Economic Valuation of Damages Caused By Xangsane Typhoon in Vietnam Using Interregional Input-Output Model

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Abstract

This paper employs an adaptive modeling framework to investigate the consequences of a natural disaster for the economy in coastal region of Vietnam. Based on inter- regional Input-Output model, we simulate the response of the economy of Vietnam to the typhoon of Xangsane in 2006. The model is found consistent with available data, and provides two important insights. First, economic processes exacerbate a total costs of 2.18% total production value and 2.35% total value added (GVA) of Vietnam in 2006. Second, it takes 3 years for Vietnam's economy to recover after the typhoon. Moreover, there is a significant relation between direct and indirect costs of the disaster.

Keywords: climate change, typhoon, extreme hydro-meteorological phenomena, economic valuation, damage, inter-regional Input Output model

I. Introduction

Vietnam is one of the countries most affected by natural disasters. Coastal areas are vulnerable because of their relatively high economic and population density. According to the World Meteorological Organization (WMO), in the past 20 years, Vietnam has suffered more than 800 natural disasters (average of 40 waves per year) with increasing intensity and frequency causing great socio economic and environmental damages. Currently, Vietnam suffers annual losses of 1.4-1.8% of GDP due to natural disasters and extreme hydrological phenomena.
In Vietnam, valuation of economic losses caused by climate change and extreme hydrological phenomena is mentioned as one of priority activities in the National Target Program on Climate Change (2008), National Strategy on Climate Change (2011) and Vietnam's National Action Plan on Climate Change (2012).

Among the studies that have been published on the assessment of disaster economic consequences, many are based on Input-Output (I/O) models, which are powerful tools to assess how a shock, on one or several sectors, propagates into the economy through intermediate consumption and demand (e.g., Haimes and Jiang (2001); Bockarjova et al. (2004); Cochrane (2004); Okuyama et al. (2004)). Further, the economic interregional I/O model system can be applied in analysis impacts on residuals generated by interregional economic activities.
In this study, we used inter-regional I/O model to evaluate the long-term economic damage of Typhoon Xangsane (2006) which is a typical extreme storm in central Vietnam during period 2005-2015. The study use Isard inter-regional model (1951) with development of Richardson (1973) and Miyazawa (1976) for specific applications in typhoon damage valuation in Vietnam.

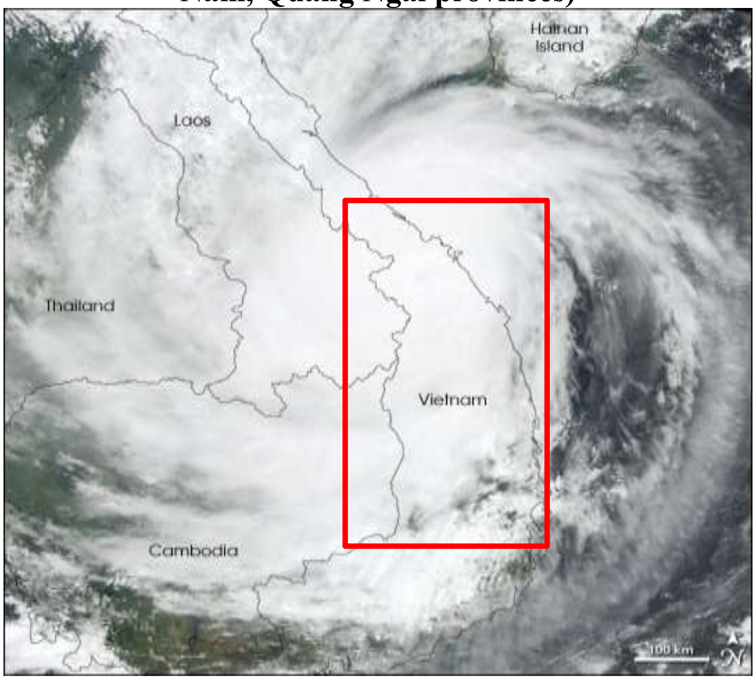
II. Overview about Xangsane Typhoon

Vietnamese authorities called Typhoon Xangsane the biggest storm to hit the country in several decades. Typhoon Xangsane formed on September 25, 2006, in the western Pacific near the coast of the Philippine Islands. Over the next 36 hours, it grew from a tropical depression (area of low air pressure) to a typhoon. The typhoon crossed the Philippines and was credited for causing 76 deaths there before crossing the East Sea and coming ashore in central Vietnam on October 1, according to the Agence France-Presse news service. As the storm came ashore in central Vietnam, it packed winds of 148 kilometers per hour (92 miles per hour), strongest level in Vietnam recorded history.

Typhoon Xangsane slammed into the coast of Vietnam on October 1, 2006, pounding the coastal city of Da Nang with sustained winds of 150 kilometers per hour (90 miles per hour) and heavy rain. The storm moved west over Laos, Cambodia, and Thailand, and by October 3, the clouds had cleared enough to give the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite a view of the hard-hit Vietnam coast. The image, top, reveals that Xangsane left extensive flooding in its wake. The land between the Vu Gia River and the Thu Bon River is covered with water. Mud gives the water on land its pale blue color in contrast to the dark blue and black seen in the ocean. As the sediment-laden water empties into the ocean, it pours a cloud of sediment into the ocean. The sediment creates the bright blue fan along the shore and in the bay near Da Nang. Though flooding isn't visible in Da Nang itself, the sediment in the bay suggests that the region may be flooded.

Most obviously flooded is Hoi An, a historic port city that is a World Heritage Site. The image shows that the Thu Bon River had burst its banks and was flowing through the city. According to the Associated Press, Typhoon Xangsane caused extensive damage in Da Nang, Hoi An, and the surrounding communities. The storm had killed 119 people as of October 2. Of these deaths, 41 were in Vietnam, and the remaining 78 were in the Philippines. In the city of Da Nang, which has 770,000 residents, 12,000 homes were destroyed and 113,000 were damaged, said the Associated Press. The provinces of Quảng Nam were also hard hit, with a total of 25 people killed. The storm damaged or destroyed around 320,000 homes, downed thousands of trees and power lines, and flooded major streets.

Figure 1: Typhoon Xangsane in 1st October, 2006 and study area (Hue, Da Nang, Quang Nam, Quang Ngai provinces)



Source: NASA image created by Jesse Allen, Earth Observatory (2006)

Significant agricultural damage was reported, especially in Hue Province. More than 3,000 square kilometers (1,200 sq. mi) of crops, mostly rice, were damaged or washed away by the floodwaters. There were also reports of heavy losses of poultry and livestock, and nearly 13 km² (5 sq. mi) of aquaculture and 786 fishing boats were lost.

3. Methodology

Input-output analysis ("I/O") is a form of macroeconomic analysis based on the interdependencies between economic sectors or industries. This method is commonly used for estimating the impacts of positive or negative economic shocks and analyzing the ripple effects throughout an economy. This type of economic analysis was originally developed by Wassily Leontief (1905–1999), who later won the Nobel Memorial Prize in Economic Sciences for his work in this area.

I/O model has been the most widely used methodology for disaster impact estimate for the recent decades (for example, Gordon and Richardson, 1996; Rose et al. 1997; and Okuyama et al., 1999). The popularity of I/O models for disaster related research is based mainly on the ability to reflect the economic interdependencies within an economy in detail for deriving 5 higher-order effects, and partly on its simplicity. The simplicity of the I/O framework has enabled integrative approaches, in which I/O models are combined with engineering models and/or data, in order to estimate higher-order effects that are more sensitive to the changes in physical destruction. Some examples of this approach include the links with transportation network models (Gordon et al., 1998, 2004; Cho et al, 2001; Sohn et al., 2004, among others), with lifeline network models (Rose, 1981; Rose et al. 1997; Rose and Benavides, 1998), and the comprehensive disaster assessment model, namely HAZUS (Cochrane et al., 1997).

The inter-regional I/O model is used to analyze economic impacts, describing on products flows between regions that allow estimation of the non-specific in a single I/O model. Leontief's standard relationship is in the form as follow:

$$A.X + Y = X \quad (1)$$

Where: A is a direct input coefficient matrix, X is vector of output, Y is a vector of final demand. In the interregional input-output analysis the matrix A was divided as:

$$A = \begin{bmatrix} A_{cc} & A_{cr} \\ A_{rc} & A_{rr} \end{bmatrix}$$

$$X = \begin{bmatrix} X_c \\ X_r \end{bmatrix}$$

$$\text{and } Y = \begin{bmatrix} Y_{cc} & Y_{cr} \\ Y_{rc} & Y_{rr} \end{bmatrix}$$

Where: Ack is sub-matrix that present region k used products of region c for intermediate input; Xc is vector gross output of region c and Xk is vector gross output of region k; Yck present final demand of region k use products of region c

Call $B = (I-A)^{-1}$

So we have X =B.Y and

$$B = \begin{bmatrix} B_{cc} & B_{cr} \\ B_{rc} & B_{rr} \end{bmatrix}$$

Follow Miyazawa (1976) the matrix B can be divided as:

$$Bcc = (I - Acc - Acr.(I - Acc)^{-1}.Arc)$$

$$Brr = (I - Arr - Arc.\ (I - Arr)^{-1}.Acr)$$

$$Bcr = Bcc.Acr(I\text{-}Arr)^{-1}$$

$$Brc = Brr.Arc(I - Acc)^{-1}$$

In other words: Bcc includes multipliers effects $(I\text{-}Acc)^{-1}$ and interregional feedback effects: Bcc + Brc - $(I\text{-}Acc)^{-1}$; Brc represent for *spillover effects* from region C to region R.

In the case of research on a sector group in a region related to other sectors in the region and other region, the matrix A can be divided as follow:

$$A = \begin{bmatrix} A^{RR}{}_{cc} & A^{RR}{}_{ck} & A^{RN}{}_{ch} \\ A^{RR}{}_{kc} & A^{RR}{}_{k} & A^{RN}{}_{kh} \\ A^{NR}{}_{hc} & A^{NR}{}_{hk} & A^{NN}{}_{hh} \end{bmatrix}$$

$$X = \begin{bmatrix} X^{r}{}_{c} \\ X^{r}{}_{k} \\ X^{N} \end{bmatrix}$$

$$Y = \begin{bmatrix} Y^{r}{}_{c} \\ Y^{r}{}_{k} \\ Y^{N} \end{bmatrix}$$

From equation (1) we have:

$$Xic = (I\text{- }AiiCC)^{-1}.(Aiicr.\ Xjc + Acr.Xr + Yicc + Yicr)\ (2)$$

$$Xjc = (I\text{- }Ajjcc)^{-1}.(Ajicc.\ Xic + Acr.Xr + Yjcr + Yjcr)\ (3)$$

$$Xr = ((I\text{-}Aiirr)^{-1}.(ANRhk.XRc + Arr.XR + Yrc+ Yrr)\ (4)$$

So, demand of i sectors group in a region is not only depend on final demand of those sector group but also depend on production demand of other sectors in the same region and others.

$$Put\text{: } vci = Vci/Xci$$

With: Vci is a vector value added of sector i, C region; Xci is a vector of output, C region

Rewrite follow matrix form, we have:

$$V = v.B.Y\ (5)$$

Where:

$$v= (vc, vr)$$

$$v.B = (Vc.Bcc+Vr.Brc, Vr.Brr +VcBcr)\ (6)$$

Final demand of C region includes products that is produced by itself and the product is produced by region r; C region used products by itself will be induced to value added of C region: Vc.Bcc; and C region used products of R region will be induced to value added of R region: Vr.Brc. Similar to the final demand of the R region.

And:

$$V = v.BY = [Vc.(Bcc.Ycc + Bcr.Yrc), + Vr.(Brc + Brr.Yrc); Vc.(Bcc.Ycr + Bcr.Yrr) + Vr.(Brc.Yrc + Brr.Yrr)](7)$$

Call ∂P is change in price and ∂X is change in production value, then:

$$\partial P = \alpha . (\partial X)^{-1} (8)$$

$$If\ \partial X>0 \rightarrow \Delta\partial P = -\alpha . (\partial X)^{-2} (9)$$

Equation (6) implies that

$$\partial X < 0 \rightarrow \Delta\partial P = \alpha . (\partial X)^{-2} \qquad (10)$$

Here α is considered the elastic coefficient determined from the value of production growth and PPI. Investment research transformed the interregional I/O model into a Ghosh (1956) interregional model. The Ghosh model has the form:

$$X = (I - A^{*\prime})^{-1} . V \qquad (11)$$

Here A *' is a Ghosh transformation matrix, V is a vector of value added

$$Put\ \ ki = Ki / Xi$$

Where Ki is the capital stock of sector i and Xi is the production value of sector I; increase the two sides we have:

$GCF = k.(I - A^{*\prime})^{-1}.\Delta V;$ with GCF is gross capital formation

for interregional:

$$(\Delta Vc, \Delta Vr) = (GCFc.(I\text{-}Acc) - GCFr.Arc, GCFr.(I\text{-}Arr) - GCFr.Acr).$$

I/O model data source

- Updated I/O table for 2016 with production value and intermediate costs calculated from the enterprise survey.
- Interregional I/O table in 2007 of 8 regions in Vietnam
- Adjustment of intermediate factor cost / regional production values according to the enterprise survey
- Check and balance the SLQ (Simple Location Quote)

SLQi = (XRij / XRj)/(XNij / XNj)

with:

XRij = Intermediate cost of sector j using product i of region R

XNij = Intermediate costs of sector j using product i of the nation

XRj = Production value of sector j

XNj = Production value of sector j of the nation.

IV. Economic loss due to Xangsane Typhoon using interregional I/O model

The table below shows 4 central provinces using products of the rest of Vietnam (ROV) for final production and final demand is greater than the ROV using 4 of 4 provinces. Some sectors have high utilization rate for production and final demand. Products of Sector No. 17, Sector No. 9, Sector No. 6 used by ROV as inputs for production are relatively large. Sector 6, sector 10 and sector 13 used by ROV for the last demand is quite high.

Table 4.1: Demand structure of 4 provinces and ROV

	Intermediate demand of 4 provinces for itself (%)	Intermediate demand of 4 provinces for ROV (%)	Final demand 4 provinces for itself (%)	Final demand 4 provinces for ROV (%)	Total demand for 4 provinces (100%)	Intermediate demand of ROV for itself	Intermediate demand of ROV for 4 provinces	Final demand Provincial ROV for itself	Final demand ROV for 4 provinces	Total demand ROV (100%)
1	66.5	0.0	33.5	0.0	100.0	68.7	0.1	31.1	0.0	100.0
2	84.8	0.0	15.2	0.0	100.0	84.3	1.4	14.3	0.1	100.0
3	58.4	0.0	41.6	0.0	100.0	62.1	0.0	37.9	0.0	100.0
4	37.7	13.9	41.5	6.9	100.0	43.1	0.1	56.7	0.1	100.0
5	32.0	15.9	49.8	2.3	100.0	36.7	0.0	63.3	0.0	100.0
6	34.2	18.4	36.0	11.4	100.0	38.3	0.1	61.5	0.1	100.0
7	4.2	0.0	95.8	0.0	100.0	12.7	0.0	87.3	0.0	100.0
8	54.0	13.8	27.5	4.7	100.0	56.2	0.0	43.8	0.0	100.0
9	47.2	17.1	28.1	7.6	100.0	50.9	0.0	49.0	0.0	100.0
10	9.9	7.1	64.3	18.7	100.0	16.0	0.0	83.9	0.1	100.0
11	42.2	0.1	57.6	0.1	100.0	44.7	0.0	55.3	0.0	100.0
12	44.6	0.0	55.4	0.0	100.0	47.9	0.2	51.8	0.0	100.0
13	3.5	1.5	67.7	27.3	100.0	3.7	0.0	96.3	0.0	100.0
14	85.3	3.4	11.1	0.1	100.0	86.7	0.1	13.2	0.0	100.0
15	83.6	11.7	4.3	0.4	100.0	84.6	0.2	15.2	0.0	100.0
16	76.2	16.8	6.8	0.2	100.0	77.7	0.1	22.2	0.0	100.0
17	46.7	31.9	13.8	7.6	100.0	49.5	0.4	49.9	0.1	100.0
18	81.1	0.3	18.5	0.1	100.0	82.0	0.0	18.0	0.0	100.0
19	52.1	0.0	47.9	0.0	100.0	55.1	0.0	44.9	0.0	100.0
20	47.2	0.4	51.9	0.4	100.0	51.2	0.0	48.7	0.0	100.0
21	67.0	4.0	27.5	1.5	100.0	68.5	0.1	31.3	0.1	100.0
22	68.9	2.6	27.6	0.9	100.0	70.8	0.0	29.2	0.0	100.0
23	58.5	10.0	27.3	4.2	100.0	60.6	0.0	39.4	0.0	100.0
24	1.1	0.0	98.9	0.0	100.0	1.2	0.0	98.8	0.0	100.0
25	2.2	0.3	92.2	5.3	100.0	5.6	0.0	94.1	0.3	100.0
26	1.8	0.2	90.8	7.3	100.0	1.9	0.0	98.1	0.0	100.0
27	10.9	1.3	81.0	6.7	100.0	15.3	0.0	84.5	0.2	100.0
28	5.8	0.0	94.2	0.0	100.0	11.9	0.0	88.1	0.0	100.0
Total	**48.35**	**11.18**	**36.63**	**3.84**	**100.00**	**51.66**	**0.15**	**48.14**	**0.04**	**100.00**

Source: Calculated from the inter-provincial I / O table of 4 central provinces and ROV (2018)

Typhoon Xangsane in 2006 with direct effects on the production value of 11 sectors, calculated from the 2016 price data, showing a decrease in output (table 4.2)

Table 4.2: Industries directly affected by Xangsane Typhoon at 4 central provinces

	Sectors	Production change due to typhoon (%)
1	Agriculture	-8.26
2	Forestry	-4.82
3	Fishery	-3.36
4	Food processing industry	-1.43
5	Textile, garment, leather	-2.60
6	Production of furniture, repair and installation	-5.66
7	Construction	-9.54
8	Trading	-3.84
9	Carriage	-9.39
10	Hotel and restaurant	-10.96
11	Real estate business	-4.93

Source: Research team (2018)

Due to the interdisciplinary nature of the industry, 11 sectors decreased, leading to the decrease of the remaining 17 industries (17) and the total production value of the region decreased by 3.83% and the total value added decreased by 4.01% labor income decreased by 3.64%, capital income decreased 5.27% and labor decreased by 1.79%.

Table 4.3: Economic loss by sector during Xangsane Typhoon at 4 central provinces

	Sector	Production reduction at 4 provinces (%)
1	Agriculture	-8.26
2	Forestry	-4.82
3	Seafood	-3.36
4	Food processing industry	-1.43
5	Textile, garment, leather	-2.60
6	Production of furniture, repair and installation	-5.66
7	Build	-9.54
8	Trade	-3.84
9	Carriage	-9.39
10	Hotel restaurant	-10.96
11	Trading in real estate	-4.93
12	Exploited	-0.59
13	Fruit and vegetable processing industry	-3.07

14	Paper processing industry	-0.47
15	Production of strawberry, rubber	-2.60
16	Non-metallic mineral products	-2.89
17	Devices	-1.59
18	electricity	-0.25
19	Country	-1.36
20	Communications	-5.62
21	Financial intermediation services	-1.49
22	Science and technology	-3.32
23	Financial support services	-2.61
24	State management, security and defense	-4.70
25	Medical	-5.62
26	Health care activities	-5.93
27	Arts, entertainment	-1.94
28	Other services	-3.39
	Total production value	**-3.83**
	Gross value added	**-4.01**
	Employee income	**-3,64**
	Labor	**-1,79**

Source: Research team (2018)

Due to the inter-regional relations, the product of this region is the input of other regions, so most sectors of the region do not directly affect the storm also reduced production, as in the table below.

Table 4.4: Economic impact spreads to rest of Vietnam (ROV)

	Sector	**Production reduction at ROV (%)**
1	Agriculture	-0.31
2	Forestry	-2.69
3	Seafood	-1.59
4	Food processing industry	-1.73
5	Textile, garment, leather	-2.89
6	Production of furniture, repair and installation	-1.93
7	Build	-2.28
8	Trade	-2.92
9	Carriage	-1.74
10	Hotel restaurant	-2.06
11	Trading in real estate	-2.58
12	Exploited	-2.77
13	Fruit and vegetable processing industry	-0.34
14	Paper processing industry	-2.88

15	Production of strawberry, rubber	-1.98
16	Non-metallic mineral products	-0.82
17	Devices	-3.00
18	Electricity	-1.43
19	Country	-2.31
20	Communications	-2.55
21	Financial intermediation services	-1.91
22	Science and technology	-1.74
23	Financial support services	-2.61
24	State management, security and defense	-2.73
25	Medical	-2.77
26	Health care activities	-3.55
27	Arts, entertainment	-2.69
28	Other services	-3.49
	Total production value	-2.15
	Gross value added	-2.31
	Employee income	-1,76
	Labor	-0,31

Source: Research team (2018)

Table 4.5: The impact of Xangsane typhoon on sectors and GVA of Vietnam

	Sector	National production (%)
1	Agriculture	-0.46
2	Forestry	-2.73
3	Seafood	-1.63
4	Food processing industry	-1.73
5	Textile, garment, leather	-2.88
6	Production of furniture, repair and installation	-2.00
7	Build	-2.41
8	Trade	-2.94
9	Carriage	-1.88
10	Hotel restaurant	-2.23
11	Trading in real estate	-2.62
12	Exploited	-2.73
13	Fruit and vegetable processing industry	-0.39
14	Paper processing industry	-2.83
15	Production of strawberry, cau su	-2.00
16	Non-metallic mineral products	-0.86
17	Devices	-2.97
18	Electricity	-1.40
19	Country	-2.29

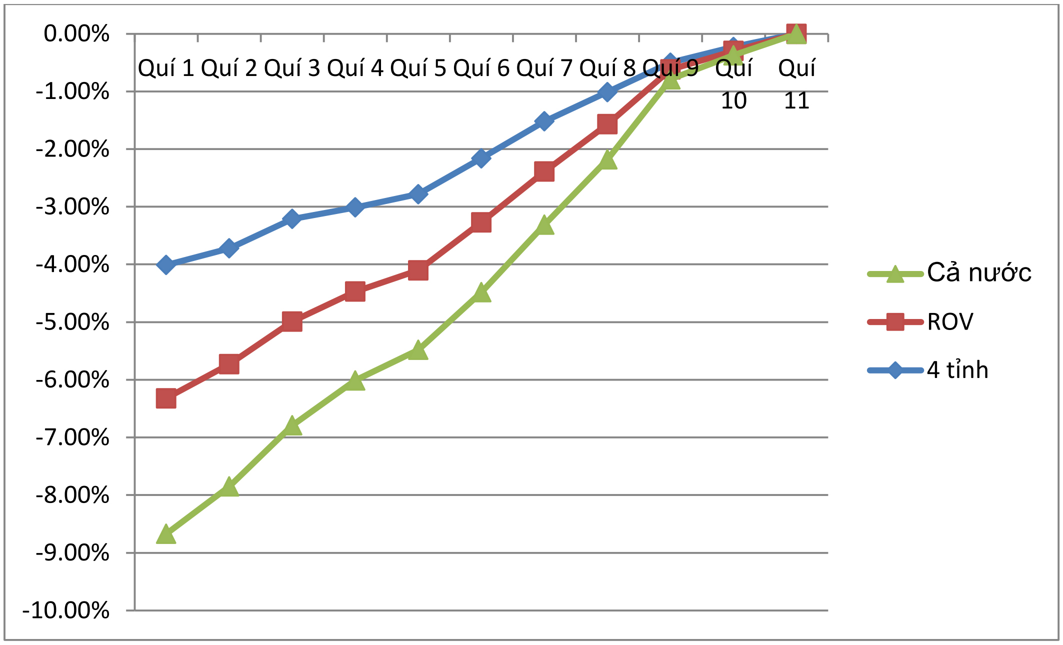
20	Communications	-2.61
21	Financial intermediation services	-1.90
22	Science and technology	-1.77
23	Financial support services	-2.61
24	State management, security and defense	-2.77
25	Medical	-2.83
26	Health care activities	-3.60
27	Arts, entertainment	-2.68
28	Other services	-3.49
	Total production value	-2.18
	Gross value added	-2.35
	Employee income	-1,78
	Labor	-0,37

Source: Research team (2018)

Direct impacts of the typhoon affect directly the 11 sectors of the four provinces of Hue, Da Nang, Quang Nam and Quang Ngai. Due to the interdisciplinary relationship, it affects the remaining sectors of the rest of Vietnam resulting in a decrease in total production value and gross value added (GVA) (2.15% and 2.31%). As a result, total production value of Vietnam decreased by 2.18%, GVA decreased 2.35%, labor income decreased by 1.78%, capital income decreased by 2, 92% and labor decreased by 0.37%.

Due to inter-regional relations, one region uses products of the other region as input costs, thus resulting in production value and GVA of the rest of Vietnam decrease. As production decreases, price increases leading to further production cycles that affects production output, price and GVA. However, this cycle will at some point converge, meaning that the effects of the storm will gradually disappear and a new price level is formed. According to calculations affected by the storm about 3 years will expire.

Figure 4.1: Periodic impact of the storm on the economy



Source: Research team (2018)

Figure 4.1 shows the effects of storms on the economy (in the 4 provinces and the rest). The most severe impacts happened right after the storm. Then, for the following quarters, the level of influence decreased gradually and about 11 quarters (3 years), these effects were eliminated (a new price level is formed).

5. Conclusion

In the event of a disaster, it will affect the economy not only in the short term but also in the medium term (1-3 years) and long term (over 3 years). Assessing the economic damage caused by natural disasters is significant in providing input into disaster management and extreme hydrological phenomena. UNEP (2005) outlines five major applications of disaster risk assessment: (i) supporting ministries in resuming production after the disaster, (ii) developing proactive measures to prevent natural disasters, (iii) being as a basis for financing investment options for disaster mitigation adaptation systems and climate change; and (iv) the socio-economic development planning of the country, locality, region or sector taking into account the potential short-term and long-term natural disasters.

This study shows that the economic consequences of typhoon Xangsane are not only short-term but also long-term, in which GDP is severely affected by the storm and rehabilitated. Implications of the study could support disaster preparedness as well as investment in post-disaster reconstruction in Vietnam.

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