

Potential of European Birch Species for Product Development of Veneer and Plywood – Recovery, Grades and Mechanical Properties and Future Market Requirements

Erkki Verkasalo, Henrik Heräjärvi

METLA The Finnish Forest Research Institute, Joensuu Research Unit, Finland

Abstract

Potential of product development for veneer and plywood products is reviewed for European silver birch (*Betula pendula* Roth.) and white birch (*Betula pubescens* Ehrh.). The review is based on selected empirical results from three large projects of the Finnish Forest Research Institute on the properties of birch wood materials and value of products, and putting them in proportion to the perspectives of future product segments, selection criteria among customers and log supply. The empirical results cover: 1) volumetric yield, visual grades and commercial value of veneers from experimental rotary cutting from timber stands of silver birch and white birch, 2) with the reference of logs of planted silver birch from Finland and both species from north-western Russia, 3) static bending properties and Brinell hardness of wood from logs of silver birch and white at different sites and age classes in Finland. The perspectives of product markets are evaluated based on focused discussions with experts from Finnish veneer and plywood industries and complementary knowledge from recent scientific literature.

Introduction

European silver birch (*Betula pendula* Roth.) and white birch (*Betula pubescens* Ehrh.) make up a considerable hardwood resource for forest products in northern Europe, Baltic Countries, Poland, Belorussia and Russia (*e.g.*, Verkasalo *et al.* 2007). Both birch species are largely used for plywood, veneers and lumber, and their further products, but also for pulping and biomass for energy. Wood and timber quality of birch is now changing when raw material from plantations (silver birch) and drained peatlands (white birch) is increasingly entering

the roundwood market. Simultaneously, the competition for birch wood for different uses is intensifying, mainly due to the increase in bioenergy, and new value chains are created. This alters the demand for and costs of different grades of roundwood and by-products in the birch-using sectors.

Birch veneers and plywood have an acknowledged position in certain niche markets, where the specific properties of the before-mentioned birch species can be implemented efficiently and economically, with a superior technical match to the end-use requirements. The composition of customers and the palette of end-products are under progress for these birch-using industries. Accordingly, the future's product and customer segmentation and market positioning and the changing raw material basis affect crucially the potential and needs of product and processing development in veneer and plywood industries.

The objective of this paper is to review the product development potential of European silver birch and white birch for veneer and plywood products based on selected empirical results from three large projects of the Finnish Forest Research Institute on the properties of birch wood materials and value of products, and putting them in proportion to the perspectives of future product segments, selection criteria among customers and log supply. The empirical results cover: 1) volumetric yield, visual grades and commercial value of veneers from experimental rotary cutting of logs from four timber stands of silver birch and white birch each, 2) with the reference of logs from two timber stands of planted silver birch and seven mixed stands of both species from north-western Russia, 3)

static bending properties and Brinell hardness of wood from silver birch logs and white birch logs from 21 timber stands at different sites and age classes. The perspectives of product markets were evaluated based on focused discussions with experts from Finnish veneer and plywood industries and complementary knowledge from recent scientific literature.

Birch species as raw material for veneer and plywood industries

Silver birch is dominant birch species in commercial forestry (plantations) due to its faster growth, larger size in mature stage, and better overall quality in terms of stem form and branchiness (e.g., Verkasalo 1997, Luostarinen and Verkasalo 2000, Heräjärvi 2002). However, the differences between the wood properties are such minor that the two species are not separated from each other in any industrial end use. Birch plywood is typically used in construction, transportation or interior facing products that set high requirements for visual quality, strength and stiffness. In parallel, high-quality birch veneers are used as face material of demanding appearance products such as furniture, interior panels, handicraft and miscellaneous special items.

In Finland, approximately 2 mill. m³ of birch logs were used in 2006, of which up to 95% for plywood and the rest for veneers and sawn goods. Of the volume, 0.87 mill. m³ were imported, with up to 98% from Russia and the rest from Estonia and Sweden (Peltola 2007). Since 2008, after the cease of log import from Russia (owing to the implementation of export tariffs of roundwood), the industries are leaning on domestic raw material sources.

Of the Finnish birch log resources (tree dbh >19.5 cm and log diameter >18 cm), silver and white birch account for 60% and 40%, respectively, in the actual log growing area in the southern half of the country (e.g., Luostarinen and Verkasalo 2000). Log availability from silver birch plantations is expected to grow to one third of the total consumption of plywood industries in 10 years. Volumes of white birch from peatlands

are also increasing, but the log dimensions or quality do not often enable the desired recovery or quality of veneers (e.g., Verkasalo 1997).

Birch wood

Birch wood is diffuse porous, relatively uniform as regards to the difference between early wood and latewood, light coloured, and has average basic density of 480–520 kg/m³ (e.g., Heräjärvi 2002). The differences between silver birch and white birch have been observed small in wood properties such as basic density, strength and stiffness, shrinkage and swelling, moisture distribution, heartwood content. Density and related properties are slightly favourable for silver birch, and general homogeneity and grain texture for white birch.

According to many studies, basic density is 1% to 8% higher for silver birch than white birch. The following values are typical for the species in log size, as naturally born and on their natural sites (Heräjärvi 2004b):

	Mean, kg/m ³	SD, kg/m ³
<i>B. pendula</i> , mineral upland	511.9	41.5
<i>B. pubescens</i> , mineral upland	478.0	30.8
<i>B. pubescens</i> , peatland	491.9	39.5

Density variation is much larger radially than longitudinally for both birch species. On mineral soils, the density is slightly higher on fertile than poor sites, but on peatlands the effect seems opposite. It is notable that the between-species differences in density are often curtailed in practical plywood and veneer mill operations by the effects of knottiness, grain deviations and tension wood.

The following wood properties are also important in different phases of birch plywood processing: fibre length 1.1 mm, volumetric shrinkage 14%, volumetric shrinkage per one percentage point change in moisture content 0.3%, pH 4.8, and extractive content 3.2% (Luostarinen and Verkasalo 2000).

Recovery of veneer

Plywood logs of white birch are of smaller diameter and volume and they include more defects affecting veneer recovery than plywood logs of silver birch. This is shown in Figure 1 presenting results from experimental rotary-cutting at two mills, where the traditional 3-point block centring technique was used (Verkasalo 1997).

Theoretical recovery of green veneer of the total log volume (o.b.), where entire peeler bolt volume excluding bark and wastes from round-up and peeler cores was assumed, was on average 56.4 % for silver birch from mineral soils, 53.2 % for white birch from mineral soils and 53.0 % for white birch from peatlands. The differences were well consistent with those in average top diameter of the logs, 22.3, 20.4 and 20.6 cm (o.b.), respectively.

True recovery of green veneer of the total log volume (o.b.), where the effects of internal log defects such as decay and checks were considered, was on average 52.3 % for silver birch from mineral soils, 47.1 % for white birch from mineral soils and 45.1 % for white birch from peatlands, respectively.

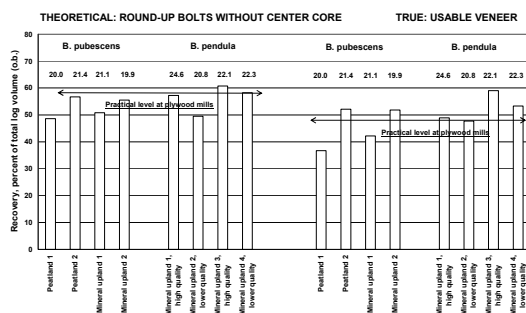
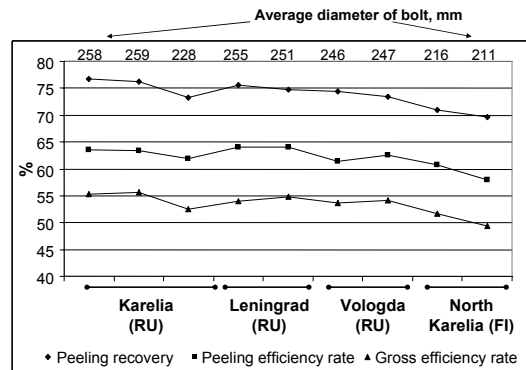


Figure 1 Total recovery of green veneer from experimental logs of white birch (*B. pubescens*) and silver birch (*B. pendula*) from peatlands and mineral uplands. Practical levels at plywood mills are shown as horizontal arrows (Koponen 1995). Mean log diameter is shown for each lot. (Verkasalo 1997).



Peeling recovery: Volumetric proportion of wet veneers of the volume of debarked, trimmed bolt
Peeling efficiency rate: Volumetric proportion of wet veneers of the volume of unbarked log
Gross efficiency rate: Volumetric proportion of dried and trimmed veneers of the volume of unbarked log

Figure 2 Veneer recovery in peeling of birch plywood logs from seven north-western Russian stands (final fellings) and two Finnish plantations (second thinnings) (Arponen 2007).

This indicated more and more severe defects in white birch compared with silver birch, and on peatlands compared with mineral soils. However, recovery had a large between-stand variation irrespective of birch species. Accordingly, average recovery from white birch logs exceeded that from silver birch logs of the lowest quality.

In the material of Arponen (2007), the recovery of green veneer of the volume of peeler bolts (u.b.) varied between 69% and 77%, depending on the log origin (Figure 2). In the case of clear-fellings from naturally grown stands in Russia, the average recovery was 75%, whereas in the domestic origin from second thinnings in silver birch plantations with smaller bolts the average was 70%. The main reason for the difference was the larger stem and, subsequently, log size in the Russian wood. The average diameters of peeler bolts in the imported and domestic materials were 24.9 cm and 21.4 cm, respectively. The proportion of dried and trimmed veneers from the volume of debarked logs was 49–66 %. The average volumetric losses, caused by butt reduction and peeler cores, were 30% in the case of domestic logs and 25% in the case of Russian logs.

Grades of veneer

Knottiness determines the commercial grade of a birch veneer sheet in more than 90 % of individual cases. Average grade distributions of green veneer in experimental rotary-cutting of white and silver birch logs are shown in Table 1 and the stand wise results in Figure 3 (Verkasalo 1997).

Based on the percentages of the best surface veneer grades A, B and S, the veneer quality was on average the best for silver birch from mineral soils and the lowest for white birch from peatlands. Grade BB includes veneers acceptable for plywood surface after patching knot holes and large knots. For white birch on peatlands, the percentage of BB was much higher than for the other groups in comparison. Grade WG includes the joint veneers and low-quality surface veneers, and grade core veneer the veneers acceptable for inner plies only.

The between-stand variation was considerable in the grade distribution for both birch species. Accordingly, the proportions of the grades A, B and S of white birch in some stands exceeded those of silver birch in the stands with the lowest quality. In this study, the average veneer quality clearly exceeded that in practical plywood production.

Table 1 Veneer grades from experimental logs of white birch (*B. pubescens*) and silver birch (*B. pendula*) from peatlands and mineral uplands.

Grade	B. pubescens, peatland	B. pubescens, mineral soils	B. pendula, mineral soils
	Proportion of all veneers, %		
A	0.0	0.0	0.2
B	4.8	7.1	7.1
S	3.5	5.5	9.8
BB	30.9	21.0	18.0
WG + joint veneer	35.8	19.9	35.2
Core	25.0	46.5	29.7
Total	100.0	100.0	100.0

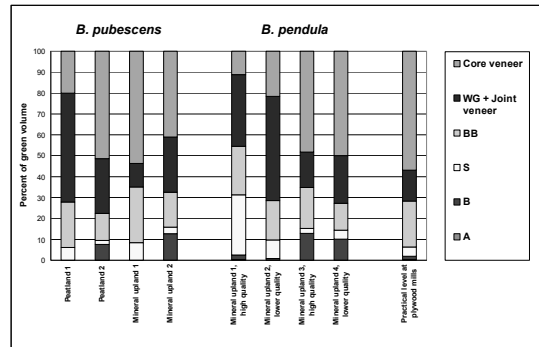


Figure 3 Grade distribution of green veneer from experimental logs of white birch (*Betula pubescens*) and silver birch (*Betula pendula*) from peatlands and mineral uplands (Verkasalo 1997). Average distribution at Finnish plywood mills is shown in the column on the right (Koponen 1995).

The grade distributions of veneers among the materials of Heräjärvi and Arponen (2008) are presented in Table 2. Geographically, relatively uniform grade distributions were seen in the stands in Leningrad region in Russia, on one hand, and in the domestic stands, on the other hand. The separate origins differed clearly from each other in terms of veneer grades within the Republic of Karelia and Vologda regions in Russia

Table 2 Veneer grades in peeling of birch plywood logs from seven north-western Russian stands (final fellings) and two Finnish plantations (second thinnings) (Heräjärvi and Arponen 2008).

Origin (stand)	Better surface quality	Other surface quality	Middle layer quality
1	9.0	21.1	70.0
2	9.5	19.4	71.2
3	2.0	8.4	89.7
5	4.9	15.3	79.8
6	3.7	16.1	80.3
11	3.9	18.9	77.1
12	5.2	24.8	70.0
Russian birch	5.5	17.7	76.9
7	1.6	17.7	80.7
8	2.2	17.1	80.6
Plantation birch	1.9	17.4	80.7

Mechanical properties

Birch wood is at its heaviest in the lower parts of the stem and near to the stem surface (Heräjärvi 2004b). The mechanical properties vary accordingly. Modulus of elasticity (Figure 4), modulus of rupture (Figure 5) and Brinell hardness (Figure 6) do not significantly differ between the white birch trees grown on mineral soils or peatlands, but silver birch provides a notably better mechanical performance (Heräjärvi 2004 a,b). In plywood production, the best strength grades are obviously obtained from surface veneers of silver birch butt logs.

Modulus of elasticity and bending strength are definitely the most important criteria of mechanical performance in construction uses in houses, bridges, concrete formwork systems, supporters of parquet etc., but also in the structures of different vehicles, such as buses, lorries, containers and ships. Good elastic properties are needed also in, for example, wind turbine blades, isolation boxes for liquefied natural gas (LNG) carriers, and, formerly, in marine and aviation applications. Surface hardness is needed as itself in house flooring and furniture, but also in the floors of different vehicles and containers. Sufficient hardness is a prerequisite for proper coating with different films or sheets, as well.

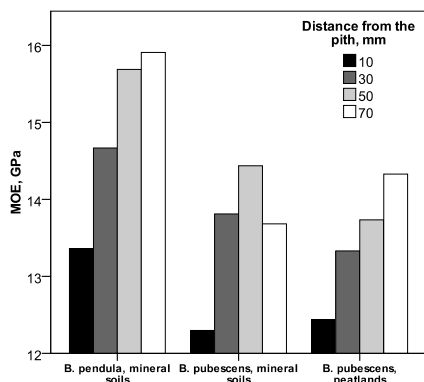


Figure 4 Radial variation of modulus of elasticity in silver birch (*B. pendula*) (N= 249) and white birch (*B. pubescens*) (N=234) on mineral soils and white birch on peatlands (N=127) (Heräjärvi 2004a).

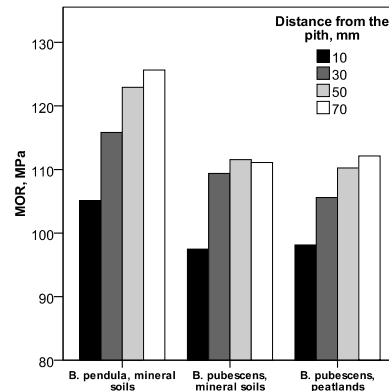


Figure 5 Radial variation of modulus of rupture in silver birch (*B. pendula*) (N=249) and white birch (*B. pubescens*) (N=234) on mineral soils and white birch on peatlands (N=127) (Heräjärvi 2004a).

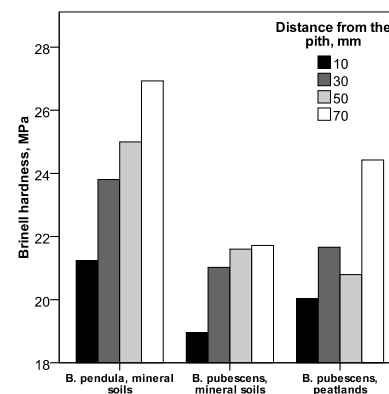


Figure 6 Radial variation of Brinell hardness in silver birch (*B. pendula*) (N=261) and white birch (*B. pubescens*) (N=199) on mineral soils and white birch on peatlands (N=159) (Heräjärvi 2004b).

Future market requirements and product development

Based on different FAO scenarios, global demand of plywood is growing at the stable rate of 1.7% during the next 15 years (comp. with 0.9% for sawn timber). The per capita consumption is expected to increase in the developing countries, and already increased since the 1960's much more rapidly in Asia and since the 1990's in Oceania than in the developed countries. The growth rate continuously slowed down in Europe and

North America. However, this concerned in the first hand softwood plywood partly due to the substitution with OSB in construction. The average global per capita consumption of plywood has remained at the same level for 30 years (*e.g.*, Kärkkäinen 2005).

It was predicted in early 2000's that in Europe there will be moderate GDP and population growth affecting demand and prices of forest products and the market balance in plywood will be fragile unless increasing per capita consumption levels are achieved in economically developed countries.

After the enlargement of the European Union, the most important factor is currently the growing production in and export from Russia. This has again plugged the roundwood flow of birch around the Baltic Sea at the level of 1990's. It has an impact on the industry competitiveness in different countries as well as the product markets.

The production of birch plywood grew rapidly in north-western Russia since the 1990's, and the growth continued at the rate of approximately 10% per annum until the economic recession. This was possible due to the vast birch resources, growing domestic consumption and, so far, good competitive ability of export to the European markets. The big growth in the production occurred mostly in the Russian domestic companies. The individual domestic companies are still generally smaller than the few foreign ones from Finland and Germany.

Globally, it is China with its strong GDP growth and high competitiveness that will increase its role also in the markets of plywood. As global future exports opportunities will increasingly arise in south-eastern Asia in all main products, also competition and production will be growing there (*e.g.*, establishment of fast-growing plantations in China).

If the short-fibre pulp industries of China will be focusing on European market, instead of the domestic market, the demand of birch pulp

may decline even more than due to the competition from eucalypt and acacia pulps from the southern hemisphere. This may have negative impacts on the economy of birch plywood industries in Finland, owing to the weakening demand of residual chips. The demand of dry by-products for bioenergy seems to develop positively, and may even accelerate if the adhesion and stability problems in pelletizing birch could be solved.

Anyhow, declining demand of birch pulpwood inevitably affects the entering of birch logs to the roundwood market in a short run. The increasing demand of energy wood could probably compensate it gradually, and secure also the forest management in young birch stands toward high-quality logs.

During 2010's, the end-use requirements of birch plywood emphasize the functionalities for consumers, on one hand, and the technically superior properties for industrial customers, on the other hand. Birch wood as it is provides a large potential for visually attractive products for interiors and furniture. The product segment is versatile, but much dependent on the trends of fashion and cultural appreciation of light-coloured appearance. Decorative plywood is usually faced with hardwood, including birch, red oak, maple, lauan (Philippine mahogany) and a large number of other hardwoods. Design systems based on plywood, for example, interior wall elements or acoustic indoor rooms, have been introduced, stressing collaboration between manufacturer, designer and customer in the delivery chain.

High-quality finishing to regulate and homogenize colour and texture and to protect surface from wear and UV-light is vital in many customer segments. Birch plywood is said to have an excellent surface hardness, damage and wear resistance. However, competitiveness in flooring and furniture products requires improvements in surface hardness of birch. Finishing oils with an optimized retention have been developed for the purpose, leaning on the good permeability

of birch wood. It is possible to raise birch in this respect to the level of oak. Here, surface roughness and adhesion properties of birch are also objects in product development. Biological incising may be used to improve phenolic resin retention. Using certain salt compounds as the effective media the surface hardness may be improved triple fold. Water glass impregnation with a strong solution of potassium silicates was recently introduced to raise surface hardness of birch by 150 %; simultaneously, the wood becomes stable against moisture-induced defects and fire resistant. Impregnation with furfuryl alcohol compounds is under testing. Impregnation with water-borne agents can be applied to veneers, but not to plywood – or any other wooden material with gluelines. Compressing drying may be used to improve surface hardness and stability against cracking, as well. A challenge is to develop service-free or self-cleaning birch surfaces using bioactive agents. Selected fungi may be used to slow down the growth of mould and discolourising fungi on wood surface, birch among others.

Birch plywood is characterised by its excellent strength, stiffness and resistance to creep. It has a high planar shear strength and impact resistance, which make it especially suitable for heavy-duty floor and wall structures. Oriented plywood construction has a high wheel carrying capacity. Improvements in veneer strength, both in the structural use aspects (bending and tension) and veneer processing (tension perpendicular to grain) provide development potential. This may be executed through optimising forest growth conditions and genetic provenances and clones as well as through technological improvements in log peeling, cutting and handling. Recent industrial tensile strength tests on the veneers showed that the specimens originating from the surface parts of the bolts are weaker than those near the pith or in between the two cases.

The processes of rotary-cutting birch are now close to their optima as regards the volumetric recovery, but the value recovery could still be improved. In veneer slicing, the machinery is varied, and mostly behind the rotary-cutting lines. The development work focuses now on making veneer sorting more efficient and rising the productivity of manufacturing small lots of plywood. It is notable that the size of an individual sales has continuously decreased (e.g., high-quality furniture plywood), but also very large lots have come to the market (e.g., plywood deliveries for LNG carriers).

In Finland, the main part of birch logs is obtained for the most demanding uses from 60-80 year-old, naturally-born silver birch stands and from mixed stands where silver and white birch are growing among Norway spruce and Scots pine. Thinning operations of silver birch plantations provide only medium quality veneers for the time being. Therefore, the logs should be allocated to mills that manufacture coated plywoods. In the future, we expect high-quality birch veneers from plantation forests as the log dimensions increase and the quality improves for knottiness.

Marginal lots to complete the domestic log flow for large dimensions and, hopefully, high quality may still be available from the neighbouring countries. It appears that the quality of Russian birch is much more dependent on the local supplier than is the case in Finland. The number of harvesting contractors as well as harvesting methods is large in Russia. In addition, the quality management of the harvesting and transportation operations fluctuates between the different workers and companies. It is also common that the best quality veneer logs are separated from the ordinary plywood logs already in logging site. As a result, the quality distribution of the plywood logs is biased due to the absence of the best qualities.

Literature Cited

Arponen, J. 2007. Tuontikoivutukin laatu. [Quality of imported birch logs in Finland]. Master's thesis on Forest Engineering and Forest Products Technology. University of Joensuu, Faculty of Forest Sciences. 50 p. (In Finnish with English abstract).

Heräjärvi, H. 2002. Properties of birch (*Betula pendula*, *B. pubescens*) for sawmilling and further processing in Finland. The Finnish Forest Research Institute, Research Papers 871. 52 p + Five Appendices.

Heräjärvi, H. 2004a. Static bending properties of Finnish birch wood. Wood Sci. Technol. 37(6): 523-530.

Heräjärvi, H. 2004b. Variation of basic density and Brinell hardness within mature Finnish *Betula pendula* and *B. pubescens* stems. Wood Fiber Sci. 36(2): 216-227.

Heräjärvi, H., Arponen, J. 2008. Log and veneer quality of Finnish and Russian birch in plywood production. In: Spear, M. (ed.). Proceedings of the International Panel Products Symposium 2008, 24th-26th September 2008, Espoo, Finland. The BioComposites Centre, Bangor, UK, p. 67-76.

Koponen, H. 1995. Puulevytuotanto. [Production wood panels]. Opetushallitus. 212p. (In Finnish).

Kärkkäinen, M. 2005. Maailman metsäteollisuus. [Forest industries of the world]. Metsäkustannus Ltd. 355 p. (In Finnish).

Luostarinen, K., Verkasalo, E. 2000. Birch as Sawn Timber and in Mechanical Further Processing in Finland. A Literature Study. Silva Fenn. Mon. 1. 40 p.

Peltola, A. (ed.). 2007. The Finnish Statistical Yearbook of Forestry 2007. Finnish Forest Research Institute. 436 p.

Verkasalo, E. 1997. Evaluating the potential of European white birch (*Betula pubescens*) for veneer and plywood by timber and wood quality. In: Nepveu, G. (ed.). Proc. IUFRO Div. 6 WP5.01.04 Biological Improvement of Wood Quality Workshop Connection between Silviculture and Wood Quality through

Modelling and Simulation Software, Kruger National Park, South Africa, 26-31 August, 1996, p. 431-439. INRA-Nancy, France.

Verkasalo, E., Heräjärvi, H., Arponen, J., Toppinen, A. 2007. Perspectives of wood resources, industry competitiveness and wood product markets for birch industries in the Baltic Sea area. In: Blanchet, P. (ed.). ISCHP '07 International Scientific Conference on Hardwood Processing, September 24-25-26, 2007, Quebec City, Canada. Proceedings, pp. 29 -35. FP Innovations Forintek Division (Canada), FCBA (Ranska) & IVALSA (Italy).