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Towards development in landlocked economies

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Abstract

This paper sets out with three objectives. Firstly, it reviews the theoretical and empirical literature on the relationship between the condition of being a landlocked developing country and the degree of economic development attained, measured by per capita income. Secondly, it contributes to the theoretical literature on the subject by suggesting a new possible reason why landlocked countries may have a low level of development: the greater relative uncertainty to which landlockedness gives rise may have a negative effect on investment incentives in the tradable sector of such countries. Thirdly, it suggests that development policy for landlocked countries should focus on investment in transport infrastructure and on regional integration.

I. Introduction

International trade barriers can have a substantial effect on the income level and economic growth rate of a small country. Obstacles to international trade often include tariffs, quotas and phytosanitary restrictions, among others, but transport costs can also be a major obstacle to international trade. Although the literature analysing the impact of transport costs on development is of long standing, the specific case of the high transport costs faced by landlocked developing countries (United Nations, 2002) has been largely overlooked in both the theoretical and the empirical literature.

The empirical evidence gathered in a number of studies indicates that landlocked **developing**[1] countries are usually among the world's poorest: according to MacKellar, Wörz and Wörgötter (2000), nine of the world's twenty poorest countries are landlocked, while the United Nations (2002) states that sixteen[2] of the thirty one landlocked developing countries in the world are classified among the "least developed". According to the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States, the thirty one landlocked developing countries are: Afghanistan, Armenia,

[1] This study excludes landlocked countries with higher per capita income levels, namely Andorra, Austria, Belarus, the Czech Republic, the Holy See, Slovakia, Hungary, Liechtenstein, Luxembourg, San Marino and Switzerland.

[2] These sixteen countries are Afghanistan, Bhutan, Lao People's Democratic Republic and Nepal in Eurasia, and Burkina Faso, Burundi, Central African Republic, Chad, Ethiopia, Lesotho, Malawi, Mali, Niger, Rwanda, Uganda and Zambia in Africa.

Azerbaijan, Bhutan, Kazakhstan, Kyrgyzstan, Lao People'sDemocratic Republic, the Former Yugoslav Republic of Macedonia,Moldova, Mongolia, Nepal, Tajikistan, Turkmenistan and Uzbekistan in Eurasia; Botswana, Burkina Faso, Burundi, the Central African Republic, Chad, Ethiopia, Lesotho, Malawi, Mali, Niger, Rwanda, Swaziland, Uganda, Zambia and Zimbabwe in Africa; and Bolivia and Paraguay in South America.

A number of previous studies have sought to establish the possible relationships between geographical conditions (such as distance to and from markets) and economic development. Within this literature (Gallup, Sachs and Mellinger, 1998; Radelet and Sachs, 1998; Venables and Limão, 2001 and 2002; and MacKellar, Wörz and Wörgötter, 2000), only a few studies have sought to test empirically whether landlocked countries as such suffer in terms of development, and if so, to understand the theoretical reasons behind this. The present study pursues this effort in three ways. Firstly, it reviews the theoretical and empirical literature on the subject with a view to synthesizing what is known about the implications that a landlocked situation has for a country's development level. Secondly, it contributes to the debate about the possible conceptual relationships involved, analysing the way in which incentives to invest in export industries oriented towards non-neighbouring countries might be affected by the greater relative uncertainty created by a country's landlocked position. Thirdly, it suggests general economic policy measures organized along two major lines, the aim being to minimize the impact that being landlocked has on a country's development[3].

The study is organized as follows. Section II shows how being landlocked may affect a country's economic development. Section II.I summarizes the arguments used to show how the higher transport costs faced by landlocked countries may adversely affect them. Possible effects of this kind on development are considered to include lower investment in the landlocked country and lower trade. Section II.II presents a theoretical model in which incentives to invest in a landlocked country in the current period are reduced by higher relative uncertainty about future transport costs, something that affects future international trade and economic development. Section III proposes two major lines of economic policy designed to reduce the impact of a landlocked situation. Section III.I discusses the importance of designing and implementing an appropriate transport policy that is properly financed and takes account of the "coordination failures" which may arise in multinational infrastructure projects. Section III.II sets forth the advantages of regional integration as a second axis in official strategies to minimize the problems faced by landlocked countries. Section IV concludes.

[3] This paper, however, does not suggest or seek to prove that a landlocked situation is the only or the main cause of the low level of development attained by landlocked countries located outside Europe. The empirical testing of this hypothesis is the logical next step to carry out in future work and a prerequisite before designing economic policy measures suiting the specific circumstances of each country.

II. Economic development in landlocked countries: the empirical evidence

This section will show that the problem faced by landlocked developing countries has two aspects. Firstly, they face higher total transport costs for their exports and imports, not only because they depend on land and air transport, which are more expensive than sea transport, but also because their trade necessarily has to cross additional borders, which can be very costly. Secondly, the total **future** transport costs faced by landlocked countries **are more uncertain** than those of coastal countries, since they are vulnerable to negative shocks not only in the landlocked country itself but also in the transit country. Both higher transport costs today and uncertainty about these costs in the future can adversely affect the country's development[4] level.

1. Total transport costs in landlocked countries

1.1 Empirical evidence

Most landlocked developing countries combine all the conditions necessary for having high transport costs:

[4] We concentrate on per capita income as a proxy for the level of development because there is a strong correlation between a country's per capita gross domestic product (GDP) and other indicators of development, such as literacy rates, etc.

- they are remote from the major consumer markets where they sell their exports,
- they depend on land and air transport (usually more expensive than sea transport), and
- their infrastructure is inadequate for their needs, and they do not have in place an appropriate legal and institutional framework, capable of fostering foreign trade.

In order to measure the transport costs of developing countries' international trade, the literature often compares between countries the ratio of *cif* (cost, insurance, freight) to *fob* (free on board) values of imports. This measure has some major shortcomings when it comes to comparing among countries: firstly, the transport costs of a country are greatly affected by the type of products it trades; secondly, these data are affected by serious measurement problems (Radelet and Sachs, 1998) and often have to be estimated. Despite this, the *cif/fob* ratio is often used as a measure, as it can be easily calculated from widely available data.

Leaving aside measurement errors and differences in trade composition, this ratio has different values in each country for a variety of reasons. Firstly, countries located at a greater **distance** from their export markets normally face higher transport costs. Secondly, freight using **different forms of transport** generally has different costs. For example, it is cheaper to send goods by sea than by land, so that countries whose commerce involves a higher proportion of land transportation usually have higher costs, and the more changes in the type of transport that are required (e.g., trans-shipment from ship to lorry or train, or vice-versa), the greater the cost. In their econometric study of the determinants of transport costs, Venables and Limão (2001) estimate that increasing journey distance by 1,000 kilometres *at sea* adds US$ 190 to transport costs, while adding the same distance *on land* costs an additional US$ 1,380. Thus, land transportation is 7.3 times as expensive as sea transportation. Additionally, those countries that have a more extensive and better **transport infrastructure** (particularly port infrastructure), supplemented by an **appropriate legal and institutional framework**, tend to have lower costs in this area.

Using the *cif/fob* ratio, Venables and Limão (2001) find that median transport costs in landlocked countries are 46% higher than the median for coastal countries. In Latin America, as table 1 shows, using *cif/fob* ratios reveals that the transport costs of Bolivia and Paraguay are significantly higher than those of Mercosur trading partners with access to the sea.

Thus, taking the average for the 1998-2002 period, table 1 shows that the transport costs of Bolivia as measured by the *cif/fob* ratio were significantly higher than those of Mercosur coastal countries and the United States. The data for Paraguay needs to be treated with caution, as they come from another source and are for a single year, but they too seem to indicate that transport costs were above those of the Mercosur coastal countries and the United States.

Landlocked countries also face the direct costs of crossing the national borders of transit countries, such as time losses and bureaucratic requirements. This means that the trade of landlocked countries has to incur the cost of crossing at least one **additional** border. A number of empirical studies, using different specifications of the "gravity model" (Head, 2003), have sought to estimate the relationship between factors such as distance or the existence of borders and trade flows. Using gravity models, studies such as McCallum (1995) and Anderson and Van Wincoop (2001) found that national borders reduce trade among countries significantly in relation to what the level of trade would have been in the absence of borders.

Table 1
CIF/FOB RATIOS FOR TOTAL IMPORTS, AVERAGE 1998-2002

Country	1998-2002 average (except Paraguay, 2000 only)
Argentina	1.0599
Bolivia	1.1297
Brazil	1.0500
Chile	1.0832
Paraguay[a]	1.0992
Uruguay[b]	1.0509
Mercosur coastal countries	1.0610
United States	1.0341

Source: ECLAC, on the basis of data from IMF *International Financial Statistics*, except Paraguay and Uruguay.

[a] Based on Latin American Integration Association (LAIA) data published in *International Trade and Transport Profiles of Latin American Countries*, ECLAC (2000, p.269).

[b] ECLAC, on the basis of official figures.

Lack of investment in infrastructure increases a country's transport costs. Using shipping data and the *cif/fob* ratio, Venables and Limão (2001) offer a numerical indication of the importance of infrastructure as a determinant of these costs. They calculate that inadequate infrastructure investment is responsible for as much as 40% of predictable transport costs in countries with access to the sea, and for up to 60% in landlocked countries.

The data yielded by cif/fob ratios allowed Venables and Limão (2001) to estimate that improvements to infrastructure in landlocked countries (without improvements in transit countries) which brought it up to the level of the upper twenty-fifth percentile among landlocked countries would reduce the transport cost differential with respect to coastal countries from 46% to 34%. Improving the infrastructure of transit countries (without improving that of landlocked countries) would reduce the transport cost differential to 43%. If the improvements were made in both the landlocked country and the transit country, the cost differential would be 31%. For any country, according to the cif/fob ratio data, a deterioration in infrastructure from the median to the seventy-fifth percentile would raise costs by an amount equivalent to an extra 2,016 kilometres of distance.[5]

1.2 Transport costs and terms of trade

Landlockedness can be thought of as a factor that permanently raises a country's import prices and lowers its export prices (net of transport costs) **in the current period**[6] (MacKellar, Wörz and Wörgötter, 2000). An important question is to what extent the international trade of a landlocked country is reduced by the higher transport costs resulting from this condition. Although the empirical literature has not yet clarified this point, there have been some initial efforts in this direction. For example, Venables and Limão (2001) estimate the elasticity of trade flows with respect to transport costs, finding values in the range (-2, -3.5). Taking a value of –3, the authors calculate that a doubling of transport costs in relation to the median for these costs reduces the volume of a country's international trade by 45%.

5 The authors obtained similar results using shipping data instead of *cif/fob* ratios.

6 Given that landlocked developing countries are not usually price setters in their export markets, they cannot pass on their higher transport costs (in relation to their competitors') to the purchasers of their products. Consequently, the price "charged" by exporters in landlocked countries is lower, as they themselves absorb this transport cost differential.

The poorer terms of trade faced by landlocked countries in relation to coastal ones could also have a negative effect on development by reducing the rate of investment in the former. This, it is argued, could then reduce the economic growth rate.

Gallup, Sachs and Mellinger (1998) and MacKellar, Wörz and Wörgötter (2000) suggest that landlocked countries have lower output growth rates mainly because of the negative effect of landlockedness on the volume of international trade. If there are "learning by doing" externalities, so that comparative advantage is endogenous, the reduction in trade that results from being landlocked may keep such countries in a "low equilibrium trap". Gallup, Sachs and Mellinger (1998) present an AK type model with transport costs in which developing countries import capital goods and the relative price of the capital goods imported is a function of transport costs. With this model, the growth rate of the economy is inversely related to transport costs, and these reduce economic growth by making imported capital goods more expensive. Thus, the higher transport costs faced by landlocked countries may reduce growth by reducing investment, **even if this investment is intended to serve the domestic market**.

Gallup, Sachs and Mellinger (1998) also propose a model whereby developing countries import intermediate goods from developed countries to be worked using local labour and then re-exported. The cost of transporting these intermediate products is thus a key determinant in the success of the export manufacturing sector. In particular, the larger the proportion of imported inputs in the final value of the product, the more sensitive the export industrial sector's competitiveness is to the cost of transporting these inputs.

The tendency in recent years towards international dispersal of the production chains of multinational enterprises has made transport costs a very important factor in the choice of location for foreign direct investment (FDI), particularly that which forms part of international value chains. Countries with high transport and market access costs may find themselves at a disadvantage as regards their ability to attract export-oriented FDI, given the high percentage of imported components that is often involved. In the apparel and electronic assembly industries, for example, imported inputs form a very significant proportion of the final product price (Radelet and Sachs, 1998).

If the cost of inputs and factors of production in a landlocked country is low enough, companies could in theory compensate for the higher costs of importing capital goods and inputs and transporting the finished product. If the transportation cost differential were very large, however, the prices of domestic factors of production would have to be lower than is possible or desirable from a socio-political point of view, and these production activities would not be viable in the landlocked country concerned.

Again, Venables and Limão (2002) suggest that the decision to locate a new investment in a country located at a certain distance from the "centre" depends not only on the transport intensity of the activity but also on its factor intensity, as compared to the transport and factor intensities of already existing activities in each location. Using a Heckscher-Ohlin type international trade model with transport costs, the authors conclude that the fact of being a long way from international markets does not necessarily prevent a region from becoming a location for any type of new investment, since the prices of its factors of production will already reflect the remoteness of its situation.[7]

Radelet and Sachs (1998) conduct an empirical study into the connection between disparities in different developing countries' sea transportation costs and their manufacturing exports and economic growth. They find that ease of access to the sea and distance from world markets have a strong impact on transport costs. Furthermore, the empirical evidence shows that countries with

[7] The authors assume that factors of production do not move among countries.

lower transport costs have experienced faster manufacturing export growth and higher economic growth over the last thirty years than those with higher transport costs. The authors consider that countries with higher transport costs will have to pay lower wages if they wish to compete in world manufacturing markets. For a sample of ninety two developing countries over the period 1965-1990, Radelet and Sachs (1998) state that none of the landlocked countries were among the fifteen largest manufacturing exporters. Almost all the countries that had been successful in this respect were located either on the main transportation routes or close to at least one developed market (Japan, Western Europe or the United States). The relationship found by Radelet and Sachs (1998) between transport costs and economic growth indicates that a landlocked country with transport costs 50% higher than those of a comparable coastal economy may have annual growth rates that are 0.3 percentage points lower. This is one of the few attempts made in the literature to calculate the size of the effect that being landlocked has on a country's growth rate.

2. International trade and investment in landlocked countries: a theoretical analysis under uncertainty

The total transport costs of a landlocked country can be divided into three components:

- transportation within the country's borders,
- transportation through transit countries, and
- sea transportation to the final destination (starting from the ports of the transit country or countries).

Unlike coastal countries, landlocked developing countries incur **additional** cost b): transportation through transit countries. This introduces uncertainty[8] about the future value of transport services, for at least two reasons:

- The cost of non-airborne transport (overland, river) through transit countries may be affected by negative shocks such as natural disasters or civil disturbances (e.g., dockers' strikes, road blockades), which for the landlocked country are completely **exogenous** and about which it can do little[9]. The exogenous nature of such potential negative shocks makes the future price of transporting goods through transit countries more uncertain. Events that lead to total disruption of transportation through the transit country (e.g., the destruction of a key bridge by a landslip, the flooding of connecting roads, the blocking of border passes by heavy snow) can be thought of as raising the cost of transportation to infinity for a given period of time. The crucial point here is that the landlocked country cannot react to such negative shocks because they take place **outside its jurisdiction**.[10]
- The price of at least some transport services through transit countries is often set in units of the transit country's currency. If transit countries are exposed to idiosyncratic macroeconomic instability, for reasons unrelated to and beyond the control of the landlocked country, large movements in the bilateral exchange rates between the former and the latter might result. Exchange-rate movements lead to an increase (decrease) in the

8 This greater uncertainty does not affect trade with non-neighbouring countries that is carried out by air. However, only a limited portion of a country's trade with non-neighbouring countries is conducted in this way. In Bolivia in 2001, for example, only 14.5% of all registered trade went to non-neighbouring countries by air.

9 This problem is particularly acute in those regions of the world that have a history of armed conflict or civil disorder, as here the conditions of access to and from the landlocked country via the transit countries are particularly uncertain.

10 In general, the likelihood of such a shock occurring is influenced by the distance to be covered and by topographical and climatic conditions in **any** country (coastal or landlocked). However, the exogenous nature of these shocks due to their occurring outside their jurisdiction only affects landlocked countries.

costs of transportation through the transit country concerned, as measured in the currency of the landlocked country, when the currency of the former appreciates (depreciates) against the latter's. The currency risk described here is exogenous to the landlocked country, like the negative shocks that might affect the cost of transportation through a transit country (measured in that country's currency).

This **additional** risk (of currency movements and adverse events occurring) faced by landlocked countries as compared to coastal countries can be expected to be more significant the more a landlocked country depends on a single transit country as a conduit for its commerce, since diversification of access routes lowers the risk of its being affected by macro instability in any given transit country or by physical disruption to transport.[11]

Other things being equal, greater uncertainty about future transport costs may adversely affect the trade of landlocked countries in two ways: by lowering the price of exported goods (net of transport costs) and by reducing investment in the tradable goods sector, which can have a negative effect on the volume of trade.

Uncertainty may reduce a landlocked country's export prices, thus worsening its terms of trade, if it undermines the perceived reliability of exporters. The study by MacKellar, Wörz and Wörgötter (2000) suggests that uncertainty about the ability of entrepreneurs located in a landlocked country to supply their customers promptly with the product required may discourage foreign customers from signing long-term export contracts and may also put foreign companies off setting up production facilities in the country. The problem is worsened if the landlocked country requires inputs to arrive within a set time (e.g., inputs for industries operating on a "just in time" basis) or if the products exported have a limited life (perishable goods) or are expensive to store. According to UNCTAD (2001), exporters can charge higher prices when contracts specify rapid delivery, whereas delivery delays may be penalized. Thus, an exporter whose products may be subject to unforeseen delays in transit might find it hard to conclude contracts at better prices.

Secondly, uncertainty may make it less attractive for private investors to invest in the tradable sector of the landlocked country. Other things being equal (suitability of infrastructure, political stability, institutional security, cost of factors of production, etc.), a risk-averse investor planning to import to or export from a country can be expected to demand higher expected returns in a landlocked developing country than in a coastal one. This is **because of the need to offset the additional risk that arises when goods are imported and exported through a transit country**. If the bilateral exchange rate falls, or if some event occurs that increases the cost of transportation through the transit country, *future* costs rise, but the possibility of these things occurring affects the decision to invest *now*. This problem is potentially greater for those industries that use large quantities of imported inputs (*maquila* industries), since the uncertainty affects not only export costs for the finished products, but also the cost of the imported inputs needed to make the product which is to be exported.[12]

We shall now present a simple model that depicts the mechanism whereby uncertainty about the cost of transportation through a transit country raises the minimum return demanded by potential investors in the tradable sector of a landlocked developing country.

[11] Always assuming that the bilateral exchange rates between the landlocked country and each of the transit countries are not perfectly correlated among themselves. This situation does not occur in Latin America (see ECLAC, 2003b).

[12] Even if there are capital markets in the landlocked country that enable exporters to insure against the volatility of transport costs, when the product exported is a commodity the cost of the insurance is met entirely by the exporter, which effectively reduces the price received and thus the return on investment in the landlocked country.

2.1 The model when there is just one transit country

2.1.1 Basic scenario: an exporter that does not import inputs

Let us suppose that a risk-averse investor needs to evaluate the possibility of investing in a landlocked developing country in order subsequently to export to markets in non-neighbouring countries, so that the products will have to be transported through at least one transit country. The alternatives open to the potential exporter, depending on relative costs and prices, might be to set up in a coastal country, to invest in the non-tradable goods sector of the landlocked country, etc. Let us assume that each investor can only invest in one project (i.e., the different possible investments are alternatives). We can call the profits obtainable from the best of these possible investment alternatives $\overline{P}_{ALT}$, when the investor invests an amount *I*. For the time being, we shall also suppose that there is just one transit country through which exports can pass and that the good exported is manufactured using domestic inputs only. There are two periods: 1 (the current period) and 2 (the following one). Let us assume that the output and exports resulting from the investment in period 1 materialize in period 2.[13]

An exporter in a landlocked developing country investing an amount *I* in period 1 obtains profits according to the equation:

$$P = \delta(e_L x - e_T t - c) \quad (1)$$

where *P* is the present value of the exporter's profits in the following period, measured in local currency, δ is the discount factor, $\boldsymbol{e_L}$ represents the real exchange rate of the local currency against the currency exports are priced in[14] (we assume exports to be priced in dollars), *x* is the dollar value of net exports transported by sea (as these are assumed to be priced in dollars as well),[15] $\boldsymbol{e_T}$ represents the exchange rate of the local currency against the currency of the transit country, *t* represents transport costs through the transit country (which we assume to be priced in that country's currency)[16] and *c* represents domestic processing and transportation costs within the landlocked country, priced in local currency. To simplify the analysis and concentrate on the insight described earlier, let us suppose that there are no fixed costs.[17]

Since our main concern is to analyse the additional uncertainty faced by developing countries due to their landlocked condition, we shall simplify the investment problem by supposing that: exporters do not discount the future (i.e., the discount factor δ is equal to 1); the exchange rate of the landlocked country against the dollar is fixed in the short term; the value of exports net of sea freight and domestic costs are given. That leaves two variables in equation (1) that are not

[13] Since what we are interested in is the decision to invest or not in conditions of uncertainty, for the sake of simplicity we have not included the benefits of the current period, when the values of the aleatory variable are already known. Including current benefits would not alter the conclusions of the analysis.

[14] In most cases, landlocked developing countries export commodities to non-neighbouring countries, and these are generally priced in United States dollars. Thus, $\boldsymbol{e_L}$ generally stands for units of local currency per dollar.

[15] International shipping companies usually quote their cargo rates in dollars.

[16] Since landlocked developing countries have small economies, the volume of transport from and to the landlocked country is probably only a small part of what is transported through the transit country. Consequently, it is reasonable to think that the main determinant of charges for transportation through the transit country levied by companies in the landlocked country (and priced in the landlocked country's currency) will be the charges (priced in the transit country's currency) set by the transportation companies of the transit country. It is to be expected, then, that the charges set by haulage companies in the landlocked country for moving goods through the transit country will be similar to and move in tandem with the charges set by haulage companies in the transit country, although currency movements and so on are likely to take time to feed through.

[17] The existence of fixed, irreversible costs in a context of uncertainty about the future gives rise to a "real options" analysis, whose treatment would deviate us from the main focus of this study.

predetermined: e_T, the bilateral exchange rate between the landlocked country and the transit country, expressed in units of local currency per unit of the transit country's currency; and the local currency costs of transporting across the transit country, represented by *t*. Since what matters to the investor is the total cost of transportation through the transit country, we shall introduce the "total transit cost" variable, represented by *S*, which combines both random variables:[18] $S = e_T \times t$. Thus, equation (1) is reduced to

$$P = A - S \qquad (2)$$

where $A = xe_L - c$ is a constant.

Suppose that potential exporters from the landlocked country are risk-averse and calculate the expected stochastic return from their investment using a concave utility function *U(P)*. This function is continuous, its two first derivatives exist and it presents constant risk aversion for different possible values of profits *P*. In particular, we consider the exponential utility function:

$$U(P) = -e^{-\lambda P} \qquad (3)$$

This function has first and second derivatives $U'(P) = \lambda e^{-\lambda P}$ and $U''(P) = -\lambda^2 e^{-\lambda P}$, so that the Arrow-Pratt absolute risk aversion coefficient is simply $R = -\frac{U''(P)}{U'(P)} = \lambda$.

We shall assume that the total transit cost *S* is normally distributed with mean μ and variance σ^2. In symbols, S ~ N(μ,σ^2). Consequently, the benefits *P(S)* are normally distributed, with mean $E(P) = \mu_P = (A - \mu)$ and variance $Var(P) = \sigma_P^2 = \sigma^2$. In symbols, $P(S) \sim N(\mu_P, \sigma_P^2)$, or $P(S) \sim N(A - \mu, \sigma^2)$. The density function of *P* is

$$f_P = \frac{1}{\sigma_P \sqrt{2\Pi}} e^{-\frac{(P-\mu_P)^2}{2\sigma_P^2}}$$

The expected utility from investing in the landlocked country is

$$EU(P) = -\frac{1}{\sigma_P \sqrt{2\Pi}} \int_{-\infty}^{\infty} e^{-\frac{(P-\mu_P)^2}{2\sigma_P^2}} e^{-\lambda(P)} dP .$$

After some algebraic manipulation (see appendix), we obtain

$$EU(P) = -e^{-\lambda(A-\mu-\frac{\lambda\sigma^2}{2})} \qquad (4)$$

[18] This simplification is obviously not minor, since the two variables are probably distributed very differently. It is helpful, however, for the purposes of the present theoretical study.

Thus, the greater the expectation μ and volatility σ^2 of total transport costs, given risk aversion λ, the lower the investor's expected utility for a given level of expected revenue *A* from an investment project in the export sector of the landlocked country.[19]

Potential exporters compare the expected utility of investing in the landlocked country *EU(P)*, indicated by (4), with the (certain) utility of choosing the best possible investment alternative, $U(\overline{P}_{ALT})$. Thus, potential exporters will invest in the landlocked country if and only if the expected return from doing so is greater than the return from the best alternative, i.e., if and only if $EU(P) > U(\overline{P}_{ALT})$. For this to be true, the following condition needs to be met (see appendix):

$$\boxed{A - \overline{P} > \mu + \frac{\lambda\sigma^2}{2}} \qquad (5)$$

Condition (5) indicates that the additional uncertainty attached to investment projects in the export sector of the landlocked country means that the expected rates of return of these projects need to be higher than the opportunity cost for potential investors to be interested, not just because of the additional expected cost of transportation through the transit country (μ), but also because of the volatility of this cost (measured by $\frac{\lambda\sigma^2}{2}$).

In a context of high capital mobility, this means that landlockedness would tend to reduce the international trade of landlocked countries with non-neighbouring countries by making investment projects in the export sector of the former less attractive. This is expected to be more significant:

the more risk-averse investors are (i.e., the higher λ is),

the higher the expected costs of transportation through the transit country are (i.e., the higher μ is), and

the greater the uncertainty surrounding the total transit cost is, as measured by its variance (i.e., the higher σ^2 is).

It should be stressed that uncertainty derives both from the volatility of the bilateral exchange rate between the transit country and the landlocked developing country, and from the possibility that a natural disaster or civil disorder may increase the cost of transportation through the transit country. Both components of the total transit cost could be included separately in the model, albeit at the cost of significantly complicating its algebra. Such a move would require the careful consideration of the distribution function to be used for both variables, given that neither of them is ever negative and that the density function of variable *t* is unlikely to be symmetric. This analysis would have to use another distribution function for the "exogenous shock to transport costs" variable, given that the cost imposed by a natural disaster, civil disorder or armed conflict is never negative or, perhaps, symmetrical. We shall leave that as an extension to be pursued in a future study.

[19] This arises from $\frac{\partial EU(P)}{\partial \mu} = -e^{-\lambda(A-\mu-\frac{\lambda\sigma^2}{2})}\lambda < 0$ and from $\frac{\partial EU(P)}{\partial \sigma^2} = -\frac{\lambda^2 e^{-\lambda(A-\mu-\frac{\lambda\sigma^2}{2})}}{2} < 0$.

2.1.2 Other scenarios: an importer, and an exporter using imported inputs

Similarly, the model can be applied to the case where a potential investor is interested in importing goods into the landlocked country rather than in exporting goods from it. Profits in the import sector in period 1 are given by the equation:

$$P = \delta(s - e_L m - e_T t) \quad (6)$$

In equation (6), *s* represents sales revenue in the domestic market for the products imported, denominated in the currency of the landlocked country, while *m* represents the cost of imports, including international shipping, priced entirely in dollars. The other variables are the same as in equation (1). If we assume that these are predetermined, we can write (6) as

$$P = B - S \quad (7)$$

Just as we obtained the exporter's expected utility in equation (4), here we can obtain:

$$EU(P) = -e^{-\lambda(B-\mu-\frac{\lambda\sigma^2}{2})} \quad (8)$$

Equation (8) is similar to equation (4), with the constant *B* instead of the constant *A*. This shows that the volatility of transport costs can affect both export and import investment in the landlocked country.

Lastly, if the exporter in the landlocked developing country imports inputs from non-neighbouring countries, the profit function becomes

$$P = \delta[e_L(x - m) - e_T(t^x + t^m) - c] \quad (9)$$

where t^m are the costs of transporting the imported inputs through the transit country and t^x are the costs of transporting the finished export products through the transit country. Both are priced in the currency of the transit country. As in section II.II.I.I, we define two random variables: $S_x = e_{T_{t2}} \times t^x$ and $S_m = e_{T_{t1}} \times t^m$. S_m is the transit transportation cost of the inputs imported during the current period, while S_x is the transit transportation cost of exports during the future period, both priced in the currency of the landlocked country. Both are random variables for the potential investor, since the decision as to whether or not to invest is taken before the outcome of either is known. Let us assume that the two variables are independently distributed,[20] since their realisation occurs in different periods, with normal distributions $S_m \sim N(\mu_m, \sigma_m^2)$ and $S_x \sim N(\mu_x, \sigma_x^2)$. The "total transit cost" variable represented by *S* is defined as $S = S_m + S_x$ and is normally distributed with mean $\mu = \mu_m + \mu_x$ and variance $\sigma^2 = \sigma_m^2 + \sigma_x^2$. If for the sake of simplicity we assume that $\delta = 1$ and that $C = e_L(x - m) - c$ is a constant, equation (9) is reduced to $P = C - S$. Then the return expected by a risk-averse investor, as per equation (4), is given by:

$$EU(P) = -e^{-\lambda(C-\mu-\frac{\lambda\sigma^2}{2})} = -e^{-\lambda(C-\mu_m-\mu_x-\frac{\lambda(\sigma_m^2+\sigma_x^2)}{2})} \quad (10)$$

[20] If the exchange rates show a trend, or if the period of time between the inporting of inputs and the exporting of finished goods is short enough, the variables S_m and S_x are not independent and the model needs to be adapted accordingly. However, the introduction of covariation between S_m and S_x only reinforces the idea that uncertainty (which would now include both the variance and covariance of imported inputs and exported products transit transport costs) stemming from the landlockedness condition requires higher *ex ante* rates of return to make atractive investment in the tradable sector of a landlocked country.

At the same time, condition (5) becomes

$$C - \overline{P} > \mu_m + \mu_x + \frac{\lambda(\sigma_m^2 + \sigma_x^2)}{2} \quad (11)$$

This result indicates that the expected return necessary for investment to take place in the export sector of a landlocked developing country is even greater when imported inputs are required than when the export industry uses only domestic inputs. This reinforces the conclusions of the previous analysis: the *additional* uncertainty affecting investment projects in the international trade sector of a landlocked country means that investors require expected rates of return well in excess of the opportunity cost.

2.2. The benefits of diversification: there is more than one possible transit country

Now, let us suppose that exporters in the landlocked developing country can export through two transit countries, ***A*** and ***B***. To simplify, we shall go back to the case of an exporter using only domestic inputs, but the analysis can be extended to cover the case of an importer or that of an exporter using imported inputs. In addition, let us suppose that:

- bilateral exchange rates between the landlocked country and each of the two transit countries are independently distributed,[21]
- there are no costs involved in switching the transporting of goods from one transit country to the other.

When there are two transit countries, an exporter is less likely to have to pay higher costs for transporting goods through a transit country in the future because the bilateral exchange rate has deppreciated or because the cost of transportation across the country concerned has suffered an adverse shock. This is because the probability of having to pay more is the probability of the total cost of transit across a country increasing in the following period, and yet it still being in the landlocked country's exporters' interests to export through that transit country. If exporters transport merchandise across transit country ***A*** now, it will be in their interests to carry on exporting through that same country in the following period if and only if it remains the least expensive option.

Because exporters can change the transit country they export through, **the expected cost of exporting falls for companies located in a landlocked country that has export routes across at least two transit countries**. The larger the number of possible transit routes for exports from a landlocked country, the less the probability that higher costs will have to be paid for transportation across transit countries in future.

In the real world, setting up a logistics system for transporting exports across a different transit country often involves the exporter incurring a fixed cost that cannot later be recovered (a "sunk" cost). Changing the transport route of exports may involve costs such as finding a suitable port in a different country, looking for a suitable haulage company to operate in the "new" transit country, recruitment, etc. In an environment where prices vary and agents change (e.g., as new haulage companies enter the market and old ones leave it), these switching costs will have to be paid every time the exporter decides to change the transit country used to send exports.

[21] This is a strong assumption, since the exchange rates of transit countries are often somewhat interrelated. For example, the greater the degree of economic integration between two transit countries, the more likely it is that the bilateral exchange rates of the landlocked country against each of these countries will be correlated.

The intuition of a two-period theoretical model (covering the current period and the following period) like the one we have presented is that, for investors, these switching costs increase the costs associated with uncertainty, by comparison with a situation where there are no switching costs. For exporters, these shift the support of the total transit cost density function for the ***alternative*** transit country to the right, increasing the mean of this cost, but without affecting the density function of this cost for the transit country through which transportation currently takes place. This reduces the role of that country's exchange rate as a potential ceiling on transport costs imposed by changes in the exchange rate against the currency of transit county ***A***, through which exports are sent in the current period. Thus, if the switching costs are high enough, exporting through alternative transit countries can be so expensive as to make it impracticable to change transit country and the analysis goes back to the scenario where there is just one transit country.

III. General policy implications

In section II we saw how, other things being equal, a landlocked situation usually entails higher transport costs for a developing country's international trade and greater uncertainty for investors as compared to the situation in a coastal country. Here we shall propose that efforts to develop landlocked countries be directed along two main lines: an appropriate transport policy and, to complement this, greater regional integration.

1. Transport policy

1.1 The benefits of investing in transport infrastructure

Investment in transport infrastructure is capable of increasing the productivity of any country, coastal or otherwise, but it is of particular significance for landlocked countries. Improving transport infrastructure leads to a direct reduction in transport costs, by reducing journey and waiting times. In particular, the benefits include:

Improved terms of trade, increasing the prices received by commodity exporters and reducing the cost of imports.

Lower costs for imported capital goods and intermediate inputs, reducing the bias against certain types of FDI in landlocked countries.

It is worth recalling Venables and Limão's finding (2001) that improving the landlocked countries' infrastructure from the twenty-fifth percentile to the seventy-fifth percentile would eliminate around one quarter of the disadvantage associated to landlockedness. Consequently, improving transport infrastructure should be a policy priority for landlocked countries, even in the absence of any improvement to the transport infrastructure of the transit country[22].

In addition, improving infrastructure has the potential to reduce the uncertainty faced by investors in relation to the costs of transportation through the transit country. Increasing the number of export routes and improving their quality makes it less likely (other things being equal) that there will be any disruption to traffic. At the same time, infrastructure improvements can decrease the impact of currency volatility by reducing the amount of the transit cost ($\boldsymbol{t}$) subject to random movements in the bilateral exchange rate ($\boldsymbol{e_T}$) between the transit country and the landlocked country.

1.2 Financing investment in transport infrastructure

Traditionally, the financing of investment in transport infrastructure in developing countries has taken the form of public-sector investment funded out of general public resources (taxes, public-sector borrowing, issuance of money) or specific multilateral credits. In recent years, this has been supplemented by granting concessions or contracts to the private sector for the construction and/or management of transport infrastructure. For a number of reasons, however, these sources of financing are often not enough to meet the needs of landlocked countries.

Firstly, these countries often operate under severe budgetary constraints or are heavily indebted, which limits public-sector investment. In particular, the difficulty of lowering current fiscal expenditure such as wages and transfers means that when revenues fall (e.g., for cyclical reasons), public investment is often the adjustment variable used to maintain fiscal solvency. This being the case, the national governments of some countries are trying to decouple transport infrastructure investment from budgetary adjustments by means of mechanisms such as multi-year budgeting. However, the lack of resources, combined with the heavy pressure placed on the fiscal accounts by unmet needs in key areas such as health or education can hinder public investment in transport infrastructure. Unless they can regain the required fiscal freedom, the ability of governments to play a direct role in the creation (and perhaps even the upkeep) of transport infrastructure will probably remain limited in many landlocked countries.

Secondly, the return on investment in transport infrastructure in landlocked countries may not be enough to attract the private sector or to provide an economic justification for public investment if the complementary infrastructure of the *transit country* is inadequate. The latter is often the case, as the governments of the transit countries are also constrained in their ability to invest in transport infrastructure.[23] In particular, a landlocked situation may result in "coordination failures" that hinder the implementation of projects to invest in road and communications infrastructure, especially multinational ones.

[22] However, investing in transport infrastructure is more profitable for a landlocked country when transit countries also invest: Venables and Limão (2001) calculate that in that case the reduction of the disadvantage associated with landlockednes is of between 33% (using cif/fob ratios) and 40% (using shipping data).

[23] "Most transit countries are themselves developing countries, often with a similar economic structure and suffering from the same lack of resources" (United Nations, 2002).

Figure 1
THE COORDINATION GAME

		Agent 1	
		Invest in landlocked country infrastructure	**Invest** in the alternative project
Agent 2	**Invest** in connecting infrastructure in a transit country	B , A	$- C_T$, P_{ALT1}
	Invest in the alternative project	P_{ALT2} , $- C_{LLK}$	P_{ALT2} , P_{ALT1}

The logic behind this obstacle to investment in infrastructure can be simply illustrated using game theory. Figure 1 represents the "strategic form" of a simultaneous game, played just once, between two "agents", who may be thought of as private-sector companies or national governments. Agent 1 is interested in investing in transport infrastructure for export (e.g., an international route) in a landlocked country, while agent 2 has to decide whether or not to invest in transport infrastructure connecting with that landlocked country across a transit country.

The "payoffs" structure of the game is as follows. When both agents invest in transport infrastructure, agent 1 obtains A and agent 2 obtains B. If agent 1 invests in infrastructure in the landlocked country and agent 2 does not invest in the connecting infrastructure, however, the former will receive $- C_{LLK}$ and the latter P_{ALT2}. Again, agent 2 obtains $- C_T$ by investing in connecting infrastructure when agent 1 does not invest in infrastructure; in this case agent 1 receives P_{ALT1}. If the two of them invest in alternative projects, agent 1 will obtain P_{ALT1} and agent 2 P_{ALT2}. We assume that $A > P_{ALT1} > 0 > - C_{LLK}$ and that $B > P_{ALT2} > 0 > - C_T$.

The diagram shows that there are no dominant strategies for either of the agents with this payment structure. There are two Nash equilibria in pure strategies: (*Invest, Invest*) and (*Don't invest, Don't invest*). The (*Invest, Invest*) equilibrium Pareto-dominates (*Don't invest, Don't invest*): i.e., both agents would receive a higher payoff if they could coordinate their infrastructure investment decisions. In the absence of explicit coordination, however, this equilibrium can only be attained in this example if each agent considers the probability of the other also investing to be sufficiently high. To be willing to invest, agent 1 has to consider that the probability ***b*** of agent 2 also investing is greater than or equal to $\frac{P_{ALT1} + C_{LLK}}{A + C_{LLK}}$. Similarly, agent 2 will be willing to invest if and only if the probability of agent 1 investing is put at $q \geq \frac{P_{ALT2} + C_T}{B + C_T}$. It is worth explaining the intuition behind these theoretical results. For the investment project to be implemented, the subjective probability (***p*** and ***q***) that each agent needs to see of the other investing has to be greater:

- the higher the cost to the investing agent is if the other agent decides not to invest (i.e., the higher C_T and C_{LLK} are),
- the lower the benefits to be obtained are when both agents invest in infrastructure (A and B),[24] and
- the greater the benefits of the alternative project are (P_{ALT1} and P_{ALT2}).[25]

[24] This arises from $\frac{\partial(\frac{P_{ALT2}+C_T}{B+C_T}.)}{\partial B} = -\frac{P_{ALT2}+C_T}{(B+C_T)^2} < 0$ and from $\frac{\partial(\frac{P_{ALT1}+C_{LLK}}{A+C_{LLK}}.)}{\partial A} = -\frac{P_{ALT1}+C_{LLK}}{(A+C_{LLK})^2} < 0$.

This approach helps us to identify the situations in which coordination failures might be expected in public- or private-sector financing of multinational transport infrastructure projects. Coordination failures, it should be noted, are not confined to complementary infrastructure investment projects. Likewise, investment in transport infrastructure is justified from a (strictly static) economic viewpoint only if there is sufficient demand from businesses for transport and communication services; but businesses often cannot develop in the absence of such a transport system.

Coordination problems deriving from the simultaneous, decentralized nature of investment decisions are often more serious when there is a significant degree of uncertainty, as it becomes difficult to calculate the future rate of return of an investment project. To solve this problem, UNCTAD (2001) suggests concentrating industrial investment projects within "transport corridors" connecting production areas in each country to ports, at the same time as infrastructure investment is taking place. According to this approach, synchronized development of production activities and infrastructure would ensure a sufficient flow of funding to make infrastructure investment attractive for the private sector, and this would draw economic activities to the corridor. UNCTAD (2001) advises governments to attract "anchor investments" to ensure the basic viability of the infrastructure, and then try to bring in more investment to consolidate the process. The net effect of this approach on a country's welfare, while it may be very positive in the right circumstances, will depend significantly on the methods used to attract these "anchor investments" and on the size (and objectives) of the project. Using tax exemptions indiscriminately or without proper analysis may result in the costs outweighing the benefits, while planning for corridor projects that are unrealistically ambitious may result in very scarce fiscal resources being wasted ("white elephants").

To sum up, given the budgetary constraints affecting public investment in transport infrastructure, most such investment will probably have to be funded by private investors, and this means that "coordination failures" have to be dealt with. For this and other reasons (which are analysed below), transport policy needs to be integrated into a broader regional development process, coordinated primarily through regional trading blocs such as the Andean Community, Mercosur, etc.

2. Regional integration

Regional integration can be a very powerful tool for reducing the problems of landlocked countries. In the first place, regional integration fosters trade, raising rates of return on investment in transport infrastructure and thus making it more likely that the private sector will be willing to invest in transport infrastructure. By lowering transport costs, the resultant improvement in infrastructure not only enhances the terms of the trade of the landlocked country, but can also reduce the expected cost of transportation in the future. This is shown by the model developed in section II.II where, as the cost of transportation through the transit country (t) falls, fluctuations in the bilateral exchange rate between the landlocked and transit countries become less important in terms of their potential effect on investment in the landlocked country.

In the second place, integration can create conditions that lead to reductions in the costs (e.g., trans-shipment and waiting times, bureaucratic obstacles, customs costs, etc.) of border crossings between a landlocked country and transit countries. Initiatives along these lines could include the unification of customs and immigration requirements among the countries in a trade bloc, the

[25] This arises from $\frac{\partial(\frac{P_{ALT2}+C_T}{B+C_T}.)}{\partial P_{ALT2}} = \frac{1}{B+C_T} > 0$ and from $\frac{\partial(\frac{P_{ALT1}+C_{LLK}}{A+C_{LLK}}.)}{\partial P_{ALT1}} = \frac{1}{A+C_{LLK}} > 0$.

introduction of transport permits that are valid in more than one country, collaboration and coordination among frontier authorities, and so on. Special efforts need to be made to harmonize the documentation demanded (United Nations, 2002) by standardizing commercial practices as far as possible and introducing jointly agreed rules and procedures for presenting the information required.

In the third place, regional integration can also "bring together" markets geographically by making it unnecessary for landlocked country exporters to cross additional borders.[26] This also reduces the transport costs involved in reaching the final market, diminishing the competitive disadvantage created in this respect by the remoteness of landlocked countries from world markets.

In the fourth place, regional integration can make it easier to coordinate multinational infrastructure projects. Negotiations among countries belonging to a trade bloc can make it more likely that a country will be credibly willing to participate in a given infrastructure project, thus reducing the effects of "coordination failures". In figure 2 in the previous section, the coordination provided by regional integration agreements should make it possible to attain the Pareto-superior Nash equilibrium (*Invest*, *Invest*), for example if it increases the subjective probabilities $\boldsymbol{p}$ and $\boldsymbol{q}$ of the agents investing. In turn, investment in infrastructure projects also reduces the impact of uncertainty on investment by creating alternative transit routes. However, cooperation processes need to take account of the probability of events occurring that might affect the ability of the parties to implement agreements. Consequently, there is a need to include mechanisms that strengthen such agreements against negative shocks such as changes in the terms of trade that affect fiscal solvency and force one of the parties to postpone its investment in an infrastructure project.

In the fifth place, regional integration can reduce exchange rate fluctuations between the landlocked and transit countries by aligning the economic cycles of participants. This would reduce uncertainty about future transport costs through the transit country. In accordance with the model in section II.II, a regional integration process that reduced the volatility of bilateral exchange rates among members would moderate the rate-of-return differential required to attract investment to the export sector of a landlocked country. In the extreme case where the countries concerned decided to adopt a common currency, nominal exchange-rate volatility would disappear.

Finally, regional integration can lower the switching costs of changing transit country. This happens if integration efforts succeed in creating multinational transport markets in which firms from different countries participate, thus making it cheaper to obtain information about transport costs, etc. Reforms to transport regulations in a landlocked country need to pursue two objectives: firstly, minimizing the impact of regulations on trade; secondly, harmonizing its rules with those applied in transit countries, to reduce the costs of businesses that have to operate in both jurisdictions. According to UNCTAD (2001), international conventions and regional (sub-regional and bilateral) agreements are the main instruments whereby harmonization, simplification and standardization of rules and documentation can be achieved. In South America, for instance, the members of Mercosur and the Andean Community have undertaken to apply common transit procedures contained in a series of regional agreements.[27]

[26] Thus, exports from a landlocked country would only have to cross one border instead of two or more.
[27] For further details of these agreements, see UNCTAD (2001) and ECLAC (2003a, Annex 3).

Conclusions

Although the relationship between transport costs and economic development has been extensively dealt with in the economic literature, the effort to analyse the possible relationships between a country's landlocked situation and its level of development has only just started, and much remains to be done.

Empirical studies by other authors reviewed in this study have found that landlocked countries generally have higher transport costs than coastal nations. Again, the theoretical literature reviewed here suggests that, other things being equal, the higher transport costs faced by landlocked developing countries as compared to coastal nations result in more expensive imports and lower prices for exports, since the costs of transportation across the transit country are paid by exporters and importers in the landlocked country. In particular, given certain assumptions about growth, the higher cost of importing capital goods and intermediate inputs could have a negative effect on economic growth. While extremely valuable, however, the contributions referred to do not exhaust the analysis of the specific circumstances of landlocked countries.

The present study has contributed to the literature on the relationship between a country's landlocked position and its level of development in three ways. In the first place, it has reviewed the empirical literature on the higher transport costs faced by landlocked countries. In the second place, it has reviewed the theoretical literature, which concentrates on analysing the possible relationships between a landlocked situation, transport costs and trade flows. In the third place, it has offered a theoretical explanation of an obstacle to

investment in landlocked countries that had not been dealt with in the literature before. This refers to the additional uncertainty attached to the future transport costs of a landlocked country. This uncertainty arises because the future costs of transportation across the transit country are an random variable, since they depend on how the bilateral exchange rate between the landlocked country and the transit country moves and on whether certain negative shocks to transport occur (e.g., dockers' strikes, landslips, floods, road blockades, etc.). By increasing the minimum expected returns demanded by potential investors, this extra uncertainty may have a negative effect on a landlocked country's development level by reducing investment in the tradable goods sector. In particular, this can hinder investment in export industries targeting non-neighbouring countries, especially if those industries have high imported inputs requirements (such as the *maquila* assembly industry). The more transit countries that are available, however, and the lower the cost of switching among them, the less of a constraint on development landlockedness will be.

With a view to reducing the potential development implications of a landlocked situation, we have proposed that economic policy should be structured around two axes: investment in transport infrastructure and regional integration. Both policy measures address the causes of the additional uncertainty faced by landlocked countries, and may therefore be useful to all such countries.

This study explains the causes behind possible disincentives to investment in tradable goods sectors in landlocked countries. It does not, however, analyse the "transmission channels" connecting the greater relative uncertainty affecting landlocked countries to their level of development,[28] and this is one direction in which this work might be extended in the future. Others include formalizing the insight set forth for the model when there is more than one transit country and switching costs exist, and analysing the relationship between landlocked and transit countries from a strategic standpoint ("hold-up" and "free riding" problems), among others.

Finally, it should be stressed that this paper has concentrated mainly on the **theoretical** aspects of the economic impact produced by a landlocked situation. Landlockedness should not be regarded, therefore, as an impassable barrier to development that condemns such countries to poverty and stagnation. The empirical evidence on the impact of a landlocked situation on the development of non-coastal countries is limited and partial, so the logical next step in the research agenda is to conduct wider and deeper empirical studies on the subject. In particular, it is necessary to incorporate into those future empirical studies the theoretical ideas set forth here concerning the potential development impact of the uncertainty that a landlocked situation creates. Only on the basis of such empirical findings and taking into account the different circumstances of each case, is it feasible to start contributing with more specific policy measures.

[28] Analysis of such transmission channels should consider how uncertainty affects trade and growth rates in landlocked countries.

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Appendix

Equation (4) is obtained from:

$$EU(P) = -\frac{1}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-\frac{(P-\mu_P)^2}{2\sigma_P^2}} e^{-\lambda(P)} dP$$

$$\Rightarrow -\frac{1}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-(\frac{(P-\mu_P)^2+2\lambda\sigma_P^2 P}{2\sigma_P^2})} dP \Rightarrow -\frac{1}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-(\frac{(P-\mu_P+\lambda\sigma_P^2)^2+2\lambda\sigma_P^2\mu_P-(\lambda\sigma_P^2)^2}{2\sigma_P^2})} dP$$

$$\Rightarrow -\frac{1}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-(\frac{(P-\mu_P+\lambda\sigma_P^2)^2}{2\sigma_P^2}+\lambda(\mu_P-\frac{\lambda\sigma_P^2}{2}))} dP \Rightarrow -\frac{1}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-(\frac{(P-\mu_P+\lambda\sigma_P^2)^2}{2\sigma_P^2}+\lambda(\mu_P-\frac{\lambda\sigma_P^2}{2}))} dP$$

$$\Rightarrow EU(P) = -\frac{e^{-\lambda(\mu_P-\frac{\lambda\sigma_P^2}{2})}}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-\frac{(P-(\mu_P-\lambda\sigma_P^2))^2}{2\sigma_P^2}} dP$$

and given that

$\frac{1}{\sigma_P\sqrt{2\Pi}}\int_{-\infty}^{\infty} e^{-\frac{(P-\mu')^2}{2\sigma_P^2}} dP = 1$ for all μ', including $\mu' = \mu_P - \lambda\sigma_P^2$, then

$$EU(P) = -e^{-\lambda(\mu_P-\frac{\lambda\sigma_P^2}{2})} \Rightarrow EU(P) = -e^{-\lambda(A-\mu-\frac{\lambda\sigma^2}{2})} \quad (4)$$

Condition (5) is obtained from:

$$EU(P) > U(\overline{P}_{ALT}) \Rightarrow -e^{-\lambda(A-\mu-\frac{\lambda\sigma^2}{2})} > -e^{-\lambda(\overline{P})}$$

$$\Rightarrow e^{-\lambda(A-\mu-\frac{\lambda\sigma^2}{2})} < e^{-\lambda(\overline{P})} \Rightarrow -\lambda\left(A-\mu-\frac{\lambda\sigma^2}{2}\right) < -\lambda\overline{P}$$

$$\Rightarrow A-\overline{P} > \mu+\frac{\lambda\sigma^2}{2} \quad (5)$$

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