CHAPTER VII

BACKPROPAGATION WITH ADDITIONAL INPUT VARIABLES

7.1 Additional Varibles

From previous chapter, the input variables include GDP growth rates and saving deposit rates. In this chapter, it is focused on whether additional input variables improve the forecasting results.

Other available variables are values of destroyed banknotes and values of admitted banknotes from 1989-1996 which are possible to be additional input variables. Input sets are defined in order to find out the minimum sum-squared error of testing data. Possible combinations of inputs are shown in Table 7.1.

Table 7.1 - Input Sets

Input Set No.	GDP Growth Rates	Saving Depostis Rates	Destroyed Banknotes	Admitted Banknotes
1	X			
2		X		
3			X	
4				X
5	X	X		
6	X		X	
7	X			X
8		X	X	
9		X		X
10			X	X
11	X	X	X	

Table 7.1 - Input Sets (cont.)

Input Set No.	GDP Growth Rates	Saving Deposits Rates	Destroyed Banknotes	Admitted Banknotes
12	X	X		X
13	X		X	X
14		X	X	X
15	X	X	X	X

7.2 Experimental Conditions

7.2.1 Training Data

Training data contains 48 input data depending on the input sets and 48 outputs data which are issued banknotes from 1989 to 1992. The input data which are GDP growth rates, saving deposit rates, values of destroyed banknotes, and values of admitted banknotes are shown in Table 5.1, 5.2, 7.2 and 7.3 respectively. The outputs, the values of monthly issued banknotes are shown in Table 5.3.

1. GDP Growth Rates (%)[*] January 1989 - December 1992

2. Saving Deposit Rates (%)[*] January 1989 - December 1992

3. Values of Destroyed Banknotes (A thousand millions of baht)[*]

January 1989 - December 1992

Table 7.2 - Destroyed Banknotes : 1989-1992

Month/Year	1989	1990	1991	1992
January	2.272	1.380	9.363	4.579
February	1.165	4.463	10.207	7.640
March	2.311	5.165	6.601	7.074
April	1.661	5.295	4.711	8.273
May	3.584	6.803	5.365	2.967
June	3.341	6.459	5.462	11.356
July	1.605	7.795	5.219	9.134

Table 7.2 - Destroyed Banknotes (1989-1992) (cont.)

Month/Year	1989	1990	1991	1992
August	2.278	6.241	4.970	7.580
September	1.510	6.822	6.382	10.978
October	3.283	8.177	6.280	6.851
Novovember	3.159	13.173	4.175	7.405
December	2.119	8.266	3.357	5.594
Total	**28.288**	**80.039**	**72.092**	**89.431**

4. Values of Admitted Banknotes (A thousand millions of baht)[†]

January 1989 - December 1992

Table 7.3 - Admitted Banknotes : 1989-1992

Month/Year	1989	1990	1991	1992
January	18.127	21.547	26.272	31.827
February	18.110	17.456	22.225	27.696
March	16.933	18.068	23.619	23.937
April	14.155	16.372	20.731	22.714
May	18.605	21.650	22.581	22.157
June	17.949	20.116	22.293	28.361
July	16.367	21.064	22.299	26.048
August	17.566	20.848	23.879	28.151
September	15.693	19.817	24.418	26.461
October	16.100	20.971	24.959	25.028
November	15.545	21.378	23.733	26.033
December	13.938	17.352	20.010	23.235
Total	**199.448**	**236.639**	**277.019**	**311.648**

5. Values of Monthly Issued Bank Notes (millions of baht) :

January 1989 - December 1992

7.2.2 Testing Data

Testing data contains 48 input data having GDP growth rates and saving deposit rates and 48 output data which are issued banknotes from 1993 to 1996. The input data which are GDP growth rates, saving deposit rates, values of destroyed banknotes, and values of admitted banknotes are shown in Table 5.4, 5.5, 7.4 and 7.5 respectively. The outputs, the values of monthly issued banknotes are demonstrated in Table 5.6.

1. GDP Growth Rates (%)† January 1993 - December 1996

2. Saving Deposit Rates (%)† January 1993 - December 1996

3. Values of Destroyed Banknotes (A thousand millions of baht)† January 1993 - December 1996

Table 7.4 - Destroyed Banknotes : 1993-1996

Month/Year	1993	1994	1995	1996
January	7.085	10.155	6.680	3.755
February	7.010	11.785	4.957	4.581
March	5.912	9.739	6.743	4.950
April	4.439	5.618	10.483	4.329
May	10.019	6.791	9.050	19.491
June	9.152	11.888	11.034	14.249
July	8.554	7.810	12.104	13.073
August	10.701	9.437	11.175	11.598
September	12.824	8.929	14.594	10.908
October	10.243	6.464	9.591	11.048
Novovember	10.048	7.239	12.820	12.067
December	12.622	7.364	5.836	7.512
Total	**108.609**	**103.219**	**115.067**	**117.561**

4. Values of Admitted Banknotes (A thousand millions of baht)[†]

Table 7.5 - Admitted Banknotes : 1993-1996

Month/Year	1993	1994	1995	1996
January	40.006	41.231	53.163	63.344
February	29.603	38.635	46.770	53.409
March	30.842	38.672	46.958	59.799
April	27.332	32.907	38.991	54.104
May	31.090	36.107	50.904	56.004
June	32.524	38.951	48.504	52.824
July	32.304	36.751	47.621	55.570
August	32.697	41.976	49.065	54.443
September	32.171	38.250	44.089	50.958
October	30.638	36.019	45.094	50.369
Novovember	32.413	40.564	49.010	51.730
December	29.890	37.760	42.947	47.380
Total	**381.510**	**457.823**	**563.116**	**649.934**

5. Values of Monthly Issued Banknotes (millions of baht)[†] :

January 1993 - December 1996

7.2.3 Initial Parameters

The issue here is to find out which input set that produces minimum sum-squared error of testing data. All input sets are tested through training while number of neurons randomly chosen are 17, 24, and 33. Other parameters remain the same.

7.2.4 Experimental Objectives

The experimental objectives are as follows:

1. Investigate the result from each input set.

2. Find the number of neurons that gives minimum sum-squared error of testing data.

3. Confirm the learning rate that gives minimum sum-squared error of testing data.

4. Investigate the result from using different training and testing data of the same inputs.

5. Investigate the result from using data from regression technique.

7.3 Training and Results

7.3.1 Investigation of the result from each input set.

This section covers test set 1-3 where weight and bias are initialized by random, epoch = 2000, learning rate = 0.001, rate of increase in learning rate = 1.05, and rate of decrease in learning rate = 0.7. The parameters are number of neurons (17, 24, 33) and input set. The results are shown in Table 7.1-7.3.

1. Test Set 1: number of neurons = 17

Table 7.6 - Training Result

Input Set No.	SSE of Training Data	SSE of Testing Data
1	0.1154170	2.4652
2	0.1672430	1.9257
3	0.1870070	3.6099
4	0.1242150	**0.7657**
5	0.1003510	2.0973
6	0.2112270	4.1739
7	0.1046720	2.0438
8	0.2112270	4.1739
9	0.1390250	0.9208

Table 7.6 - Training Result (cont.)

Input Set No.	SSE of Training Data	SSE of Testing Data
10	0.1869880	3.6215
11	0.0834194	96.2065
12	0.1092240	48.3578
13	0.1870780	3.6571
14	0.1870780	3.6571
15	0.1886160	3.7626

From Table 7.6, input set number 4 gives the minimum sum-squared error of testing data which is 0.7657.

2. Test Set 2: number of neurons = 24

Table 7.7 - Training Result

Input Set No.	SSE of Training Data	SSE of Testing Data
1	0.1108640	2.7580
2	0.1634150	1.5190
3	0.1956810	3.9479
4	0.1209870	**0.8192**
5	0.0913409	3.8151
6	0.1872040	3.6748
7	0.1148300	2.5111
8	0.1872040	3.6748
9	0.0982086	7.0563
10	0.1870090	3.6092
11	0.1870510	3.5980
12	0.0881156	2.1600
13	0.1957760	3.3177
14	0.1957760	3.3177
15	0.1869980	3.6361

From Table 7.7, input set number 4 gives the minimum sum-squared error of testing data which is 0.8192.

3. Test Set 3: number of neurons = 33

Table 7.8 - Training Result

Input Set No.	SSE of Training Data	SSE of Testing Data
1	0.1123180	2.5457
2	0.1603520	1.0502
3	0.1870590	3.5964
4	0.1207300	**0.9408**
5	0.0941573	2.3127
6	0.1884690	3.4967
7	0.1087480	8.4094
8	0.1884690	3.4967
9	0.1438510	3.9884
10	0.1870310	3.6474
11	0.1905730	3.8304
12	0.0818196	12.6601
13	0.1870100	3.6089
14	0.1870100	3.6089
15	0.1869870	3.6244

From Table 7.8, input set number 4 gives the minimum sum-squared error of testing data which is 0.9408.

From the test set 1-3, it indicates that only using the value of admitted banknotes as the input variable results in the minimum sum-sqaured error of testing data in all three randomed number of neuron. Input set number 4 is chosen for further training. Also it can be concluded that choosing the appropriate input variables leads to better results.

7.3.2 Finding the number of neurons that gives minimum sum-squared error of testing data.

Input set 4 (normalization type B) is used. Weight and bias are initialized by random, epoch = 2000, learning rate = 0.001, rate of increase in learning rate = 1.05, and rate of decrease in learning rate = 0.7. Input set 4 is chosen for further training since it provides the minimum SSE of testing data. Parameter is number of neurons (1-48). The results are shown in Table 7.9.

Table 7.9 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.199936	3.2545
2	0.121093	0.7855
3	0.121270	0.8832
4	0.187593	3.5439
5	0.187212	3.5794
6	0.124481	1.5667
7	0.123004	1.0562
8	0.122329	1.2545
9	0.122280	1.1861
10	0.121205	0.9669
11	0.122682	1.1527
12	0.121150	0.9559
13	0.121000	1.3562
14	0.123035	1.1600
15	0.121232	0.8114
16	0.120959	0.8016
17	0.124215	0.7657
18	0.121677	1.1204
19	0.121524	0.8701
20	0.120905	1.3331
21	0.120155	0.8307
22	0.120833	0.8248
23	0.124480	1.5373

Table 7.9 Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
24	0.120987	0.8192
25	0.122775	1.2103
26	0.121280	1.1441
27	0.121439	0.8623
28	0.120743	1.1029
29	0.120807	0.9336
30	0.121532	0.8330
31	0.122142	1.2341
32	0.121338	0.9831
33	0.120730	0.9408
34	0.130287	1.0785
35	0.121558	1.2055
36	0.120822	1.1399
37	0.120381	0.8583
38	0.122751	1.3721
39	0.124838	0.9474
40	0.121149	1.0746
41	0.123281	1.0423
42	0.120512	1.0005
43	0.124971	1.2826
44	0.120753	1.2778
45	0.121385	**0.7646**
46	0.120217	0.8930
47	0.120545	0.9186
48	0.123937	1.2691

From Table 7.9, the number of neurons that generates the minimum sum-squared error of testing data is 45 where the error is 0.7646. Number of neurons has an influence on the result.

7.3.3 Confirmation of the learning rate that gives minimum sum-squared error of testing data.

Input set 4 (normalization type B) is used. Weight and bias are initialized by random, epoch = 2000, rate of increase in learning rate = 1.05, rate of decrease in learning rate = 0.7, and number of neurons = 45. Parameter is learning rate. The results are shown in Table 7.10.

Table 7.10 - Search by Learning Rate

Learning Rate	SSE of Training Data	SSE of Testing Data
0.0009	0.121360	0.7565
0.0010	0.121386	0.7646
0.0050	0.121607	0.7718
0.0080	0.121378	0.7622
0.0090	0.121359	**0.7535**
0.0200	0.121369	0.7590
0.1000	0.121376	0.7613

Learning rates have been used to optimize the result. From Table 7.10, the best learning rate is 0.009 and data is trained for more than 100,000 epochs. The last SSE of testing data is 0.5003. The figures of forecasting issued banknotes are shown in Table B.1. From Table B.1, the errors of forecasting issued banknotes in 1993-1996 are 4.5%, 6.27%, -8.68%, and 12.56% respectively while the overall error is 8.6%. Forecasting new issued banknotes and errors are compared in Table 7.11 and 7.12.

Table 7.11 - Comparison the results from NN (Table B.1) and Regression

Year	Neural Network (Millions of Baht)	Actual (Millions of Baht)	Regression (Millions of Baht)
1993	214,917.61	235,221.00	240,990.35
1994	245,929.15	279,240.00	275,134.97
1995	267,242.47	323,147.50	317,050.22
1996	267,160.67	371,620.00	354,069.77

Table 7.12 - Comparison the errors from NN (Table B.1) and Regression

Year	Neural Network (%)	Regression (%)
1993	8.63	**-2.45**
1994	11.93	**1.47**
1995	20.92	**1.89**
1996	28.11	**4.72**

Changing learning rate improves accuracy of the results. However the final results are not better than those of regression technique.

7.3.4 Investigatation of the result from using different training and testing data of the same inputs.

Input set 4 (normalization type B) is used. Weight and bias are initialized by random, epoch = 2000, learning rate = 0.009, rate of increase in learning rate = 1.05, and rate of decrease in learning rate = 0.7. Parameter is number of neurons. Training data and testing data are mentioned in Table 7.13. The training results are shown in Table A.1-A.9. The forecasting figures of issued banknotes and new issued banknotes are summarized as demonstrated in Table 7.14 and 7.15 respectively.

Comparison of the minimum sum-squared error of testing data from Table A.1 to A.9 is demonstrated in Table 7.13.

Table 7.13 - Summary from Table A.1-A.9

Forecasting for year	Table	Training Data	Testing Data	No.of Neuron	Minimum SSE of Testing Data
1996	**A.1**	1992-1995	1993-1996	47	**0.4100**
1996	A.2	1991-1995	1992-1996	10	0.4581
1996	A.3	1990-1995	1991-1996	10	0.4977
1996	A.4	1989-1995	1990-1996	10	0.5180
1995	**A.5**	1991-1994	1992-1995	43	**0.3005**
1995	A.6	1990-1994	1991-1995	20	0.3418
1995	A.7	1989-1994	1990-1995	4	0.3605
1994	**A.8**	1990-1993	1991-1994	25	**0.2244**
1994	A.9	1989-1993	1990-1994	14	0.2444

From Table 7.13, different ranges of data result in different sum-squared error of testing data. Table A.1, A.5, and A.8 give the results with minimum sum-squared error for 1996, 1995, and 1994 respectively where data in each test set cover four years.

Table 7.14 Summary of Forecasting Issued Banknotes from Table B.1-B.10

Table	Year	Actual (millions of baht)	Forecast (millions of baht)	Error (millions of baht)	% of Error
B.1	1993	436,080	416,266.81	19,813.19	4.50
	1994	523,030	490,221.05	32,808.95	6.27
	1995	637,780	582,398.37	-55,381.63	-8.68
	1996	741,860	648,691.67	93,168.33	12.56
	Sum	**2,338,750**	**2,137,577.80**	**201,172.2**	**8.60**
B.2	1993	436,080	458,417.56	-22,337.56	-5.12
	1994	523,030	538,173.73	-15,143.73	-2.90
	1995	637,780	635,778.69	2,001.31	0.31
	1996	741,860	702,716.02	39,143.98	5.27
	Sum	**2,338,750**	**2,335,085.90**	**3,664.10**	**0.16**
B.3	1992	363,712	369,541.26	-5,829.26	-1.45
	1993	436,080	443,341.13	-7,261.13	-1.67
	1994	523,030	526,221.35	-3,191.35	-0.61
	1995	637,780	632,654.46	5,125.54	0.80
	1996	741,860	701,874.10	39,985.90	5.39
	Sum	**2,702,462**	**2,673,632.30**	**28,829.70**	**1.07**
B.4	1991	314,474	325,284.62	-10,810.62	-3.44
	1992	363,712	363,340.16	371.84	0.10
	1993	436,080	443,325.61	-7,245.61	1.66
	1994	523,030	530,119.99	-7,089.99	-1.36
	1995	637,780	633,875.23	3,904.77	0.61
	1996	741,860	701,503.62	40,356.38	5.44
	Sum	**3,016,936**	**2,997,449.20**	**19,486.80**	**0.65**
B.5	1990	268,076	282,609.56	-14,533.56	-5.40
	1991	314,474	326,750.28	-12,276.28	-3.90
	1992	363,712	368,376.77	-4,664.77	-1.28
	1993	436,080	453,030.03	-16,950.03	-3.89
	1994	523,030	542,348.83	-19,318.83	-3.69
	1995	637,780	643,343.08	-5,563.08	-0.87
	1996	741,860	705,839.10	36,020.90	4.86
	Sum	**3,285,012**	**3,322,297.70**	**-37,285.70**	**-1.14**

Table 7.14 Summary from Table B.1-B.10 (cont.)

Table	Year	Actual (millions of baht)	Forecast (millions of baht)	Error (millions of baht)	% of Error
B.6	1992	363,712	362,989.02	722.98	0.20
	1993	436,080	430,993.65	5,086.35	1.17
	1994	523,030	512,236.74	10,793.26	2.06
	1995	637,780	609,001.33	28,778.67	4.51
	Sum	**1,960,602**	**1,915,220.70**	**45,381.26**	**2.31**
B.7	1991	314,474	334,489.01	-20,015.01	-6.36
	1992	363,712	372,394.34	-8,682.34	-2.39
	1993	436,080	448,394.21	-12,314.21	-2.82
	1994	523,030	527,983.11	-4,953.11	-0.95
	1995	637,780	622,766.52	15,013.48	2.35
	Sum	**2,275,076**	**2,306,027.20**	**-30,951.19**	**-1.36**
B.8	1990	268,076	283,119.73	-15,043.73	-5.60
	1991	314,474	325,074.33	-10,600.33	-3.37
	1992	363,712	361,460.65	2,251.35	0.62
	1993	436,080	437,516.81	-1,436.81	-0.33
	1994	523,030	523,189.92	-159.92	-0.03
	1995	637,780	633,757.66	-4,022.34	0.63
	Sum	**2,543,152**	**2,564,118.70**	**-20,966.70**	**-0.82**
B.9	1991	314,474	318,124.18	-3,650.18	-1.16
	1992	363,712	351,913.91	11,798.09	3.24
	1993	436,080	424,579.62	11,500.38	2.64
	1994	523,030	500,315.48	22,714.52	4.30
	Sum	**1,637,296**	**1,594,933.10**	**42,362.90**	**2.59**
B.10	1990	268,076	279,291.36	-11,215.36	-4.18
	1991	314,474	322,350.00	-7,876.29	-2.50
	1992	363,712	360,672.69	3,039.31	0.84
	1993	436,080	434,388.83	1,691.17	0.39
	1994	523,030	506,407.94	16,622.88	3.18
	Sum	**1,905,372**	**1,903,110.80**	**2,261.18**	**0.12**

Table 7.15 Calculating New Issued Banknotes from Table 7.14

Table	Year	Actual (millions of baht)	Forecast (millions of baht)	Error (millions of baht)	% of Error
B.1	1993	235,221	215,401.61	19,819.39	8.43
	1994	279,240	246 429.15	32,810.85	11.75
	1995	323,148	267,767.97	55,380.03	17.14
	1996	371,620	278,465.67	93,154.33	25.07
	Sum	**1,209,229**	**1,008,064.40**	**201,164.60**	**16.64**
B.2	1993	235,221	257,552.36	-22,331.36	-9.49
	1994	279,240	294,381.83	-15,141.83	-5.42
	1995	323,148	321,148.29	1,999.71	0.62
	1996	371,620	332,480.02	39,139.98	10.53
	Sum	**1,209,229**	**1,205,562.50**	**3,666.50**	**0.30**
B.3	1992	203,705	209,534.36	-5,829.36	-2.86
	1993	235,221	242.475.93	-7,254.93	-3.08
	1994	279,240	282,429.45	-3,189.45	-1.14
	1995	323,148	318,024.06	5,123.94	1.59
	1996	371,620	331,648.00	39,972.00	10.76
	Sum	**1,412,934**	**1,384,111.80**	**28,822.20**	**2.04**
B.4	1991	170,430	181,240.22	-10,810.22	-6.34
	1992	203,705	203,333.26	371.64	0.18
	1993	235,221	242,460.41	-7,239.41	-3.08
	1994	279,240	286,328.09	-7,088.09	-2.54
	1995	323,148	319,244.83	3,903.17	1.21
	1996	371,620	331,277.62	40,342.38	10.85
	Sum	**1,583,364**	**1,563,884.40**	**19,479.57**	**1.23**
B.5	1990	150,983	165,516.66	-14,533.66	-9.63
	1991	170,430	182,705.88	-12,275.88	-7.20
	1992	203,705	208,369.87	-4,664.87	-2.29
	1993	235,221	252,164.83	-16,943.83	-7.20
	1994	279,240	298,556.93	-19,316.93	-6.92
	1995	323,148	328,712.68	-5,564.68	-1.72
	1996	371,620	335,613.10	36,006.90	9.69
	Sum	**1,734,347**	**1,771,640.00**	**-37,292.95**	**-2.15**

Table 7.15 Calculating New Issued Banknotes from Table 7.14 (cont.)

Table	Year	Actual (millions of baht)	Forecast (millions of baht)	Error (millions of baht)	% of Error
B.6	1992	203,705	202,982.12	722.88	0.35
	1993	235,221	230,128.45	5,029.55	2.17
	1994	279,240	268,444.84	10,795.16	3.87
	1995	323,148	294,370.93	28,777.07	8.91
	Sum	**1,041,314**	**995,926.34**	**45,387.66**	**4.36**
B.7	1991	170,430	190,444.61	-20,014.61	-11.74
	1992	203,705	212,387.44	-8,682.44	-4.26
	1993	235,221	247,529.01	-12,308.01	-5.23
	1994	279,240	284,191.21	-4,951.21	-1.77
	1995	323,148	308,136.12	15,011.88	4.65
	Sum	**1,211,744**	**1,242,688.40**	**-30,944.39**	**-2.55**
B.8	1990	150,983	166,026.83	-15,043.83	-9.96
	1991	170,430	181,029.93	-10,599.99	-6.22
	1992	203,705	201,453.75	2,251.25	1.11
	1993	235,221	236,651.61	-1,430.61	-0.61
	1994	279,240	279,398.02	-158.02	-0.06
	1995	323,148	319,127.26	4,020.74	1.24
	Sum	**1,362,727**	**1,383,687.40**	**-20,960.40**	**-1.54**
B.9	1991	170,430	174,079.78	-3,649.78	-2.14
	1992	203,705	191,907.01	11,797.99	5.79
	1993	235,221	223,714.42	11,506.58	4.89
	1994	279,240	256,523.58	22,716.42	8.14
	Sum	**888,596**	**846,224.79**	**42,371.21**	**4.77**
B.10	1990	150,983	162,198.46	-11,215.46	-7.43
	1991	170,430	178,305.60	-7,875.60	-4.62
	1992	203,705	200,665.79	3,039.21	1.49
	1993	235,221	233,523.63	1,697.37	0.72
	1994	279,240	262,616.04	16,623.96	5.95
	Sum	**1,039,579**	**1,037,309.50**	**2,269.48**	**0.22**

From Table 7.14, errors of forecasting issued banknotes for 1996, 1995, and 1994 range from 4.86% to 5.39%, 0.63 to 4.51, and -1.36 to 2.59 respectively, excluding Table B.1. Overall errors range from -1.6% to 2.59%. Different ranges of data incur different results. Since the overall errors of forecasting are lower than those of individuals in general, a possible forecasting method can be conducted by deducting the known figures from the summation.

From Table 7.15, errors of forecasting new issued banknotes for 1996, 1995, and 1994 range from 9.69% to 10.53%, 1.24% to 8.91%, and 5.95% to 8.14% respectively, excluding Table B.1. Overall errors range from -2.55% to 4.77%.

The minimum error for each year is demonstrated in Table 7.16.

Table 7.16 Comparison the errors from NN (Table B.2-B.10) and Regression

Year	Neural Network (%)	Regression (%)
1993	NA	-2.45
1994	5.95	1.47
1995	1.24	1.89
1996	9.69	4.72

Comparing to Table 7.12, the accuracy of result is improved. However the results are still not more accurate than those of regression technique.

7.3.5 Investigate the result from using data from regression technique

Data used in training and testing include lnGDP (millions of baht), saving deposit rates (%), and D8586 during 1989-1995 as shown in Table 7.17. Training data

and testing data are summarized as demonstrated in Table 7.18. Weight and bias are initialized by random, epoch = 500, rate of increase in learning rate = 1.05, and rate of decrease in learning rate = 0.7. Parameters are number of neurons, learning rate, and error goal. The results are shown in Table C.1-C.4.

Table 7.17 - Data for Training and Testing for 7.3.5

Year	GDP	lnGDP	Saving Rate	D8586	New Issued Banknotes
1980	662,482	13.4037	8.00	0	-
1981	760,356	13.5415	9.00	0	-
1982	841,569	13.6430	9.00	0	-
1983	920,989	13.7332	8.50	0	-
1984	988,070	13.8035	9.00	0	-
1985	1,056,496	13.8705	8.50	1	-
1986	1,133,397	13.9407	5.50	1	-
1987	1,299,913	14.0778	5.50	0	-
1988	1,559,804	14.2601	6.75	0	-
1989	1,856,992	14.4345	7.25	0	-
1990	2,183,545	14.5965	11.00	0	-
1991	2,506,635	14.7345	8.50	0	-
1992	2,834,200	14.8573	6.25	0	-
1993	3,179,500	14.9722	5.00	0	235,221.0
1994	3,634,848	15.1061	5.00	0	279,240.0
1995	4,194,600	15.2493	5.00	0	323,147.5
1996	-	-	-	-	371,620.0

Table 7.18 - Training and Testing Data

Data/Forecast	1993	1994	1995	1996
Training:				
Input	1980-1991	1980-1992	1980-1993	1980-1994
Output	1992	1993	1994	1995
Testing:				
Input	1981-1992	1981-1993	1981-1994	1981-1995
Output	1993	1994	1995	1996

Those parameters which give the minimum error for each year are summarized in Table 7.19.

Table 7.19 - Summary of the Outstanding Results

Year	No. of Neuron	Learning Rate	Error Goal	SSE of Training	SSE of Testing	Output	% of Error
1993	3	10^{-2}	10^{-2}	9.30×10^{-4}	1.03×10^{-6}	234,200	0.43
	8	1	10^{-2}	1.15×10^{-3}	5.48×10^{-6}	237,560	-0.99
1994	5	1	10^{-1}	1.81×10^{-3}	2.23×10^{-6}	277,750	0.53
	5	1	10^{-2}	1.81×10^{-3}	2.23×10^{-6}	277,750	0.53
1995	2	10^{-1}	10^{-2}	2.41×10^{-3}	2.73×10^{-5}	328,370	-1.61
1996	8	1	10^{-1}	3.26×10^{-3}	3.35×10^{-7}	371,040	0.16
	8	1	10^{-2}	3.26×10^{-3}	3.35×10^{-7}	371,040	0.16

From Table 7.19, the forecasting new issued banknotes with minimum errors in 1993, 1994, 1995, and 1996 are 234,200, 277,750, 328,370, and 371,040 respectively. For parameters, even the outstanding ones are not seen, they can be ranged. The range of learning rates is from 10^{-2} to 1 while that of error goals is from 10^{-2} to 10^{-1}. The number of neurons for each year is different from others. Hence it may not be a good indicator to search for the result. SSEs of training data range from 9.30×10^{-4} to 3.26×10^{-3}.

Table 7.20 - Comparison the results from NN (Table C.1-C.4) and Regression

Year	Neural Network (Millions of Baht)	Actual (Millions of Baht)	Regression (Millions of Baht)
1993	234,200	235,221.00	240,990.35
1994	277,750	279,241.00	275,134.97
1995	328,370	323,147.50	317,050.22
1996	371,040	371.620.00	354,069.77

Table 7.21 - Comparison the errors from NN (Table C.1-C.4) and Regression

Year	Neural Network (%)	Regression (%)
1993	**0.43**	-2.45
1994	**0.53**	1.47
1995	**-1.61**	1.89
1996	**0.16**	4.72

This approach performs better than regression technique.

7.4 Discussion of the Result

Several approaches have been introduced to search for the forecasting figures with minimum errors. The results of each approach are compared and shown in Table 7.22.

Table 7.22 Comparison percentages of error from Three Approaches of NN and Regression Analysis

Year	Neural Network			Regression Analysis
	Table 7.12	Table 7.16	Table 7.22	
1993	8.63	NA	**0.43**	-2.45
1994	11.93	5.95	**0.53**	1.47
1995	20.92	**1.24**	-1.61	1.89
1996	28.11	9.69	**0.16**	4.72

From Table 7.22, neural network has shown its ability to forecast the new issued banknotes with higher accuracy than the regression technique does.

7.5 Conclusion

The following conclusions are made based on the experimental objectives.

1. Each input set gives different results. Value of admitted banknotes is the parameter that gives the minimum sum-squared error of testing data where monthly training data and testing data are 1989-1992 and 1993-1996 respectively.

2. After the proper input set is found, the number of neurons is the next parameter to find out. The number of neuron that gives minimum sum-squared error of testing data is 45. (See Table 7.9)

3. The learning rate that gives minimum sum-squared error of testing data is 0.009. (See Table 7.10) Further trainings are conducted. The results of forecasting new issued banknotes are not better than those of regression technique. See Table 7.22 for comparison.

4. Using different training and testing data of the same input results in accuracy improvement.

5. Using data from the equation of regression technique results in the minimum errors comparing to other approaches as demonstrated in Table 7.22.