_{VM}^P = I(1+\delta)\left[\delta I\left(1-L_S^M\right)-L_D+1\right]/(\delta I+1)^2. \tag{32}$$

The value of imports in foreign currency is:

$$\tau_{VM}^P = (1+\delta)\left[\delta I\left(1-L_S^M\right)-L_D+1\right]/(\delta I+1)^2. \tag{33}$$

Here $L_D^E, L_S^E, L_D^M, L_S^M$ are elasticity of import and export demand and supply at $I = 1$;

$$\alpha = a/c;\ \ \beta = -d/b r_0 = -L_D^E/L_S^E;\ \gamma = g/e;\ \delta = -f r_0/h = -L_D^M/L_S^M;$$

$$L_D^E = \frac{\beta(\alpha-1)}{1+\alpha\beta};\ L_S^E = \frac{1-\alpha}{1+\alpha\beta};\ L_D^M = \frac{\delta(\gamma-1)}{1+\gamma\delta};\ L_S^M = \frac{1-\gamma}{1+\gamma\delta}.$$

2. Necessary Condition for Improvement of Trade Balance

The trade balance in foreign currency is equal to:

$$B^Q = V_E^Q - V_M^Q, \tag{34}$$

And in national currency it is equal to:

$$B^P = V_E^P - V_M^P. \tag{35}$$

A behavior of trade balance depends not only on dynamics of exports and imports values in relative terms, but also on their absolute values. That was a reason why Bickerdike-Robinson-Metzler condition remained unsolved for price elasticity of supply and demand in general form. It is solvable only for the case of zero trade balance.

Indeed, let us introduce the necessary condition for improvement of trade balance[3] as $B^Q > B_0^Q$ that transforms into:

$$V_M^Q\left(\pi^Q - 1\right) > V_{M0}^Q\left(\pi_0^Q - 1\right), \tag{36}$$

Where $\pi^Q = V_E^Q / V_M^Q$,, index «0» refers to the period before devaluation, and the period after devaluation is not marked.

If before devaluation the trade was balanced $\left(\pi_0^Q = 1\right)$, taking into account the normalized equations (9, 23) and (17), condition (36) would be[4]:

$$\tau_{VE}^Q > \tau_{VM}^Q \text{ або } \frac{f(1+h)}{h-f} < \frac{b(1+d)}{d-b}, \tag{37}$$

For zero balance, dynamics of trade balance during devaluation is determined only by difference between growth **rates** of exports and imports values, i. e. by the behavior of their **normalized** functions and isn't determined by their absolute values. If exports value grows or declines slower than imports value, trade balance is improved. In the opposite case it worsens.

Three simple conclusions[5] follow from (37):

1. As $f < 0$, from the right part of inequality follows that the trade balance is improved with devaluation if foreign demand for our export is elastic $\left(|d| > 1\right)$.

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[3] Hereinafter we examine trade balance in foreign currency. Its analysis for national currency is similar.
[4] This condition can be found from (8.21) and (8.16) from T. Durnburg (1989).
[5] First two of them coincide with classical.

2. If terms of trade are improved after devaluation ($bh < df$), condition (37) is valid. Thus, the trade balance is improved both in national and foreign currencies.

3. If $bh > df$ this condition is executed only for **very low levels of export and import demand elasticity**.

It is impossible to make more certain conclusions. Thus, if $|d| < 1$ and $bh > df$ it is necessary to solve inequality (37) for specific values of elasticity. It is also clear that trade balance can be improved not only under improvement of the terms of trade as it is affirmed in classical theory (Lindert, 1992), but also under many situations when terms of trade deteriorates.

3. Condition of Devaluation Decrease in Imports Value

Let $\tau^{Q}_{VMгр}$ be a marginal level of import value growth rate[6], and we impose a condition that $\tau^{Q}_{VM} \geq \tau^{Q}_{VMгр}$. Solution of this inequality in respect to f gives a condition of import value decrease by no less, than $(1-\tau^{Q}_{VMгр})100\%$:

$$f \geq f_{гр} = \frac{h \lg \tau_{VMгр} / \lg I}{1 + h + \lg \tau_{VMгр} / \lg I}. \qquad (38)$$

For example, if $\tau_{VMгр}$ = 0.95 and I = 1.2 (it means that in case of a 20% devaluation of national currency, imports value should decrease by more, than 5%), the following is true:

$$f_{гр} = \frac{-0{,}28h}{0{,}72 + h}. \qquad (39)$$

As a result, at low imports supply elasticity (h < 0,4) the decrease in import value due to devaluation cannot exceed 95%, but only for goods with demand elasticity above or equal to 0.1 (in absolute terms).

Substituting different τ_{VMI} (column 1 Table 1) and h at I = 1.2 in formula (39), we get marginal values of demand elasticity f_I (column 3), which ensures reduction rate of imports value not less pre-specified τ_{VMI} at a 20% devaluation.

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[6] It is to remind that imports' value in foreign currency decreases always with devaluation, e. g. $\tau^{Q}_{VM} < 1$.

If import demand elasticity exceeds these marginal values in absolute terms or if supply elasticity is lower, the speed of imports value reduction will be longer, than pre-specified, and trade balance will improve.

4. Determination of Marginal Level of Decrease or Increase in Export Value τ_{VEl} that Ensures Improvement of Trade Balance at Pre-Specified Level of Import Value τ_{VMl} Reduction Caused by Devaluation

Taking into account (9, 23) and (17), out of (36) we get:

$$\tau_{VE}^{Q} > \tau_{VEap}^{Q} = \frac{\tau_{VM}^{Q} - 1}{\pi_0^{Q}} + 1. \qquad (40)$$

This condition means that for implementation of condition (36) the rate of reduction of export value can exceed the rate of reduction of import value only by certain value $1 - \frac{1}{\pi_0^{Q}}$ depending on π_0^{Q}. More negative trade balance in the base period (i. e., the smaller is π_0^{Q}) means less requirements regarding dynamics of exports value, and vice versa.

As can be seen, logic of deduction of conditions for trade balance stabilization introduced in abstract at the beginning of this article, follows from inequality (40).

Determination of τ_{VEl} is made on the basis of inequality (40) (column 5 Table 1).

Table 1.

Marginal values of changes of expenses for import and export proceeds in foreign currency which provide stabilization of trade balance at *I* = 1.2, and appropriate to these values marginal elasticity of export and import supply and demand

Marginal level of reduction of expenses for import	Bottom borders of elasticity of		The prevailing factor of reduction of imports: physical volume (M) or the currency price (Q_M)	Marginal level of increase or reduction of export proceeds	Top borders of elasticity of		Change of terms of trade	Change of physical volume of export	Change of export price	Elasticity of		Index of devaluation, sufficient for trade balance stabilization for h, f_f, d and b	Change of terms of trade	Change of physical volume of export	Change of export price
	imports supply	imports demand			exports demand	exports supply				exports demand	exports supply				
$\tau^{\$}_{VMfp}$	h	f_{fp}	M or QM	$\tau^{\$}_{VEfp}$	d	b_{fp}	U	τ_E		d	b	I_g	U	τ_E	
0.98	**0.2**	**–0.02**	**Q_M**	1.09	–1.54	9.86	0.87	27.49	–14.59	–1.1	5	1.73	0.63	63.69	–36.11
0.98	1	–0.06	=	1.09	–1.6	5.62	0.88	25.49	–13.23	–1.2	5	1.34	0.71	45.46	–26.82
0.98	2	–0.08	M	1.09	–2	1.75	0.92	18.57	–8.16	–1.5	5	1.24	0.83	27.81	–15.09
0.98	5	–0.09	M	1.09	**–3**	**0.91**	**0.96**	**13.63**	**–4.17**	–1.7	5	1.18	0.87	23.50	–11.68
0.98	10	–0.10	M	1.09	**–5**	**0.66**	**0.98**	**11.23**	**–2.11**	–1.7	1	1.33	0.79	19.63	–10.01
0.95	**0.2**	**–0.06**	**Q_M**	1.06	–1.33	11.79	0.88	24.35	–15.11	–1.1	5	1.34	0.78	29.89	–21.16
0.95	**0.4**	**–0.10**	**Q_M**	1.06	–1.4	4.01	0.89	20.83	–12.64	–1.3	5	1.22	0.84	23.28	–14.87
0.95	1	–0.16	=	1.06	–1.6	1.56	0.95	15.51	–8.62	–1.5	5	1.17	0.87	20.03	–11.46

5. Derivation of Conditions for Necessary and Sufficient Decrease or Increase in Export Value

Substituting τ_{VE}^{Q}, determined in (40), in inequality (23), we receive two solutions:

$$\begin{aligned} &\text{a) } b > \frac{d \lg \tau_{VE\,zp}^{Q} / \lg I}{d + 1 + \lg \tau_{VE\,zp}^{Q} / \lg I} \text{ under } (|d| > 1), \\ &\text{b) } b < \frac{d \lg \tau_{VE\,zp}^{Q} / \lg I}{d + 1 + \lg \tau_{VE\,zp}^{Q} / \lg I} \text{ under } |d| < 1. \end{aligned} \qquad (41)$$

Substituting in (41) different values I (for example, I = 1.2), τ_{VEI} $^{\tau_{VEI}}$ (column 5 Table 1) and d (column 6), we receive required values b (column 7).

In case of «a» export value increases under any value b, thus trade balance improves always.

In case of «b» for export supply elasticity b higher (41), rate of decrease in exports value will be higher, than imports value, thus trade balance deteriorates; for export supply elasticity b lower (41), rate of decrease in exports value will be lower, thus allowing better trade balance improvement.

Thus, for import of goods with supply elasticity, not lower than for example 0.4 and with demand elasticity in absolute terms not higher than 0.1 decrease in imports value due to devaluation at I = 1.2 cannot exceed 5%. If primary imports coverage by exports before devaluation (at I = 1) was not lower, than 0.9, exports value should fall more, than by 5.56% in order to achieve trade balance improvement. In its turn, that requires that export demand elasticity in absolute terms above or equal to 0.2, and the supply elasticity does not exceed 0.129. (Other values are possible (for example, –0.5 and 0.84; –0.6 and 2.17), but all of them should satisfy condition (41))[7].

Thus, inequalities (38, 40, and 41) form the **necessary** condition of trade balance stabilization.

The sufficient condition could be derived assuming that the purpose of devaluation will be achieved when initially negative trade balance becomes at least zero after devaluation. A condition **of sufficient** devaluation for initially negative trade balance is represented by inequality:

[7] Table 1 does not consist this data.

$$B^Q \geq 0. \quad (42)$$

Its solution results in next inequality:

$$\tau_{VE}^Q > \tau_{VE\,zp}^Q = \tau_{VM}^Q / \pi_0^Q. \quad (43)$$

Thus, **the sufficient** condition differs from the **necessary** one only if $\tau_{VE\,I}^Q$ is calculated from inequality (43) instead of (36), which is substituted in the same inequality (43).

As can be seen from Table 1, achievement of zero trade balance for $I = 1.2$ and $\pi_0^Q = 0{,}95$ for example for the sixth pair of goods requires that exports value grow by 5.56%. It happens when export demand elasticity is not lower than 1.33 in absolute terms, and supply elasticity is not lower than 11.8. If export demand elasticity is negligibly higher ($d = -1.4$) in absolute terms, supply elasticity can be only 4.0, and in the case if $d = -1.6$, then $b = 1.56$.

But if export demand elasticity is lower than 1.33 in absolute terms, it is impossible to stabilize trade balance for $\pi_0^Q = 0{,}95$ by the 20% devaluation. In this case higher devaluation is necessary.

If import has other characteristics (like higher (in absolute terms) demand elasticity or lower supply elasticity), they produce higher rates of import value reduction caused by devaluation. That cuts requirements towards behavior of export value. At $\tau_{VM}^{\$} = 0{,}9$ exports value may not grow, at 0.85 it can even decrease, although by no more, than 5.6%, and at 0.8 exports value can drop by 11.1%.

But if import demand is fairly inelastic (–0.02 in the case of supply elasticity not below 0.2 or –0.1 in the case of supply elasticity not below 10), the rate of imports value reduction, caused by devaluation, will not exceed 2%. In this case, the growth of export value, caused by devaluation, cannot be lower than 8.9%. It will be achieved, if export demand elasticity is higher, than 1.54 in absolute terms. Then the supply elasticity has not to be lower than 10 and it is rather unlikely for majority of goods. At $d = -2$ export supply elasticity could be reduced to 1.75, and at $d = -5$ up to 0.7. Higher export demand elasticity (in absolute terms) means lower country losses during its attempt to achieve the zero trade balance. Hence, at $d = -1.54$ terms of trade worsen by 13%, export price in foreign currency falls by 14.6% forcing increase in physical volume of exports by 27.5%. But at $d = -3$ terms of trade worsen only by 4%, the price falls by 4%, and the physical volume has to grow by only on 13.6%.

If the initial trade balance deficit constitutes 20% of imports, i. e. $\pi_0^Q = 0{,}8$, V and devaluation is 20%, the zero trade balance can be achieved only for very elastic goods that rare exports and imports have. For example, if imports has low demand elasticity $(|f| < 0{,}1)$, reduction of imports value will not

exceed 2% at I =1.2. In this case, achievement of zero balance requires that growth of exports value does not fall below 22.5%, which is possible only if export demand elasticity is not lower than 2.4 in absolute terms, and supply elasticity is 9.3. That is unrealistic for the most of goods. Other combinations are possible: –3 and 3.8; –5 and 1.9; –7 and 1.6, but they are also unlikely.

If import demand elasticity is higher in absolute terms (from –0.1 to –0.26) and reduction of imports value reaches 5%, the best combination of exports elasticity is (–3 and 2.7). Even if imports value drops by 15%, exports elasticity have to be (–1.7 and 1.54) in the best case. Only if import value reduces by 19% export demand elasticity can range between –1.1 to –1.5 in absolute terms and the supply elasticity between 2.4 and 0.24.

In case when devaluation starts at zero trade balance and it aimed to achieve a certain level of proficit $\pi_1^Q > 1$, condition (36) turns into inequality

$$\tau_{VE}^Q > \pi_1^Q \tau_{VM}^Q, \tag{44}$$

Which is similar to condition (38) if $\pi_1^Q = 1/\pi_0^Q$, i. e. Table 1 for $\pi_0^Q = 0{,}9$ is equivalent to Table 1 for $\pi_1^Q = 1{,}1$.

If exact elasticity is known, it is possible to determine the level of devaluation necessary and sufficient for achievement of zero trade balance. The following formula is received by solving equation (43):

$$I_\partial = \left(\pi_0^Q\right)^{\frac{(h-f)(d-b)}{f(1+h)(d-b)-b(h-f)(1+d)}}. \tag{45}$$

It is clear from Table 1, at $\pi_0^Q = 0{,}9$, increase in export value by 8.9%, which ensures zero trade balance is possible under several conditions. In particular, it requires that if export demand elasticity stays not higher than 1.1 in absolute terms and if supply elasticity is low ($b = 0.5$), devaluation should not be less of 110%, and if supply elasticity is quite unrealistically high ($b = 5$), devaluation stay above 73%. Only at $d = -1.5$ and $b = 5$ the required devaluation rate reaches 24%. The level of necessary devaluation weakly depends on supply elasticity and increase of $|d|$ up to 1.7 allows reducing necessary devaluation by 2.5 times.

If trade balance requires only a 5.56% increase in exports value, it can be reached by 34% devaluation even for goods with export demand elasticity –1.1 and supply elasticity 5. If demand elasticity reaches –2, supply elasticity can be even lower than 1.

If import is so elastic that its values decreases by more than 10% at of 20% devaluation, so for achievement of zero trade balance it is enough that exports value decrease, but slower than imports value. Thus, if import demand elasticity is negligibly lower, than 1 in absolute terms: between –0.7 and –0.9 (in this case supply elasticity stays between 0.3 and 5.0), export demand elasticity

in absolute terms can be both low as well as high. In the latter case, the zero trade balance is achieved with small devaluation at any supply elasticity (e.g., at $d = -1.2$; b = 0.5 I_S= 12%, and at $b = 5$ I_S= 11%). If d is close to zero, supply elasticity can be the same (e. g., at $d = -0.2$ and $b = 0.2$ $I_S = 1.24$, and at $b = 0.3$ already $I_S = 1.29$).

The most significant devaluation is necessary for the goods with high supply elasticity and low demand elasticity, i. e. if terms of trade worsen to the large extent. So, at $f = d = -0.2$, $h = b = 2$ none devaluation stabilizes trade balance, if before devaluation is $\pi_0^Q = 0{,}9$. Even at $h = b = 0.2$, the necessary devaluation is 69%. At high supply elasticity value I_S barely correlates with its changes, stronger with changes of export demand elasticity, and to the greatest extent with import demand elasticity. The value I_S ranges in actually possible devaluation $1 < I_S < 1{,}5$ at $f = -0.2$ only if $d = -0.6$, $h = 1$, $b = 0.1$ or $h = 0.4$, $b = 0.6$, and at $f = -0.4$ already, if $d = -0.2$, $h = 1$, $b = 0.13$ or $h = 0.4$, $b = 0.24$.

For a situation when devaluation starts at zero trade balance, the level of necessary devaluation is calculated with the following formula:

$$I_S = \left(\pi_1^Q\right)^{\frac{b(1+d)(h-f)-f(d-b)(1+h)}{(d-b)(h-f)}}. \qquad (46)$$

Results for linear functions of exports and imports supply and demand are almost the same. Formulas (37-46) turn into following:

$$\frac{\left(L_S^E - L_D^E\right)\left[L_D^E L_S^E(1-I) + IL_S^E - L_D^E\right]}{\left(IL_S^E - L_D^E\right)} > \frac{\left(L_S^M - L_D^M\right)\left[L_S^M - L_D^M L_S^M(1-I) - IL_D^M\right]}{\left(L_S^M - IL_D^M\right)^2}, \qquad (37')$$

Where L_S^E, L_S^M are supply elasticity for exports and imports respectively; L_D^E, L_D^M are demand elasticity for exports and imports.

$$L_D^M > L_{Dзв}^M = \frac{B \pm \sqrt{C}}{2A}, \qquad (38')$$

$$B = 2\tau_{VMвр} I L_S^M - (1-I)\left(L_S^M\right)^2 - (1+I)L_S^M;$$

Where $C = \left(L_S^M\right)^2\left[L_S^M(1-I)^2\left(L_S^M - 4\tau_{VMвр} - 2\right) + I(I-4)\right]$;

$$A = \tau_{VMвр} I^2 - (1-I)L_S^M - I.$$

$$L_D^E < L_{Dзв}^E = \frac{D \pm \sqrt{D^2 - 4FE}}{2F}, \qquad (41')$$

$$D = 1 + L_S^E(1-I) + I - 2\tau I;$$

Where $E = I\left(L_S^E\right)^2(1-\tau I);$

$$F = 1 - L_S^E(1-I) - \tau.$$

$$GI^4 + HI^3 + KI^2 + NI + S = 0, \qquad (46')$$

$$G = L_D^M L_S^E\left[SL_D^M\left(1-L_D^E\right) + L_S^E\left(L_S^M - 1\right)\right];$$

$$H = SL_D^M\left[2L_S^M L_S^E\left(1-L_D^E\right) + L_D^M L_D^E\left(L_S^E - 1\right)\right] - L_S^E\left[L_S^M L_S^E\left(1 - L_D^M - 2L_D^M L_D^E\left(L_S^M - 1\right)\right)\right];$$

Where $K = SL_S^M\left[L_S^M L_S^E\left(1-L_D^E\right) - 2L_D^M L_D^E\left(L_S^E - 1\right)\right] + L_D^E\left[L_D^M L_D^E\left(L_S^M - 1\right) - 2L_S^M L_S^E\left(1 - L_D^M\right)\right];$

$$N = L_D^E L_S^M\left[SL_S^M\left(L_S^E - 1\right) + L_D^E\left(1 - L_D^M\right)\right];$$

$$S = \pi_0^Q\left(L_S^E - L_D^E\right)/\left(L_S^M - L_D^M\right).$$

A calculation of Table 1 from formula (37'-46') has given approximately the same results, as for power functions.

Thus, if relationship between supply and demand for exports and imports, on one hand, and their prices on the other are described by functions, close to linear or power ones, formulas (37–46) or (37'–46') allows defining necessary and sufficient conditions of foreign trade balance stabilization by means of devaluation. Table 2 provides foreign trade experts with idea when necessary and sufficient conditions are satisfied in the space of supply and demand elasticity of exports and imports.

Certainly, it is necessary to carry out similar studies for other cases of supply and demand functions for exports and imports.

Table 2.

Growth Rates of Export and Import Prices τ Caused by Devaluation at I = 1.3, in percentage

$\beta = \delta$	0.1	0.2	0.4	0.8	1	1.5	2	4	6	10
τ_{PE}	2.4	4.5	7.8	12.4	14	17	19	23	25	27
$-\tau_{QE}$	21	20	17	13.6	12.3	10	8.4	5.1	3.7	2.4
τ_{PM}	27	24	21	15.7	14	11	9.1	5.4	3.8	2.4
$-\tau_{QM}$	2.4	4.3	7.2	11	12.3	14.6	16	18.9	20.1	21

6. Behavior of Foreign Trade Parameters in the Case of Devaluation

Directions of changes of foreign trade parameters had been already determined in classical studies, but quantitative estimations have not been produced until now. However, these estimations are very important for practical purposes.

Prices. The prices and terms of trade do not depend only on levels of elasticity, but rather on their ratios $\beta = -\frac{d}{b}$ and $\delta = -\frac{f}{h}$. Noticeable growth of export price in national currency and reduction of import price in foreign currency (approximately 15–20% of the devaluation level (i. e. a 30% devaluation of national currency corresponds to 4.5–6% growth)) achieves at values β and δ not lower, than 0.3–0.4. A change of prices reaches 80–85% of devaluation level at $\beta = \delta > 6$, and virtually does not change much afterwards. Significant decline of export price in foreign currency and increase of import price in national currency starts at $\beta = \delta \le 5-4$ and remains constantly high at $\beta = \delta < 0{,}2-0{,}15$ (Table 2).

The essential increase in **physical volume of exports** starts from low elasticity of demand and supply 0.3–0.4, and quickly accelerates together with increase in any of elasticity. At $b = -d = 0.7$ and $I = 1.3$[8] it grows by 9.6%, at $b = -d = 1$ by 14%, at the 1.5 level by 22%, at the level of 2 by 30%, and at the level of 3 by 48%.

Exports value in foreign currency decreases, if $|d| < 1$, and increases, if $|d| > 1$. Essential changes start only at rather high elasticity rates (Table 3).

But because of significant reduction in prices, foreign-currency export efficiency drops to a large extent. Thus, if before devaluation exports' profitability constituted 20%, after devaluation would fall to 5% at $d = -3$ and $b = 3$.

At inelastic demand ($|d| < 1$) exports value in foreign currency decreases with rise of export supply elasticity and reduction of export demand elasticity (in absolute terms) (Table 3).

An export value in national currency grows along with devaluation very quickly. Higher export demand elasticity always increases growth of exports value, and higher export supply elasticity causes the growth of value only if $|d| > 1$; if $|d| < 1$, higher export supply elasticity reduces it (Table 3).

[8] Hereinafter, all figures are for 30% devaluation ($I = 1.3$), if other is not specified.

Table 3.

Growth rates of export values in foreign and national currency provoked by devaluation, I = 1.3, in percentage

$d = f$	–0.2	–0.2	–0.2	–0.2	–0.7	–0.7	–0.7	–0.7	–1.5	–1.5	–1.5	–1.5	–3	–3	–3	–3
$b = h$	0.3	0.6	1.5	3	0.3	0.6	1.5	3	0.3	0.6	1.5	3	0.3	0.6	1.5	3
$\tau_{v_E^Q}$	–12	–15	–17	–18	–2.3	–3.6	–5.2	–6.2	2.2	3.8	6.8	9.1	4.9	9.1	19	30
$\tau_{v_E^P}$	15	11	8.0	6.8	27	25	23	22	33	35	39	42	36	42	55	69
$\tau_{v_M^P}$	13	17	20	22	2.4	3.7	5.5	6.6	–2.2	–3.7	–6.3	–8.4	–4.7	–8.4	–16	–23
$\tau_{v_M^Q}$	–12.8	–10	–7.4	–6.3	–21	–20	–19	–18	–25	–26	–28	–30	–27	–30	–35	–41

A physical volume of imports starts significantly to decrease at low rate of elasticity supply and demand 0.3–0.4. At $f = -0.4$, $h = 0.3$ the rate of its reduction is equal to 4.4%, at $h = -f = 1.5$ is 18%, and at $h = -f = 3$ is 33%.

The rate of reduction of import value in foreign currency is significant, when import demand elasticity (in absolute terms) is higher, and import supply elasticity is lower (Table 3). In this case the most favorable situation for importer is when goods have high import demand elasticity and low import supply elasticity. Then reduction of **import value in foreign currency** caused by devaluation to the large extent, due to fall in price against the background of minimal loss in **physical volume** of import.

Since goods with high value added are usually more elastic, than resources, devaluation changes not only physical volumes of export and import, but also their commodity structure. Namely, it reduces a share of highly elastic goods in imports and increases this share in export.

A relative dynamics of exports and imports values caused by devaluation depends only on elasticity, while parameters of exports and imports *a, c, e, g* change just the scale of these curves. Therefore, it is possible to study the influence of elasticity on trade balance. For this purpose, we combine all exports value's curves with different elasticity at $I = 1$ in one point and all imports value curves in other. These points are arranged in such a way that trade balance is negative and is equal to 10% of import value. It is achieved by selection of factors *a, c, e, g*. Thus, for these factors before devaluation (at $I = 1$) accept $V_{E0}^P = 1{,}4556$, $V_{M0}^P = 1{,}6174$, $TB_0^P = -0{,}1618$, $V_{E0}^Q = 0{,}2911$, , $V_{M0}^Q = 0{,}3235$, $TB_0^Q = -0{,}0324$.

Now have a look to pairs of goods that have identical demand ($d = f$) and supply ($b = h$) elasticity (Table 4).

Table 4.

Growth rates of merchandise trade parameters with various elasticity

$b=h$	$d=f$	τ_{PE}	τ_{QE}	τ_E	V_E^P	V_E^Q	$\tau_{v_M^P}$	$\tau_{v_M^Q}$	τ_M	V_M^P	V_M^Q	B^P	B^Q	U
0.3	–0.1	6.8	–17.9	1.99	1.59	0.244	21.7	–6.3	–1.9	–1.93	0.297	–0.346	–0.053	–12
0.3	–0.2	11.1	–14.6	3.2	1.67	0.257	17.0	–10	–1.9	1.83	0.282	–0.166	–0.0256	–5
0.3	–0.4	16.2	–10.6	4.6	1.77	0.272	11.9	–14	–4.4	1.73	0.266	0.039	0.006	3.8
0.3	–1	22.4	–5.9	6.2	1.89	0.2911	6.2	–18	–5.9	1.62	0.249	0.275	0.042	15
0.3	–3	26.9	–2.4	7.4	1.98	0.305	2.4	–21	–6.9	1.54	0.237	0.443	0.068	24
1.5	–0.4	5.7	–18.7	8.6	1.67	0.257	23.0	–5.4	–8.0	1.83	0.282	–0.160	0.025	–14
1.5	–2	16.2	–10.6	25	2.12	0.272	11.9	–14	–20	–1.45	0.222	–0.672	0.103	3.8

At low elasticity $(b=h=0{,}3; d=f=-0{,}2)$, $a=12{,}69$, $c=4$, $e=1$, $g=1{,}2$ a 30% devaluation of national currency results in minor improvement of trade balance in foreign currency (by 21%), but does not make it positive. At the same time the trade balance in national currency worsens by 2.6%. These changes occur mostly due to significant price changes, when export price in foreign currency decreases faster, than import price (14.6% against 10%) and export price in national currency grows slower, than of import (11% and 17%). Thus, terms of trade worsen by 5% (inequality (19) for these goods looks like $bh = 0{,}09 > df = 0{,}04$)[9]. Physical volumes of both exports and imports change insignificantly (by ±3% respectively), but it is enough to «overweight» the difference in growth rates of prices.

At even lower demand elasticity $(d=f=-0.1)$, the difference between rates of export and import price reduction becomes greater (–17.9% vs. –6.3%), and rates of changes of physical volumes falls by to ±2%. As a result, exports value in foreign currency decreases by 16.2%, and imports value only by 8.2%. Thus, the terms of trade worsen to 12%, trade balance in foreign currency to –0.053, and in national it worsens to –0.346.

At higher demand elasticity $(d=f=-0.4)$, the trade balance becomes positive reaching 0.06 in foreign currency and 0.04 in national currency. It is achieved because the rates of reduction of export price in foreign currency slowed down to 10.6%, and import price growth rate accelerated to 13.9%. As a result, export value in foreign currency decreased only by 6.5%, whereas imports value – by 17.7%. Consequently, terms of trade improved by 3.8% $(bh = 0.09 < df = 0.16)$..

Further increase in demand elasticity strengthens these trends. At $d=f=-1$ exports value in foreign currency does not fall because price reduction is balanced with respective increase in physical volume, and imports value decreases by 23.1%; the balance reaches 0.042. In national currency the export

[9] According classical theory the balance for these goods should be worsen.

price grows by 22.4%, the import price – by 6.2%, exports value – by 30% and imports value remains constant. As a result, the trade balance in national currency reaches 0.27. The term of trade improves by 15% ($df = 1$).

At even more elastic demand, exports value in foreign currency does not decrease; moreover, it increases, while the rate of export price reduction becomes lower than the growth rate of its physical volume. Reduction rates of import price in foreign currency, import volume, and, hence, imports values almost do not increase (at $d = f = -2$ they equal to 20.4; 6.6 and 25.7% respectively; and at $d = f = -3$ they are 21.2; 6.9 and 26.7%). The trade balance in foreign currency for such goods increases to 0.061 ($d = -2$) and 0.068 ($d = -3$) respectively. Terms of trade improve by 21.4% and 24.0%. The balance in national currency reaches 0.4 and 0.44 respectively due to large increase in export value (by 34.5% and 36.4%) and decrease in import value by 3.4% and 4.7%. The former is due to faster price increase (by 25.6% and 26.9%), and the former is due to fast decrease in physical volume of import (by 6.6% and 6.9%) despite to insignificant increase in prices (by 3.5% and 2.4%).

Higher supply elasticity slows down improvements in trade balance at inelastic demand ($|d| = |f| < 1$), and accelerates it if demand is elastic ($|d| = |f| > 1$). So, at $I = 1.3$ and at $b = h = 1{,}5$ and $d = f = -0{,}4$ the trade balance still remains negative (trade terms worsen by 14% ($bh = 2.25 > df = 0.16$)), and at $d = f = -2$ it achieves 0.1 and 0.67 in foreign and national currencies respectively (trade terms improves by 3.8% ($bh = 2.25 < 4$)).

Slower improvement of trade balance **in foreign currency** is caused by higher reduction of exports value (due to faster price reduction) and by lower reduction of imports value. Thus, foreign-currency efficiency of both exports and imports decreases with increase in supply elasticity.

A rapid improvement of trade balance in foreign currency for goods of demand elasticity is a result of increase in exports value and decrease of imports value (at $d = f = -2$ to 0.326 and 0.222 respectively). But both increase in exports value and improvement of trade balance are inefficient: the former is due to higher increase in export volume despite accelerating price decrease; the latter is due to higher reduction in volume despite slower price fall.

Summarizing, we can state that the most acceptable options of trade balance stabilization are when export price in foreign currency reduces as insignificantly as possible. In this case, an extensive component of trade balance improvement is minimal (see Table 1 in bold). Such options are possible, if elasticity of import demand is low, and elasticity of export demand is high. The higher is supply elasticity of imports, the higher can be its demand elasticity. In export situation is opposite: the higher is demand elasticity, the lower can be supply elasticity.

In imports the most acceptable option of trade balance stabilization is when price in foreign currency falls to the largest extent. It is applicable for goods of low supply elasticity and high demand elasticity.

The behavior of trade balance **in national currency** is similar, but factors differ: at $d = f = -0{,}4$ increase in export price is considerably lower (5.7% vs. 16.2%), and in import price is higher (23% vs. 12%). So, national-currency efficiency also decreases.

At $d = f = -2$ exports value grows faster, and imports value grows slower, but here also prices increase slower, than physical volumes.

Thus, though necessary conditions of trade balance stabilization in foreign and in national currencies are similar (see (26)), factors influencing their changes are different and require separate analysis.

Conclusion

As it follows from obtained results, **the necessary** condition of trade balance stabilization is valid for very wide range of supply and demand elasticity of exports and imports. It is valid not only in case of the terms of trade improvement, but also in cases, when terms of trade deteriorates.

However, the **sufficient** condition is valid for a very limited range of goods. If before devaluation the trade deficit constitutes more than 20% of imports value, then at low import demand elasticity (from –0.1 to –0.25) and almost any elasticity of its supply exports must be very elastic (for instance, demand elasticity $d = -2.0$ and supply elasticity $b = 2.7$). Requirements to exports' elasticity could be reduced (for example, to $d = -1.1 \div -1.5$, and, $b = 2.4 \div 0.4$ respectively), but only at the expense of respective increase in import demand elasticity (in nominal terms).

If initially the trade deficit was equal to 10% of imports value, then requirements to elasticity of export would be significantly lower. In case of low elasticity of imports, export demand elasticity could be from $d = -1.4 \div -2.0$ with supply elasticity from $b = 4.0 \div 0.4$. If elasticity of imports is high, export demand elasticity could range from $d = -0.1 \div -0.3$ with supply elasticity from $b = 0.25 \div 3.6$.

We found that quantitative result for linear and power functions are similar, thus there is hope that obtained results have a general character.

So our results are an instrument for National bank for exact planning of necessary devaluation. If our exports and imports have such elasticity, that **the sufficient** condition of trade balance stabilization is valid for certain devaluation level, then National bank can devaluate national currency to this level and be

sure, that the balance deficit, which was before devaluation, becomes zero or planned proficit.

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