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"A SIMULATION OF STRUCTURAL CHANGES IN THE ECONOMY OF THE REGIONS AFFECTED BY THE CHERNOBYL CATASTROPHE"

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YASTREMSKY A.I. A SIMULATION OF STRUCTURAL CHANGES IN THE ECONOMY OF THE REGIONS AFFECTED BY THE CHORNOBYL CATASTROPHE

1°. INTRODUCTION. Ecological conditions over vast areas of Ukraine, Belarus and Russia has changed fundamentally after the Chornobyl catastrophe. The change has affected that not only man's environment but also the economy has changed too. The simulation of structural changes in the economy of these regions is the subject of this article. Since May 1986 a great amount of practical and scientific research has been done seeking to understand the consequences of the catastrophe and studying the current situation has been done. Vast data bases have been assembled containing information about nuclei contents in soil, plants, water, air, birds, and animals, and their impact on human health and on the product quality.

The question that has been examined thus far is: "What happened?" The question that must be posed and examined now is: "What must be done?" I have participated in several projects dealing with Chornobyl problems, have visited Chornobyl many times, have met with many scientists and experts, mostly radiobiologists and specialists in the field of atomic energy. I have tried to examine Chornobyl as an economist. Thefocus of myresearch is the economic problem of Chornobyl disaster and the management of the economy under new oonditions. I would like to focus myattention not only on ready recipes, but also on the management of the economy under contamination without which practical questions practical questions cannot be answered.

The main idea of this article is that:"If man's environment has changed after the Chornobyl catastrophe then the economic structure of this regions must be changed".

Example: Milk production. Milk is the main source of inner contamination of man. Milk purification process requires enormous amount of funds and resources. The question then arises: "Maybe we should not produce milk perhaps we should produce another kind of products?" To do this to we need to discover new methods of cultivating and to supply new technologies. But are there methods and technologies available now? Yes. Ukrainian, Bielorussian and Russian scientists have proposed a series of new innovations which offer an opportunity to produce pure products in contaminated regions. Let us consider some of them.

2°. NEW TECHNOLOGIES.

There currently are technologies based on growing of specific plants, that do not accumulate nuclides. Among there are: Jerusalem Artichoke and potatoes.

There also are technologies based on long trophic dispersion chains. One of examples of trophic chains is bfollowing:

soil -- plant -- plant fodders -- animals -- nourishment from cattle-breeding -- humans.

It is important that the final product be free of nuclides.

Let us now consider the Conversion Factor (CF) notion. CF is quotient of the contamination concentration of the n-th link product to the one of the (n-1)-th link. If CF is greater than one than we have cumulative chain, the opposite case gives us - the dispersion chain.

Example of cumulative chains:

"Water -- week-duck -- duck -- duck egg".

Example of dispersion chains:

Soil -- cereals -- vegetable fodder - animal -- animal fodder -- fur-bearing animals breeding -- fur".

Another production technologies of intermediate contaminated products which can be used in special clean products output technologies are seed- growing, young animals husbandry in contaminated region for future cattle-breeding in clean regions and others. There likewise are products that cannot be consumed by humans. For example, oily flax growing for varnish and paint production used in airspace industry.

An additional there are products for scientific research. For example, contaminated cucumber seed used in radiobiological laboratories

Finely, there are plants that absorb nuclides.It is known that some plants (for example, Crucifiers) can accumulate the radioactive nuclides. These plants are grown in order to clean the territory and then the harvest is localized in a special way. This method of territory cleaning was proposed by D.Grodzinsky [1].

Thus as evident we have many old and new technologies which can be used in contaminated regions as well as in noncontaminated. Which of them is better or the best? It depends on region and farm specificity. I have formulated special model combining all technologies and giving the opportunity to answer the questions about optimal specialization of farms under contamination. Accordingly to the National Ukrainian Chornobyl Program nearly six thousand collective farm require respecialization.

3°. ASSUMPTIONS.

The following are main assumptions and characteristics of a model.

1) The model has a market character: some resources can be bought and products can be sold. However, we take into account that the State Administration can distribute some resources;

2) There is a special meter service giving an opportunity to define contamination concentration in the soil, and in the intermediate and final products;

3) The price of the contaminated product is determinedby the market, that is, the contamination concentration influences the product utility and product price.

Typical price dependencies on contamination concentration, including nuclides concentration, are shown in figures 1-3.

All function shown in figures 1-3 are either nonincreasing or decreasing. The simplest dependency shown in fig. 2 is mostly used.

More exotic dependencies are shown in fig. 4 and 5. As noted earlier the price increase in product which is used in radiobiological laboratories for scientific researches. But the market potential for such product is very limited.

4) The next important assumption is that an economist can obtain information about product quality that has contamination concentration, and is produced with a definite technology and resources containing certain nuclide concentration. In other words, we assume that we know the price of the j-th product, produced with 1,...m resources with $\nu_1,\ldots,\nu_m$ contamination concentration;

5) A formulated model maximizes profit or income subject to contamination concentration resources constraints;

6) Input data for a model are:

-areas of plots;

-contamination concentrations in the soil;

-conversion factor;

-resources specific input for -plant-growing and cattle-breeding production;

-crop productivity.

8) Crop-productivity and conversion factors are random. Hence models are the stochastic programming problem. Model maximizes expectation of profit or income and can maximize expected utility of profit or income.

9) Our model (models) takes into account the polluters as stocks. There are many models describing the interaction between the economy and the environment. The Leontiev-Ford model [5] is especial well-known. It balances useful and pollution productions. A great number of optimization models are known, in which the profit needs to be maximized subject to pollution production constraints. Such models contain the following typical constraints:

$$\sum_j f_{qj} x_j \le F_q \quad \forall q, \tag{1}$$

where

f_{qj} is the q-th specific pollution production by the j-th technology;

F_q is the q-th ultimate pollution production;

x_j is the j-th technology intensity.

We would like to accentuate that F_q are flows, because they characterize the ultimate pollution production per where

A is a specific resource input matrix;

b is the resources vector;

p is the production prices vector.

A fundamental question arises: "How would the enterprise management be changed, if resources are contaminated?"

Using assumption 2 and 3 let us denote by $p_j(\nu_1,\ldots,\nu_m)$ the price of the j-th product, produced with resources 1,...,m with $\nu_1,\ldots,\nu_m$ contamination concentrations. Thus the model can be formulated as such:

$$\sum_j p_j(\nu_1,\ldots,\nu_m)x_j \dashrightarrow \max,$$
$$\sum_j a_{ij}x_j \le b_i \ \forall \ , \qquad (3)$$
$$x_j \ge 0.$$

There is no essential difference between the models (2) and (3). Both are linear programming problems. But the price differences, naturally, will have an impact on the production structure.

A more difficult model appears when there are resources containing different contamination concentrations. For example, soils or fodders for animals with different contamination concentrations. In this case the model appears as such:

$$\sum_j \sum_{\nu_1=1}^{\mu_1} \cdots \sum_{\nu_m=1}^{\mu_m} p_j(\nu_1,\ldots,\nu_m)x_j(\nu_1,\ldots,\nu_m) \dashrightarrow \max,$$

unit of time. The situation after the catastrophe is essentially different: the environment already contains the polluters (the long living radioactive nuclides). So, we need an ecological-economical model in which the polluters come out as stocks.

So, our model takes into account the polluters (the long living radioactive nuclides) as stocks.

10) Technical details: A model of agriculture under contamination is two-step stochastic linear programming problem by J.Dantzig and A.Madansky [2]. It contains nearly two hundred variables. It is a very difficult mathematical problem. To solve it we used special numerical methods, stochastic quazigradient methods by Yu.Ermoliev. Special Software РОСЬ (ukrainian term - Ризику Оптимізація Стохастична) was designed at the Economic Cybernetics Department of Kiev Shevchenko University and at the Economics Department of the University of "Kiev-Mohyla Academy". Software РОСЬ is oriented on social-economic applications under Risk.

Let us consider some of formulated models.

4^{o}. ENTERPRISE MODEL UNDER CONTAMINATION

Let us consider one of the simple variants of the Production Planning by L.Kantorovich [4]:

$$(p,x) \longrightarrow \max, \quad Ax \le b, \quad x \ge 0, \qquad (2)$$

$$\sum_j \sum_{\nu_1=1}^{\mu_1} \cdots \sum_{\nu_{i-1}=1}^{\mu_{i-1}} \sum_{\nu_{i+1}=1}^{\mu_{i+1}} \cdots \sum_{\nu_m=1}^{\mu_m} a_{ij}\, x_j(\nu_1,\ldots,\nu_m) \le$$

$$\le b_i^{\nu_i} \qquad (\nu_i = 1,\ldots,\mu_i;\ \forall\, i) \qquad (4)$$

$$x_j(\nu_1,\ldots,\nu_m) \ge 0,$$

where

b_i is the i-th resources with ν_i contamination level;

μ_i is a number of the i-th resources contamination level;

$x_j(\nu_1,\ldots,\nu_m)$ is the j-th production using 1,...,m resources with $\nu_1,\ldots,\nu_m$ contamination levels.

Model (4) has a considerably greater dimension in comparison with model (3). But there may be a lot of special cases when the dimension greatly decreases. One of such cases will be studied later.

5°. THE FARM MODEL UNDER CONTAMINATION

The farm produces plant-growing and cattle-breeding products. Soil is the main source of contamination. The plant-growing production can be used as a fodder for cattle-breeding. The plant-growing production has a different contamination level depending on its specificity and the soil on which it is grown. Hence, it influences plant-growing production prices. Cattle-breeding production prices depend on $(j_1,\ldots,j_I)$ combination, where j_l is the j-th fodder grown on the i-th soil.

the model can be formulated as follows:

$$\sum_i \sum_j p_{ij} z_{ij} +$$
$$+ \sum_k \sum_{j_1=1}^{J} \cdots \sum_{j_I=1}^{J} p_k(j_1,\dots,j_I) y_k(j_1,\dots,j_I) \longrightarrow \max,$$

$$a_{ij} x_{ij} \geq z_{ij} +$$
$$+ \sum_k \sum_{j_1=1}^{J} \cdots \sum_{j_{i-1}=1}^{J} \sum_{j_{i+1}=1}^{J} \cdots \sum_{j_I=1}^{J} b_{ik} \times$$
$$\times y_k(j_1,\dots,j_{i-1},j,j_{i+1},\dots,j_I) \quad \forall\, i,j; \qquad (5)$$
$$\sum_i x_{ij} \leq S_j \;\forall\, j;$$
$$(x,y) \in \mathfrak{D},$$

where

i is the plant-growing production index ($i \in I$);

k is the cattle-breeding production index ($k \in K$);

j is the plot index ($j \in J$);

S_j is the j-th plot area;

a_{ij} is the crop capacity on the j-th plot;

p_{ij} is the price of the i-th crop grown on the j-th plot;

b_{ik} is the i-th crop specific input for the k-th cattle-breeding production;

$p_k(j_1,\dots,j_I)$ is the price of the k-th cattle-breeding production received from $1,\dots,I$ fodders grown on $j_1,\dots,j_I$ plots;

x_{ij} is the plot area under the i-th crop;

z_{ij} is the sale of i-th crop grown on the j-th plot;

$y_k(j,\dots,j)$ is the k-th cattle-breeding production received from $1,\dots,I$ fodders grown on $j_1,\dots,j_I$ plots;

$\mathfrak{D}$ is a set of couples satisfying the resources constraints.

6°. SPECIAL CASE. DISPERSION TROPHIC CHAINS

Model (5) describes the correlation between trophic chains of two kinds: "soil-plants" and "soil-plant-animal". More long and detailed chains are possible. For example, "soil - plant - vegetable fodder - animal fodder - fur-bearing animals breeding - fur".

It is obvious that long dispersion chains can give ecological clean output.

Let us consider the special case of model (5). Let all trophic chains "soil - plant - animal" shown in figure 1 be dispersion chains.

The soil contamination concentration is about ten timesgreater than feasible ones. The CF is 0.25. So, contamination concentration in plants grown on these soils is 2.75 times greater than feasible one. Hence $p_{ij} = 0$. But in cattle-breeding production contamination concentration has only 0.625 of feasible levels. So, in this case $p_k(j_1,\dots,j_I)$ = = p_k, where p_k is the "usual" market price. It is not difficult to prove that model (5) transforms into the following one:

$$\sum_k p_k y_k \dashrightarrow \max; \sum_j a_{ij}\ x_{ij} \ge \sum_k b_{ik} y_k\ \forall\ i;$$

$$\sum_i x_{ij} \le S_j\ \forall\ j;\ (x,y) \in \mathfrak{D}, \qquad (6)$$

where

y_k is the k-th cattle-breeding production.

The dimension of problem (6) is several time less than the one of problem (5).

Models (5) and (6) were given as examples of "soil - plant - animal" chains; an optimal combination. It is not difficult to expand these models to chains of different lengths and combinations.

6°. STOCHASTIC ANALOG OF OPTIMAL MANAGEMENT MODEL UNDER CONTAMINATION

A number of agriculture parameters, in particular, the crop capacity, are random variables. Besides that, a specificity of management under contamination is important additional source of Uncertainty and Risk, in particular, conversion processes of nuclides per links of trophic chains. Hence (see fig. 1-5) agriculture production prices are variables too. Let us formulate a stochastic analog of one of the considered models, just of model (6).

Let $p_k(\omega)$ are the random cattle-breeding production prices. $a_{ij}(\omega)$ are random crop-capacities, ω is the elementary event of some probability space $(\Omega, \mathcal{A}, P)$.

We shall assume that the decision about plot distribution is made before observation of crop-capacities, production quality (contamination concentration), and production prices. But the decision about cattle-breeding can be adapted to crop-capacity and to the realizations of production prices. Hence by [3] terminology we have a following decision-observation chain:

decision (plant-growing plan: x) - observation (crop-capacity, prices: ω) - decision (cattle-breeding plan: y).

Stochastic analog of model (6) is a two step stochastic linear programming problem:

$$F(x) = E \sum_k p_k(\omega) y_k(x,\omega) \longrightarrow \max;$$

$$\sum_i x_{ij} \le S_j \ \forall \ j; \qquad (7)$$

$$y(x,\omega) = \{y_k(x,\omega)\}_k = \arg\max\{ \sum_k p_k(\omega) y_k :$$

$$: \sum_j a_{ij}(\omega) x_{ij} \ge \sum_k b_{ik}(\omega) y_k \ \forall \ i; \ (x,y) \in \mathfrak{D}\};$$

$$x \in Q = \{x: \forall \ \omega \ \exists \ y \supset (x,y) \in \mathfrak{D}\}.$$

Model (7) maximized expected income. Expected utility profit or income can be maximized also according to the Expected Utility Theory by J.von Neumann, O.Morgenstern and L.Savage [6], [7], that is

$$F(x) = EU(\sum_k p_k(\omega) y_k(x,\omega)),$$

where $U(\cdot)$ utility function by J.von Neumann, O.Morgenstern

[6] is defined by income.

Numerical and quality analyses of problem (7) were carried out using software РОСЬ (Ризику Оптимізація Стохастична (Ukrainian)) designed at the Economic Cybernetics Department of Kiev Shevchenko University and the Economics Department of the University of "Kiev-Mohyla Academy". It based on stochastic quazigradient methods [3] and special post optimal methods of model under Risk and Uncertainty [8].

7°. RESULTS OF CALCULATIONS

I have made calculations on nearly 20 collective farms of the Ivankov region (which is near Chornobyl). I have assumed that soil is main source of contamination, and have taken into account only cesium-137. The main results are as follows.

1) The nontraditional technologies in this region (technical crops, in particular, oily flax growing for varnish and paints, seed-growing, raising hot house vegetables on clean soil, Jerusalem artichoke, fur-bearing animals breeding) are advancing for the forefront;

2) potatoes and cereals save its positions, because they don't accumulate nuclides and can be used for technical spirit production. Cereals can be used as fodders for cattle-breeding in enough long dispersion chains;

3) majority of collective farms mustn't produce milk accordingly our calculations;

4) production of meat using directly for man's consumption decreases very much. But meat production saves as animal fodder for fur-bearing animals breeding;

5) beside approximation to optimal plan we calculate marginal prices of resources and products by theory of stochastic marginal prices for models under Risk [8]. Marginal prices give a possibility of operative testing new technologies effectiveness.

8°. EXTENSIONS AND CONCLUSIONS

Formulated models which have been analyzed are the embodiment of basic principles and characterize the general idea: The need for management to adapt to work under combination. This idea requiresconstruction a new model which can be named ecologic economic model where contamination comes out as stocks. This models can be developed and specified in several ways.

1) In taking into account social and demography factors;

2) In simulation contaminated and clean regions relations;

3) In taking into account specificity economy (inflation, transition period peculiarities);

4) In synthesizing contaminated region model and national economy models synthesis;

5) In formulation of models with pollution in the form of

stocks and flows.

Although this research is not final, following conclusions can be proposed(?).

1) In the majority of cases contaminated regions **can and must work.** Useful production is possible even within to 30 kilometerzone. The contaminated regions **can and must** be transformed from resource-devourers into active and effective economy units;

2) The rehabilitation contaminated regions depends on the adoption of non-standard decisions, non-traditional technologies and new vision of the problem in particular;

3) Introduction of an effective management system in the contamination regions and discarding(?) certain prejudices. In shortly(?) the economy must use and produce only clean ingredients. Contaminated product can be marketed. Intermediate contaminated products use will not do any harm. It is important that people should consume only clean final products and be able to live in a clean environment;

4) Finally, because the Earth is a Zone, the proposed approach has a global character.

I am gratefull professor B.Dmitrishin (USA) and professor Yu. Ermoliev (Ukraine) for their help and attention to my article.

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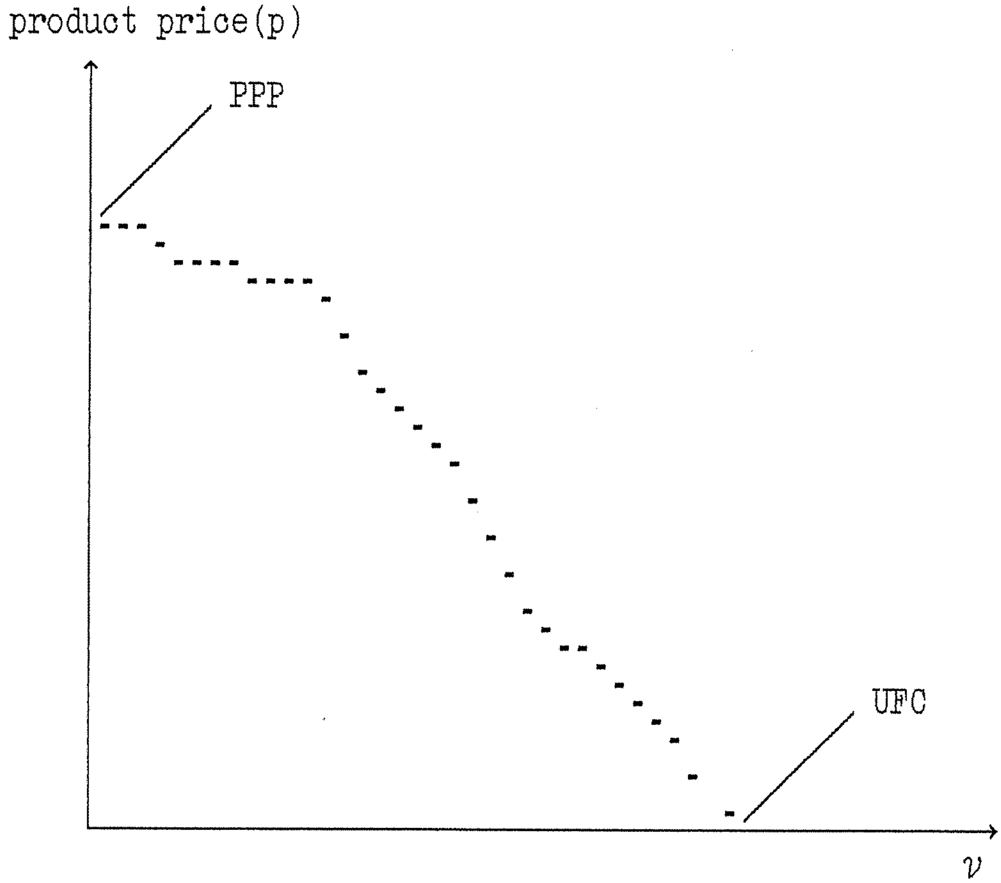


Figure 1 (PPP - pure product price, UFC - ultimate feasible concentration).

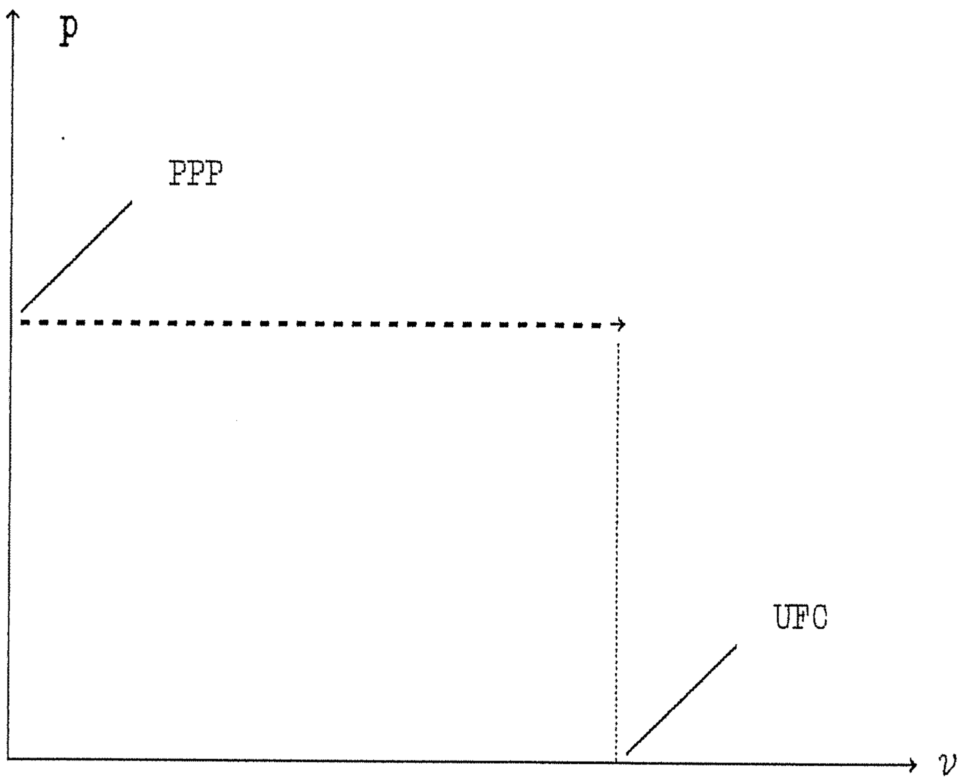
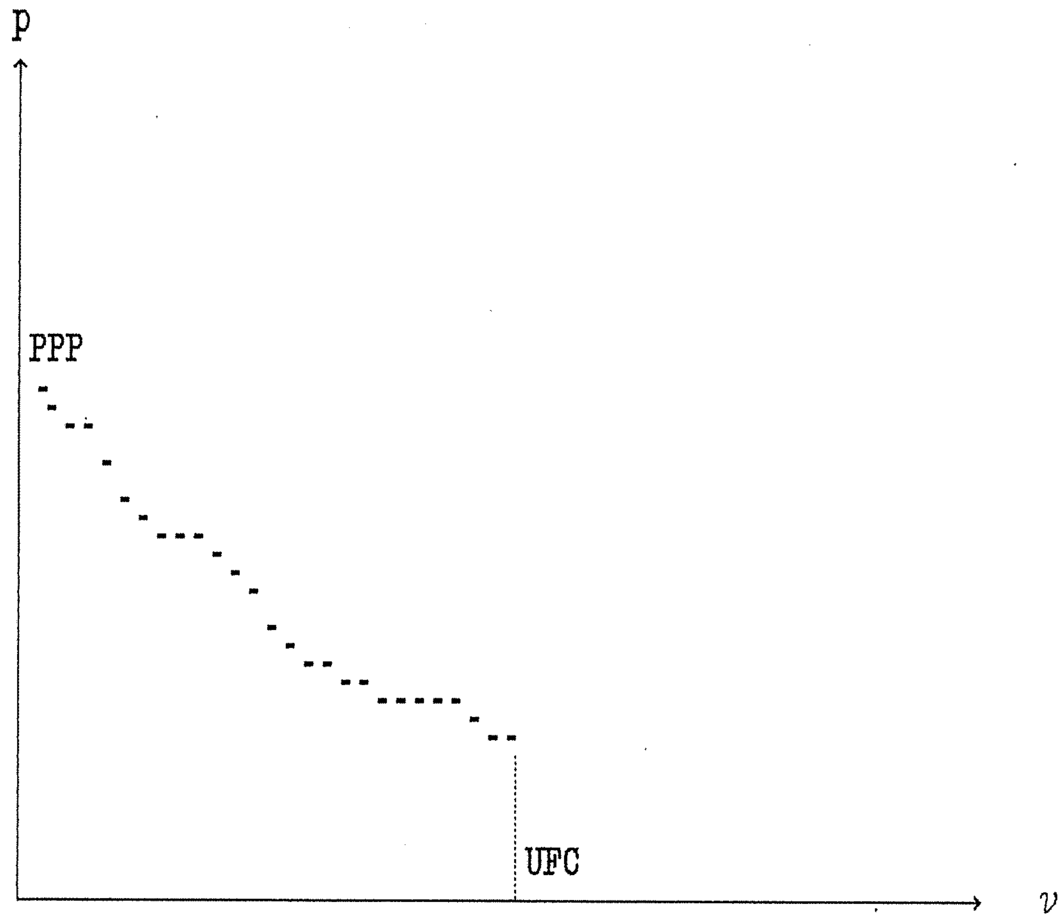


Figure 2



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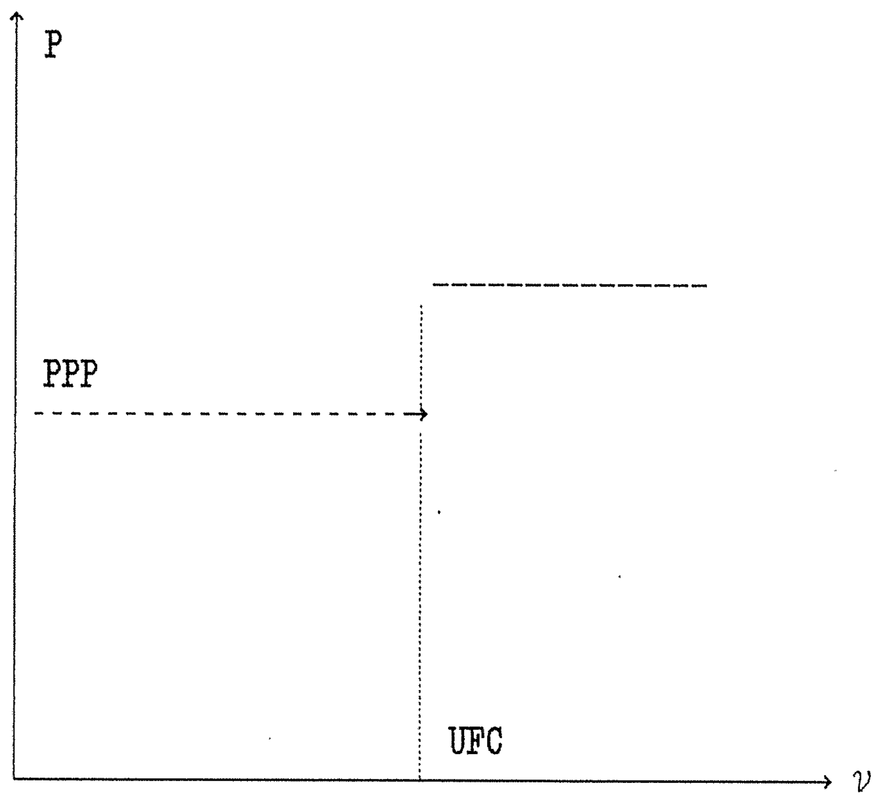

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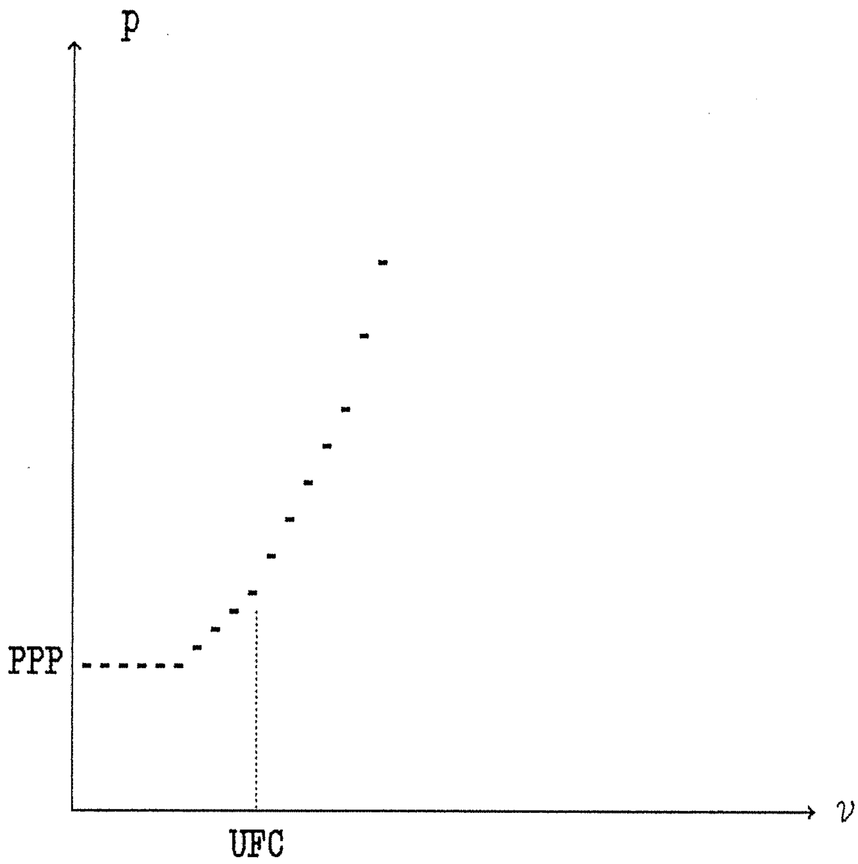

Figure 5.